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Hinduja National Power

COMPREHENSIVE ENVIRONMENTAL IMPACT ASSESSMENT, ENVIRONMENTAL MANAGEMENT PLAN, RISK ANALYSIS, AND EMERGENCY PREPAREDNESS PLAN FOR THE PROPOSED 2×520 MW THERMAL POWER PLANT NEAR VISAKHAPATNAM

TATA CONSULTANCY SERVICES

HINDUJA NATIONAL POWER CORPORATION LIMITED

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Environment and Natural Resources Management Group
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April 1997

PREFACE

Hinduja National Power Corporation Limited (HNPCL) has proposed to set up a 1040 MW (2 units of 520 MW each) coal-fired thermal power plant (TPP) at a site on the Bay of Bengal coast about 25 km SW of Visakhapatnam in Andhra Pradesh (AP). HNPCL requested Tata Consultancy Services (TCS) to conduct a comprehensive environmental impact assessment (EIA) of their plant, review their proposed environmental protection strategies and suggest enhancements where appropriate. The resulting environmental management plan (EMP) would be implemented by HNPCL at the proposed plant to preserve the environmental quality of the area. HNPCL also requested TCS to carry out an indusrial risk analysis (RA) of the plant and prepare an emergency preparedness plan (EPP).

A rapid EIA-EMP-RA-EPP report based on one season's environmental quality data collected during winter 1995-96 was prepared by TCS for HNPCL in April 1996 and was subsequently presented to the Ministry of Environment and Forests (MoEF) in July 1996. The Ministry cleared this report in September 1996. This is a comprehensive report covering background environmental quality data collected during four seasons of 1995-96.

The EIA presented in this report is based on the details of the project provided by HNPCL and their EPC contractors Mitsubishi Heavy Industries (MHI), Japan, and data (primary and secondary) on the environmental quality of the area collected by TCS.

The comprehensive EIA report on this project was submitted to the Andhra Pradesh Pollution Control Board (APPCB) in January 1997. Upon review of the document, APPCB requested that the combined impact on air quality due to HNPCL's TPP as well as National Thermal Power Corporation's (NTPC's) Simhadri Thermal Power Station, proposed to be built adjacent to HNPCL's TPP, be assessed. The assessment was presented to APPCB in April 1997. The EIA was subsequently accepted by APPCB in the same month.

The present version of this report incorporates the information submitted to APPCB. Combined impacts due to stack emissions from HNPCL and NTPC are presented. Only Sections 3.1.2 (de-

scribing the existing air quality) and 4.2.1 (describing the impact on the air environment) have been modified. Earlier versions of these sections are given in Appendix G. Also given in Appendix G are the details submitted to APPCB, based on which clearance was awarded.

ACKNOWLEDGEMENTS

The TCS project team would like to thank the following organisations and individuals for their assistance and for providing data for this study:

- Andhra Pradesh State Electricity Board
- Andhra University, Visakhapatnam
- Archaeological Survey of India, Visakhapatnam
- Burhani Centre for Environmental Studies, Visakhapatnam
- Central Marine Fisheries Research Institute, Visakhapatnam
- Chief Planning Officer, Visakhapatnam Urban Development Authority, Visakhapatnam
- Department of Archaeology, Andhra Pradesh, Hyderabad
- District Industries Centre, Viskhapatnam
- District Census Office, Visakhapatnam
- Hinduja National Power Corporation Limited, Hyderabad
- India Meteorological Department
- Institute for Solid Waste Research and Ecological Balance (INSWAREB), Visakhapatnam
- Mandal Revenue Officers, all Mandals around Palavalasa
- Mitsubishi Heavy Industries, Japan
- Mr P Srirama Murthy, Visakhapatnam
- National Power PLC, UK
- Prof M V Venkat Rao, Visakhapatnam
- Public Works Department, Andhra Pradesh
- Superintendence Company of India (P) Limited
- Visakhapatnam Steel Plant
- Zoological Survey of India

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EXECUTIVE SUMMARY

1.0 Introduction

Hinduja National Power Corporation Limited (HNPCL) is a company promoted by the Hinduja Group through its nominated subsidiary Machen Development Corporation of Panama, National Power PLC of the United Kingdom (UK), and Ashok Leyland Limited of India. HNPCL proposes to build a 1040 MW (2 units of 520 MW each) coal-fired thermal power plant (TPP) at a site between the villages Palavalasa and Thikkavanipalem on the Bay of Bengal coast, about 25 km SW of Visakhapatnam in Andhra Pradesh (AP). The site will be connected by a new road to NH5 near Lankelapalem and by rail to the broad gauge Calcutta-Chennai line via a new spur at Duvvada station. The total land area for the plant site is 2682 acres and that for the rail/road corridor is 1012 acres.

This power project, when conceived by the Andhra Pradesh State Electricity Board (APSEB), had received environmental clearance from both state and central governments. Nevertheless, since the original environmental impact assessment (EIA) had been carried out more than five years earlier, HNPCL felt it appropriate to carry out a fresh EIA reflecting any changes in the background environmental quality, in anticipation of the requirements of either statutory or lending agencies. When the "consent order for establishment" was transferred from APSEB to HNPCL, the Andhra Pradesh Pollution Control Board (APPCB) notified HNPCL that a comprehensive EIA report be prepared on the project. The Ministry of Environment and Forests (MoEF) of the Government of India also requested for an environmental reappraisal before transferring the clearance from APSEB to HNPCL.

As a forerunner to this comprehensive EIA, a rapid EIA report was prepared in April 1996 and was submitted to MoEF. After a review of this report by the Environmental Appraisal Committee of MoEF on power plant projects, the project received an environmental clearance.

This comprehensive EIA was submitted to APPCB in January for final clearance. Upon review, APPCB requested that the combined impact on air quality due to HNPCL's TPP as well as Na-

tional Thermal Power Corporation's (NTPC's) Simhadri Thermal Power Station proposed to be built adjacent to HNPCL's TPP be assessed. The assessment was presented to APPCB and was subsequently accepted by APPCB.

The specific objectives of this project were:

1. to review the current environmental status of the area within a 30 km radius of the proposed TPP site,
2. to estimate the environmental impact of the proposed project on the surrounding environment,
3. to prepare a comprehensive environmental management plan (EMP) to ensure that the environmental quality of area would be preserved, and
4. to conduct an industrial risk analysis of the proposed project and prepare an emergency preparedness plan (EPP).

This report is divided into eight chapters. The introductory chapter discusses the need, the objectives and the scope, and the methodology for carrying out this EIA study. Chapter 2 gives the power plant details and utilities. Chapter 3 describes the existing environmental scenario within a 30 km radius of the proposed plant site. Chapter 4 assesses the impact potential of the project without any measures to mitigate adverse impacts. Chapter 5 describes the environmental management plan including long-term environmental management options. Chapter 6 evaluates the environmental impact of the proposed plant under different scenarios. Chapter 7 details the risk analysis study carried out on the HNPCL plant and recommends measures to minimise risk. Chapter 8 describes the emergency preparedness plan of HNPCL.

2.0 Power Plant Details and Utilities

HNPCL's proposed CBTPS will use washed coal as fuel. A desalination plant will be set up for meeting the sweet water requirement. Sea water from the Bay of Bengal will be used for once-through cooling, desalination, and ash handling.

Coal will be transported by rail to the project site from Ananta and Bharatpur mines, via Duvvada on the Calcutta-Chennai main line. The route from Duvvada to the TPP will consist of a single-track rail spur with passing places constructed as part of the project works and owned by HNPCL. HNPCL is discussing a transportation agreement with the Indian Railways (IR) who will be responsible for transporting the required quantity of washed coal every

year from the washery to the unloading point at the power station. Coal will be transported in dedicated bottom-discharge wagons. To ensure timely and reliable delivery of coal, HNPCL plans to subscribe to the "Own Your Wagon (OYW)" scheme.

Coal from each bunker will be transported to coal furnace via feeders and coal mills. Each steam generator [steam capacity 1705 T/h maximum continuous rating (MCR)] will be furnished with pulveriser-feeder combinations. Two coal feeders will be provided for each pulveriser. The steam generator system of the boiler will transfer the heat released during the combustion of fuel (coal) to the feed water and steam. Heat transfer will also take place in the reheater to increase the temperature of the cold reheat steam, required by the intermediate pressure turbine.

The steam turbine will be standard Mitsubishi two-cylinder, tandem-compound, double-exhaust, condensing re-heat turbine designed for high operating efficiencies and maximum reliability.

The generator and excitation system will convert turbine mechanical energy to electrical energy. The excitation system will provide control of generator terminal voltage by controlling current supplied to the generator field. The generator will be a two pole 50 Hz machine, consisting of cooling systems (hydrogen- and water-cooled). A 400 kV substation with one-and-half breaker configuration is proposed for connecting two 520 MW generators to four transmission circuits for feeding power to the grid.

The HNPCL plant will be equipped with a state-of-the-art "DIASYS-UP" digital control and instrumentation system (DCIS) of Mitsubishi Heavy Industries (MHI). The integrated DCIS will provide power plant control, monitoring, data logging, and protection and interlocking of the units.

Two 776 kVA emergency diesel generator (DG) sets will be provided to meet the load requirement for the safe shutdown of the plant during an emergency and for emergency lighting.

Over 99% of HNPCL's total water requirement will be for cooling. Apart from cooling, 0.042% of the total water requirement will be for process (boiler make-up), 0.02% for service water, 0.01% for coal handling, 0.02% for bottom ash handling, and 0.01% for domestic use. The total daily water requirement of the plant is expected to be 5862981 m^3/d, which will be met by drawing water from the Bay of Bengal. Out of this, 80,421 m^3/d of sea water will be desalinated for meeting the sweet water requirement of 6064 m^3/d.

3.0 Existing Environmental Scenario

The HNPCL site is located between 17°32'42"N-17°35'N Latitude and 83°6'45"E-83°10'E Longitude. The maximum elevation of the proposed plant area is about 5 m above mean sea level (MSL). The proposed ash pond site would be mostly on a mud flat area, whose elevation ranges from sea level up to a maximum of 1.1 m above MSL. Most of the plant area is flat, dry, and barren land at present, except towards the south of site, where cashew and *Casuarina* plantations exist. The area surrounding the HNPCL site is essentially rural, bound by hillocks on three sides except S and SE where the Bay of Bengal exists. The proposed site is located about 2 km SW of Visakhapatnam Steel Plant (VSP) boundary.

3.1 Air Environment

The temperature, RH, rainfall, and cloud cover data at Palavalasa are typical of moderate sub-tropical climate.

The predominant wind direction in the area is from the south-western to the north-eastern quadrant with relatively higher wind speeds (above 10 knots) in summer season compared to other seasons.

As expected in a rural area, the 98th percentile concentrations of SO_2, NO_x, SPM, RPM, and CO were observed to be low and well within the CPCB limits for residential, rural, and other areas. In general, higher concentrations were observed during winter. During monsoon, pollutant concentration were comparatively lower.

3.2 Noise Environment

Equivalent noise levels (L_{eq}) at all locations around the HNPCL plant site were found to be well within the recommended limits for industrial areas (75 dBA during the day and 70 dBA during the night). At most locations the highest L_{eq} values were recorded during the first three months of the year.

3.3 Water Environment

Surface Water

Several tanks exist in the villages in a 30 km radius of the HNPCL plant site. The major uses of these village tanks are bathing, washing, and irrigation. The salient features of the analysis are as follows:

- Water quality was found to be generally acceptable except for BOD which exceeded recommended limits at all locations. Appikonda creek was found to be the most polluted of all surface water bodies monitored, which could be attributed to the discharge of effluents into the creek. As expected, Kaniti reservoir water quality was found to be best. This reservoir is the raw water source for VSP.
- The concentrations of most parameters tested were higher during pre-monsoon than in the other seasons.
- pH was found to be highly alkaline during pre-monsoon. In other seasons, it was in the slightly alkaline range.
- Water from all the village tanks was found to be *moderately hard* to *hard* but that from the Thikkavanipalem and Appikonda creek was found to be *very hard*. During monsoon, hardness was relatively lower than in other seasons.
- Dissolved oxygen (DO) content was high, indicating good aeration of the water. During pre-monsoon, DO concentrations were lower at some locations than during other seasons, possibly due to relatively higher ambient temperatures.
- Concentrations of nutrients - phosphates, nitrates, nitrites, TKN, and ammoniacal nitrogen - were low.
- Heavy metals were generally present in low quantities. Mercury concentrations, however, were found to be fairly high in all samples during winter.
- Coliform organisms were found in all samples, indicating faecal contamination.
- Pesticides were absent from all samples during winter, but could be detected during other seasons, making the water unsuitable for public water supplies or bathing. The water from most of these water bodies, however, is used for irrigation, for which no standard is specified under IS 2296.
- Poly-aromatic hydrocarbons were absent from all samples during all seasons.
- Radioactivity could not be detected in any sample.

Groundwater

A number of groundwater (GW) sources (open wells and bore-wells) were observed in the villages surrounding and adjacent to the HNPCL plant site. Major uses of these GW sources are drinking, washing, bathing, and irrigation. Most of these wells go dry during the summer months. The groundwater table in the area was found to be generally between 0.5 m and 10.5 m below ground level, depending upon the season. The salient features of groundwater quality analysis are as follows:

- No significant seasonal variation was observed in the groundwater quality in the area.
- GW quality was found to be generally acceptable as per IS 2296, except for BOD (at GW1 and GW13) which marginally exceeded the standard for public water supplies and bathing *ghats* during winter. In other seasons, the BOD was found to be within acceptable limits. Water from GW18 is used for salt farming, hence IS 2296 limits are not strictly applicable to it. At most locations from where water is drawn for drinking, the water quality was found to conform to drinking water standards (IS 10500) except for total dissolved solids.
- pH was in the neutral to slightly alkaline range.
- Heavy metals were either absent or were present in traces.
- Water at all locations was found to be *moderately hard* to *hard*.
- Phosphates and TKN concentrations were relatively low.
- Oil and grease, phenolic compounds, poly-aromatic hydrocarbons and pesticides were absent.
- Coliform organisms was either absent or low, indicating low levels of faecal contamination.
- Radioactivity could not be detected in any sample.

Marine Water

Marine water samples from 2.5 m depth were collected from fifteen locations in a 30 km radius of the proposed TPP. The salient features of this analysis are as follows:

- Marine water quality was generally found to be good as per "Primary Water Quality Criteria for Class SW-I Waters" of the Central Pollution Control Board, except for lead, cadmium, and oil and grease.
- pH was in the alkaline range (8.1-8.5) except at MW14 (near Kothapatnam), where pH was found to be slightly acidic during winter.
- Dissolved oxygen (DO) content was generally found to be high (6-7 mg/L). This could be attributed to good mixing of the sea surface with air and planktonic growth resulting in photosynthetic oxygen production.
- As expected in marine water, conductivity values, total hardness, and concentrations of total dissolved solids, chlorides, and sulphates were very high at all locations. During post-monsoon, values of these parameters were lower than in the other three seasons.

- Concentrations of nutrients - phosphates, TKN, nitrates, nitrites, and ammoniacal nitrogen were low.
- BOD and COD were low at all locations, indicating relatively low degree of organic pollution. BOD levels during pre-monsoon were higher than in the other seasons.
- Heavy metals were generally present in low quantities, except cadmium and lead. Cadmium exceeded the CPCB's recommended criteria during pre-monsoon. In other seasons, however, cadmium levels were within acceptable limits except at MW1. Lead exceeded recommended criteria at most locations throughout the year.
- Phenolic compounds, poly-aromatic hydrocarbons, radioactivity, and pesticides were absent at all locations.

Thus the marine water quality in a 30 km radius of the proposed site was generally found to be good as per "Primary Water Quality Criteria for Class SW-I Waters" of the CPCB.

3.4 Land Environment

HNPCL's proposed project site is more or less flat and gently sloping towards south and south-west. Major part of the area is covered by mud flat and coastal sand dunes. The elevation of the mud flat ranges from sea level up to a maximum of 1.1 m above MSL. The mud flat is barren and bound by a creek towards the west and salt pans towards north and north-west. There are no major rivers in and around the area except few seasonal stormwater drains which drain into a creek near Thikkavanipalem.

Out of all landuses, agriculture is the predominant (36%) in an area within 30 km of the HNPCL plant site. A large fraction (over 16%) is barren and uncultivable. Forest land covers about 12% of the land.

The area can be classified into the following major units:

- beach
- coastal sand dunes
- mud flat
- salt flat
- moderately weathered pediplain
- shallow weathered pediplain
- residual hill
- structural hill

The soil at and surrounding the HNPCL plant site varies in textural classification. Predominant textural class is silty-clay and silty except the locations near the coast, where soil is sandy. Soil at the plant site near cashew plantations is sandy, whereas the soil from the mud flat area (proposed ash pond) is silty to silty-clay. Infiltration rates at most locations were found to be low except at locations where the soil is predominantly sandy. Infiltration rates in the ash pond area were also found to be low. The pH of the soil in the area was found to be in the neutral range during winter and pre-monsoon seasons whereas during monsoon and post-monsoon seasons, the pH was in the alkaline range. The nutritional status of the soil was found to be moderate with fairly high amounts of organic matter, moderate NPK content, and adequate quantities of the micro-nutrients B, Mn, Cu, and Zn except during pre-monsoon. The soil was non-saline with low electrical conductivity (less than 350 μmhos/cm). In the ash pond area, however, conductivity was found to be higher (900-1500 μmhos/cm). At all the locations the soil was characterised by low concentrations of NaCl and absence of Na_2CO_3. This type of soil can be made suitable for agricultural purposes with adequate soil amelioration and water management practices.

3.5 Biological Environment

The various terrestrial habitats in the area around the HNPCL site are (a) hill forest, (b) swamps with thorny forest, (c) urban settlement, (d) village settlement with orchards, (e) agricultural plantation, (f) coastal dune vegetation, (g) mud flat, and (h) salt pans and aquaculture. No reserve forests exist within the core zone (10 km) of the HNPCL plant site. The nearest reserve forest, at Pudimadaka, is 12 km away.

The coastal vegetation is mainly of three types (a) vegetation of open coast, (b) vegetation of saline marshes, and (c) vegetation of the rocky coast. Most of the flora are of tropical type with wide range of distribution. Endemic species were not encountered during in the TCS survey. Most of the plant species recorded during this survey commonly occur in other habitats as well. Only a few plants could be considered rare in these habitats. None could be found in the core zone.

The dense cover of cashew and *Casuarina* forest offers adequate protection to the wildlife that inhabits the area, which includes reptiles as well as mammals. A part of the proposed ash pond area harbours swampy vegetation. Due to its periodic inundation by stormwater, this habitat attracts wading and marsh birds,

and mammals such as jackals and civets, for foraging as well as nesting and roosting. Buffalo and poultry birds are the most common livestock in almost all of the *Mandals* surrounding the HNPCL plant site.

The common aquatic habitats in the area around the HNPCL site are (a) freshwater reservoirs, (b) coastal sub-tidal zones, and (c) coastal littoral zones.

The plankton in freshwater, brackish water, and saline water in the area vary widely with respect to species composition and diversity. The Bay of Bengal coast near Visakhapatnam is one of the important habitats for marine algae, with rocky outcrops scattered along the coastline on which benthic algae grow. Both freshwater and brackish water bodies in the area around the HNPCL site harbour a number of macrophytic plants and marsh plants.

None of the freshwater fish in the area belongs to rare or endangered categories as per Indian Board of Wild Life (IBWL).

Various marine and coastal avi fauna were recorded during the TCS team's visit. Flocks of migratory ducks and other waders were regularly seen along the coast (100-300 m off the coast).

The interstitial sands harbour a rich variety of protozoans, nematodes, annelids, gastrotrichs, kinorhynchs, crustaceans, and molluscs. The tidal fauna also include micro-, meio-, and macrofaunal species of invertebrates.

Visakhapatnam coast is mostly rocky with sandy beaches in certain stretches. The inter-tidal region is narrow and does not exceed 100 m. The rocky outcrops at Appikonda/Kuttukonda and Pudimadaka offer ideal habitats for invertebrates such as molluscs, crustaceans, sea anemones, echinoderms, sponges, etc. The sandy beaches support only sand-burrowing forms such as crustaceans (crabs) and molluscs (gastropods and bivalves).

Five fishing villages, including Pudimadaka and Mutyalammapalem, are located within a 20 km radius of the HNPCL plant site. The fish catches off the shore near the HNPCL site have been reported to be poor by the local fishermen.

3.6 Socio-economic Environment

The area in a 30 km radius of the proposed project site falls under thirteen *Mandals* of Visakhapatnam district. A total of 284

villages and 11 towns exist in the area. The population of the area according to the 1991 census was 1683515, out of which 51.4% were males and 48.6% were females. Literacy rates were moderate (about 52%).

All thirteen *Mandals* have good facilities for primary and secondary education, while facilities for higher education are inadequate. Most of the thirteen *Mandals* surrounding the HNPCL plant site have primary health centres. All the *Mandals* have veterinary hospitals and dispensaries facilities. Main livestock are poultry, cattle, buffaloes, sheep, and goats. All *Mandals* have potable drinking water. The communication system of the region is moderately good. Bus is the main mode of public transport. Good post and telegraph services are available in all the *Mandals*. All the villages in thirteen *Mandals* in a 30 km radius of the proposed project site are electrified, but face extended power cuts every day. Recreational facilities except cinema halls do not exist in most of the *Mandals,* but are available in nearby towns and cities.

A majority (about 65%) of the population in the villages surrounding the HNPCL plant site are non-workers, and only a third are main workers. Thus there is potential for HNPCL to hire local persons during both construction and operational phases.

The existing health status surrounding the proposed plant site is fair. Health problems in the area include air-borne, water-borne, as well as vector-borne diseases. Most of these can be attributed to poor living conditions.

Almost all the roads providing access to the project site at Palavalasa carry much less traffic compared with their respective capacities. The roads, however, need to be strengthened for catering to HNPCL's construction related traffic.

Most of the individuals surveyed in the nearby villages were aware of the proposed project. Seventy two percent of the people expressed a positive attitude towards the project, hoping that it would bring about the economic development of the area which would lead to an improvement in the basic amenities, hence quality of life. Sixteen percent of the people indicated that the HNPCL project was not welcome in the area, whereas 12 percent of the people did not express any opinion. Most of the respondents, whether in favour or not, stressed the need for stringent pollution abatement measures to be adopted at the HNPCL plant, including development of a greenbelt in the surrounding villages. They also expressed the opinion that local people be employed during both construction and operational phases of the plant.

The negative opinion was stronger near the HNPCL plant site; as one went further away from the site, the response was more and more positive. Nevertheless, the positive response exceeded the negative response even in the areas close to the HNPCL plant site.

Respondents in Palavalasa expressed the opinion that they should be given more compensation than that recommended at present by the Revenue Department of the Government of Andhra Pradesh. For this reason, respondents in this village expressed strongly negative opinion about the project.

In general, people with positive opinion about the project expressed a sense of relief, considering their experience of regular power cuts in Visakhapatnam. Some of them even demanded that power generated by the HNPCL's proposed TPP should be distributed only within the state and not shared with any other state.

4.0 Impact Potential

This section summarises the pollution potential of HNPCL's power plant and its possible impacts on the surrounding environment during both construction and operational phases without considering the environmental management measures and proposals of HNPCL. The power plant will have impacts of varying magnitude on different environmental components. These impacts could be categorised as

- primary impacts, i e, impacts which occur as a direct result of the project activities, and
- secondary and tertiary impacts, i e, impacts which occur as a result of primary and secondary impacts, respectively.

Most of the impacts during the construction phase are temporary and localised, hence not very significant. Traffic on existing roads will increase during the construction phase, resulting in some impacts on the air quality and noise level. Once HNPCL's own approach road is ready, however, these impacts will be mitigated.

About 6700 persons will be employed at the site during construction at its peak. This will be beneficial for the unemployed population of the nearby area who can work as construction workers and labourers.

Since the land acquired or proposed to be acquired for the plant and the road/rail/transmission corridors is not inhabited, there will be no need for rehabilitation and resettlement of families.

4.1 Air Environment

The Industrial Source Complex - Short Term (ISCST) model (USEPA, 1987)[1] was used to predict changes in air quality, i e, maximum ground level concentrations (GLCs) of various pollutants, due to the emissions from HNPCL's plant. Conservative estimates were made for the modelling exercise to predict worst-case impact (*coal having the highest ash and sulphur at the same time, no sulphur going into ash, and worst-case meteorological data collected at the HNPCL site*). Since another thermal power plant of similar capacity, the Simhadri thermal power station, is planned next to HNPCL by NTPC, air quality modelling was carried out taking into consideration the emissions from NTPC plant as well.

The air quality simulation indicated that only SO_2 would be of significance with respect to impact on air quality. For the other parameters - SPM, NOx, and CO - the maximum increments in the GLCs due to emissions from HNPCL stack were found to be insignificant. The predicted maximum concentrations of these pollutants with observed background levels are compared with national air quality standards in the following table. The existing concentrations in the table are the maximum 98th percentile values out of the six air quality monitoring locations.

Parameter	Ground level concentration			Standard
	Existing (98th percentile value)	Increment (worst case)	Total	(for industrial areas)
SPM ($\mu g/m^3$)	127	2	129	500
NO_x ($\mu g/m^3$)	39	10	49	120
CO (mg/m^3)	2.8	0.004	2.804	5.0

SPM and NO_x: 24 h average values, CO: 8-h average values

It can be seen from the above table that the estimated 24 h concentrations of these pollutants would be well within limits for industrial areas.

The increments in SO_2 concentrations due to HNPCL alone as well as due to HNPCL + NTPC (H+N) are given in Table 1. It can be observed from the table that the maximum GLCs would be well within the limits specified by CPCB even under worst-case condi-

[1]USEPA, 1987, Industrial Source Complex - Short Term (ISCST) Model, United States Environmental Protection Agency, EPA-450/4-88-002a.

Table 1. Predicted changes in ambient SO_2 concentrations due to stack emissions from HNPCL and NTPC

Location	Distance from stack (km)	Direction with respect to stack	Season during which maximum GLC (existing + incremental) is likely to occur	Background GLC (24 h) 98th percentile value	Power station	Incremental GLC impact range		Total expected GLC (existing + incremental)	
						Maximum*	Minimum**	Maximum*	Minimum**
Palavalasa	3	NE	Pre-monsoon	25	H	47	31	72	56
					H+N	52	32	**77**	**57**
Peddapalem	6	N	Winter	27	H	41	22	68	49
					H+N	44	26	**71**	**53**
Chipurapalli	6	WNW	Post-monsoon	19	H	24	15	43	34
					H+N	50	30	**69**	**49**
Thikkavanipalem	3	SW	Post-monsoon	17	H	45	32	62	49
					H+N	48	34	**65**	**51**
Deshapatrunipale	9.5	N	Pre-monsoon	22	H	15	9	37	31
					H+N	48	28	**70**	**50**
Peddagantyada	14	NE	Pre-monsoon	25	H	23	16	48	41
					H+N	28	17	**53**	**42**

Note: Effect of rain was not considered for predicting worst case impacts

H - HNPCL * Maximum - with 0.8% sulphur and no sulphur retention in ash

N - NTPC ** Minimum - with 0.6% sulphur and 20% retention in ash

tions. Hence the impact of HNPCL's plant on the air environment would be well within acceptable limits. Even if NTPC's power station is considered, the ambient air quality standards in the area are unlikely to be violated.

The impacts given above represent worst-case scenario. On most occasions, however, the plume from HNPCL's stack is likely to rise much higher than predicted here. Consequently, *the average GLCs are likely to be about half of the concentrations predicted for the worst-case scenario.*

4.2 Noise Environment

The principal sources of noise at the HNPCL plant will be turbines, air compressors, fans, mills, pumps, pressure release valves, etc. Besides these, transportation (by rail), crushing, and handling (by conveyor belts) of coal will also have the potential to raise the noise levels. Apart from the sources inside the plant, the movement of trucks and other vehicles to and from the plant will also contribute to increased noise level inside the plant premises. If mitigative measures are not taken, these can increase the ambient noise levels inside the factory area and its surroundings. These could have impacts on the workers inside the plant. Thus, to mitigate the impact of HNPCL's power plant on the ambient noise levels, suitable noise abatement measures will be required.

4.3 Water Environment

HNPCL's water requirement will be met by obtaining water from the Bay of Bengal. In addition, fresh water would also be required for various purposes. Initially HNPCL had planned to obtain fresh water from the Yeleru canal, but later decided to install a desalination plant and use sea water as the source. Thus, HNPCL's power plant will not exert any additional pressure on the existing water resources of the area.

HNPCL will discharge its cooling water and desalination effluent into the sea through an outfall. The condenser and other systems at HNPCL's plant will be designed to ensure that the rise in temperature of cooling water is maintained within 5°C of the ambient sea water temperature, as per MoEF's stipulation, to reduce its impact on the Bay of Bengal.

Thermal plume modelling was carried out to provide improved estimates of the area of impact of the thermal plume resulting from the CW discharge from HNPCL's plant, following on from the

initial results reported in the rapid EIA report[2]. The modelling exercise was carried out using the latest version of Cornell Mixing Zone Expert System (CORMIX)[3] version 3.10. The CORMIX modelling gives a fair indication of the area which would be affected by the CW discharge. This improved model allowed a more realistic set of cases to be modelled than was possible with the version used previously. To estimate worst-case impacts, a range of ambient conditions were considered for modelling. From this exercise, the following conclusions were drawn:

1. In all cases, the initial dilution of the CW discharge will be rapid, and the area of 2°C rise above the ambient is less than 500 m from the outfall.
2. The temperature rise due to the CW outfall at the two rocky outcrops near the HNPCL site will be less, absolute rise being 1.2°C above ambient at the most.
3. The plume is predicted to form a buoyant, vertically-stratified layer, being limited typically to the top 2 m to 4 m of the water column.

HNPCL would use sea water to make ash slurry, which will be dumped in the ash pond. This is not expected to have significant impact on the groundwater in the area, which is already saline.

According to the soil investigation reported by Black and Veatch International[4], the ash pond area is covered with the clayey soil classified as "CH" or "CL." As per IS-1498, the clayey soil classified as "CH" or "CL" is practically impervious. The coefficient of permeability for the clayey soil in the proposed ash pond area is of the order of 10^{-6} cm/s. Through this soil, the time required for the leachate to traverse the 200 m distance to the plant boundary will be over 500 years. Thus, for all practical purposes, the leachates from the ash pond will be retained in the area and are unlikely to pollute groundwater.

All around the ash pond area there are numerous salt pans which use saline groundwater for making salt. Analysis of water collected from a well near the salt pans indicated that the water is saline, and unfit for drinking. Thus the increase in the salinity of

[2]Tata Consultancy Services, 1996, Rapid Environmental Impact Assessment, Environmental Management Plan, Risk Analysis, and Emergency Preparedness Plan for the proposed 2×520 MW Thermal Power Plant near Visakhapatnam.

[3]Jones G R, Nash J D, and Jirka G H, 1996, CORMIX 3: An Expert System for Mixing Zone Analysis and Prediction of Buoyant Surface Discharges, United States Environmental Protection Agency, Washington D C.

[4]Black and Veatch International, 1995, Onshore Subsurface Investigation Interpretative Report.

the cooling water discharge from HNPCL due to brine and treated ash water blowdown will be negligible, and is not likely to affect the marine water quality.

To determine the direction of groundwater flow in the ash pond area, TCS conducted a leach pit test. To assess the impact of ash pond leachates on the groundwater in the area, TCS conducted a test on fly ash collected from the Visakhapatnam Steel Plant (VSP), since VSP also uses the same coal which HNPCL plans to use. In addition, a bench-scale column test was performed in the laboratory for evaluation of adsorption and dispersion coefficients of the clay particles in the proposed ash pond area. The following salient observations were made from these tests:

- The pit tests in the ash pond area indicated that the direction of groundwater flow was towards the centre of the mud flat area rather than towards the villages in N, NE and NW directions.
- Leachate tests indicated that the amounts of heavy metals leaching into re-circulation water from the fly ash would be very low.
- The permeability of the clay in the ash pond area is very low (to the order of 10^{-4} to 10^{-5} cm/s).

The bedrock below the HNPCL site slopes from NE towards SW, i e, towards the Bay of Bengal. Therefore, even if any leachates reach the groundwater, they would flow towards the sea rather than towards the inhabited areas on the land side.

Considering the results of the tests conducted by TCS and the information presented in this section, the impact of HNPCL's wastewater discharges on the groundwater of the area is expected to be insignificant.

4.4 Land Environment

In the absence environmental protection measures, the land environment at and surrounding the proposed HNPCL plant could be affected by

- deposition of SPM and other gaseous emissions released from stacks
- dumping of solid wastes and sludge generated from different sources

Major pollutants which may be emitted from the stacks are SO_2 and SPM. Deposition of these on the soil can affect the soil pH and its nutritional status. Wastewater from the plant, if discharged untreated on land, can impair the soil quality by adding a large quantity of organic load (biodegradable and non-biodegradable), alteration of pH, bulk density, permeability, water-holding capacity, and nutrient status.

The major solid waste expected from the HNPCL plant will be ash. The maximum quantities of ash which could be generated based on 36% ash and 670 T/h coal consumption are listed below.

Type of ash	Ash production rate (T/h)
Bottom ash	60
Economiser ash	10
Fly ash	171
Total	241

Disposal of ash will be to the ash pond. A 360 ha (890 acres) area has been earmarked by HNPCL for the ash pond.

4.5 Biological Environment

Terrestrial Ecology

Terrestrial plant species could be subjected to the emission from thermal power plant containing oxides of sulphur, nitrogen, CO, HC. Nevertheless, if the prescribed standards for emission through recommended stack height is followed, the emissions are not likely to cause any significant damage.

Since the major habitat for terrestrial fauna fall under the buffer zone rather than the core zone, no significant impact could be foreseen due to the proposed power plant.

Although the impact of HNPCL's project on terrestrial ecology is not expected to be significant, the proposed environmental management plan will have to ensure (i) controlled emissions of air pollutants (within permissible limits), (ii) adequate stack height (iii) adequate safety while disposing of ash and monitoring of ash pond, (iv) appropriate greenbelt around township and plant area, (v) proper disposal of solid waste and (vi) annual environmental audit.

Aquatic Ecology

The survey around the HNPCL plant site indicated that the fish catches off the coast near the site are poor. Most of the fishing activity is north-east of Visakhapatnam.

According to the modelling exercise carried out to estimate the area which will be affected by HNPCL's cooling water discharge, the temperature rise will be 2°C of the ambient at about 0.5 km from the outfall location, and 1°C in about 2.5 km. Thus a very small area will be affected. At the rocky outcrops near Thikkavanipalem and Appikonda, the two habitats of concern near the HNPCL site, the temperature rise will be less than 0.4°C and 1.2°C, respectively. This temperature rise is very low from an ecological point of view, and its impact on the marine flora and fauna will be insignificant.

HNPCL's proposed plant is unlikely to affect the migratory route of birds in view of large air space used by the migrant species, and their continued use of the same route in spite of extensive industrialisation of the Visakhapatnam area during the past few years.

4.6 Socio-economic Environment

The main reasons for setting up the power plant near Visakhapatnam are to (i) augment the power generation capacity, hence reduce the deficit between power demand and supply in Andhra Pradesh in the medium term, and (ii) to install thermal capacity into a grid predominantly served by hydroelectric schemes, as a back-up in case of failure of the monsoon. In addition, the power generated by HNPCL will also improve the stability of the grid system at Visakhapatnam.

Skilled as well as unskilled manpower will be required for the operation of the plant. It is estimated that about 1000 persons will be working at the plant during the operational phase. In addition, indirect employment is expected to be generated for many more people. Thus employment opportunities will be created in the region.

Secondary growth resulting from the setting up of the HNPCL plant will create self-employment opportunities for the local villagers and thus increase their income level. This would also trigger improvements in the basic amenities, particularly transportation, telecommunication, electricity, educational and medical fa-

cilities, etc.; thus would improve the quality of the life of the local people.

5.0 Environmental Management Plan

The environmental impact during the construction phase will be mostly temporary and localised. The environmental management measures which would be required during the construction phase are: (i) Water sprays to suppress dust that would rise due to construction-related traffic, (ii) stormwater drainage channel around the ash pond bund to prevent flooding upstream of the ash pond, (iii) temporary toilets for the construction workers, collection of sewage from these toilets, and transportation to temporary septic tanks (effluent from the septic tanks could be used for greenbelt irrigation); (iv) keeping the cutting of trees at site to a minimum.

5.1 Air Pollution Control

Air pollution controls would include engineering the height of all stacks adequately, so that the ambient concentrations of the air pollutants in the area remain within the stipulated limits. Fugitive emissions will be controlled by (i) spraying water at hoppers to suppress dust emission during unloading, (ii) transferring coal to the stockyard by a closed conveyor system, (iii) using high capacity conveyor at low speed rather than low capacity conveyor at high speed, (iv) using chute with necessary stone-box or similar arrangement to prevent straight drop, (v) providing a conveyor discharge hood at each transfer tower, (vi) covering all conveyors, and (vii) providing the coal crusher building with a dust extraction system.

The major pollutants from the stacks of HNPCL's TPP will be SO_2 and SPM, and relatively smaller amounts NO_x and CO. As stipulated by MoEF, HNPCL will build a 275 m tall stack for effective dilution and dispersion of pollutants and will use washed, low-sulphur Indian coal (0.8% S) for its TPP. Two electrostatic precipitators (ESPs), one for each unit, will be installed for the removal of particulates from the steam generator flue gas to achieve a guaranteed outlet emission of 90 mg/Nm^3 over the full range of design coal and 115 mg/Nm^3 (at 12% CO_2, dry) with one field out of service.

Apart from the boiler stack emissions, pollutants will also be emitted, albeit occasionally, from the auxiliary boiler stack and the

DG set stack. The auxiliary boiler will use LFO as the fuel at a maximum rate of 2.7 T/h. Since LFO may contain a maximum of 1.8% sulphur, the maximum SO_2 discharge can be 97.2 kg SO_2/h. This would necessitate a stack height of 55.3 m, as per CPCB guidelines. The DG set stack will be raised 5.6 m above the roof of the DG set house, as per CPCB's formula.

5.2 Noise Pollution Control

Noise from any one major equipment at the plant will not exceed 85 dBA at 1 m from the equipment at a height of 1.2 m. Noise and its consequent adverse impacts will be reduced by:

- Stopping leaks from steam lines, compressed air lines, and high pressure equipment
- Providing acoustic lagging and silencers at various locations to reduce rattling and vibration
- Providing noise-proof cabins (control rooms) for operators wherever remote control of noisy equipment is possible
- Providing ear plugs or ear muffs to workers in high noise areas
- Encasing noise-generating equipment wherever possible

5.3 Water Pollution Control

Cooling Water

HNPCL proposes to use once-through cooling system using sea water from the Bay of Bengal. Apart from small a amount of cooling water (CW) which would be used to make ash slurry, the rest will be discharged into the Bay of Bengal through an outfall. In addition to CW, other wastewater streams will also be discharged through the outfall. The resultant temperature of these streams at the outfall discharge will be 4.966°C (less than 5°C) above that of the ambient. The outfall discharge point will be located below the low tide level; thus it will always be completely submerged. The intake will be located approximately 500-600 m offshore from the coastline. The intake and outfall locations will be planned in such a way that re-circulation of outfall water into the intake will be avoided.

Cooling water will meet the minimum national standards (MINAS) for discharge into the sea. The MINAS parameters will be regularly monitored to ensure their limits in the cooling water discharge.

Ash Water

Sea water is proposed to be used for making ash slurry, which will be dumped into the ash pond. Decanted water from the ash pond will be re-circulated in the system. Continuous re-circulation of sea water, however, can lead to the concentration and precipitation of salts which could lead to severe fouling of pumps. Periodic blowdown of sea water from system will therefore be required. The frequency of the blowdown will depend upon the season.

The conductivity of the ash water will be checked continuously. If the conductivity reaches 1.5 times the conductivity of normal sea water, water re-circulation will be stopped and the water will be led to an effluent treatment plant. Sea water would then be drawn into the re-circulation system from the condenser discharge for make up. The effluent treatment plant is being designed to treat a maximum of 50% blowdown which may be required in the worst case. The treatment system will be designed to achieve quality better than the relevant CPCB standards. The sludge from the treatment plant will be recycled to the ash pond.

Desalination Unit Wastewater

Wastewater from the desalination unit will be discharged into the Bay of Bengal via the cooling water outfall. Provision will also be made for offering the brine to the local salt farmers if there is interest. The water will be concentrated by about 8%.

Industrial Effluent

Industrial effluent will comprise unit (oily) wastewater, boiler blowdown and cleaning wastewater, laboratory wastewater, and demineralisation (DM) plant wastewater.

Oily wastewater from plant drains, transformers, and oil tank areas will be collected and directed to the oil-water separation systems. Water from the oil-water separation systems will be led to wastewater collecting pond/storage basin. It is expected that oil to be used in transformers will be free of poly-chlorinated biphenyls (PCBs). Nevertheless, as prescribed by APPCB, any oil containing PCBs will be collected separately, stored at site, and disposed of in a secured landfill. Non-PCB oil will be incinerated in the boiler.

Boiler blowdown and cleaning wastewater, DM plant effluent, and laboratory wastewater will also be directed to the wastewater collecting pond/storage basin and channelled to the industrial effluent treatment system. Treated water, before being discharged to

the cooling water outfall, will meet standards for land application for irrigation. It is therefore recommended that this water be used for irrigation of the greenbelt at HNPCL. Sludge from the clarifier will be thickened and dewatered before final disposal to the ash pond.

Domestic Wastewater

Considering the sub-soil conditions at the HNPCL site, groundwater level, and maintenance cost, HNPCL will have a septic tank and upflow anaerobic filter system. The treated effluent will be used for irrigating the greenbelt, coal stock cooling, dust suppression, etc. The sludge from this system will also be used for greenbelt development, as a soil conditioner/manure.

Stormwater

Stormwater runoff from the coal yard will be collected by gravity flow through concrete open ditch to a sedimentation tank. Clarified water will be reused for dust suppression. Sludge from the sedimentation tank will be transported by dump truck and disposed of into the ash pond. Stormwater from power plant area will be led to a stormwater reservoir by gravity flow through concrete pipes with manholes and reused for coal handling, ash handling, and greenbelt irrigation. Stormwater from the ash disposal area will be reused for making ash slurry.

Stormwater in the area which currently drains into the mud flat will be prevented once the ash bund is built. Therefore, a channel will be provided around the ash pond for the water to drain into the Bay of Bengal.

5.4 Solid Waste Management

The major solid waste from a coal-based power plant is fly ash. Apart from fly ash, three other categories of solid wastes are expected to be generated from the proposed project: (i) ETP sludge, (ii) sludge from sewage treatment plant, and (iii) solid wastes from plant and colony. ETP sludge and sludge from the sewage treatment plant will be disposed of as mentioned earlier. The domestic waste will have to be disposed of in a suitable landfill. Waste oil from the oil-water separator will be mixed with fuel for burning in the boiler. Sludge from boiler cleaning will be mixed with coal and burnt in the boilers.

The ash handling system at HNPCL will consist of the following major units:

- Bottom ash system
- Fly ash system
- Ash slurry system and
- Ash water system

Bottom ash (BA) system would collect, quench, crush and transport the bottom ash from the furnace hoppers to the ash slurry sump for subsequent pumping to the ash pond.

The fly ash system will collect dry fly ash from ESP hoppers and transfer those to the fly ash storage silo. At the silo discharge point, the fly ash will be mixed with water to form a wet slurry which will be fed to the ash slurry sump.

The dry ash from the economiser hoppers, the air heater hopper and the flue gas duct hopper will be transferred to the cinder ash silo. The discharge from the cinder ash silo will be mixed with water and discharge will be mixed with water and dumped to the ash slurry sump.

Provisions will be made for dry disposal of ash. Enclosed spouts will be used to accomplish dry unloading to avoid escape of dust.

The on-site ash disposal pond will be made impervious to avoid groundwater contamination. Escape of dust from the ash pond will be minimised by (a) maintaining a water level of 15 cm above the ash stored in the ash pond and (b) greenbelt surrounding the pond. The total area of the entire ash pond will be about 360 ha (about 890 acres). The bottom of the ash pond with coefficient of permeability less than 10^{-5} cm/s will be left as it is. A clay blanket with a minimum thickness of 500 mm and permeability of the order of 10^{-8} cm/s will be provided where the coefficient of permeability is more than 10^{-5} cm/s. Further, HNPCL plans to leave 200 m between the ash pond and the property boundary. These measures will ensure that the leachates from the ash pond will be retained in the area and will not pollute groundwater.

Fly ash can be used in:

- Building materials
- Cement manufacturing
- Landfill, road construction, railway track construction, etc.
- Extraction of minerals

- Manufacture of special-grade materials such as ceramics
- Soil conditioning

Of the above, the latter three uses are still in their infancy and limited to laboratory- or pilot-scale. Hence the discussion here is limited to the first three uses which can be presently considered for HNPCL. Considering the potential uses of fly ash and its demand for downstream uses, HNPCL's fly ash utilisation plan was prepared. The salient features this plan are as follows:

- Hardware will be provided as a part of the project for:
  - collecting 100% fly ash from ESP hoppers in dry form in silos
  - loading dry fly ash onto open (through use of paddle mixers) and closed truck (through use of telescoping chutes) under the silos without causing dust nuisance
  - segregating dry ash based on fineness and offering ash from any ESP hopper to a user for appropriate use
  - loading dewatered bottom ash in a truck, for ash to be used for landfilling
- Area will be provided in the plant layout for setting up ash users plants.
- Fly ash will be offered free of cost to any user for 10 years from the start of power plant operation.

HNPCL has been continuously interacting with various potential ash users and has concluded MoUs for possible utilisation of ash from the plant. Only those companies which showed keen interest and have the technology and the resources to set up these plants were chosen for the MoUs. As the project nears financial close, HNPCL will advertise in leading regional newspapers about the hardware provided in the plant and that fly ash and bottom ash would be made available free of cost for the first 10 years after the start of the operational phase. It is anticipated that the need for bottom ash and fly ash will pick up as more and more awareness is created in the region through the above endeavour, especially for constructing roads and landfilling. Demand is likely to increase further in future when the availability of clay - for landfilling, embankments for roads and railways, and brick-making - becomes scarce, which would make ash products more competitive. Legislative support from the government promoting the use of products based on ash is also likely to help in use of ash in future.

Scouting of ash users has been pursued vigorously by HNPCL and will be actively pursued in future as well. It is expected that

the ash users' interest will also grow further, when activity starts at the site. This is expected to generate further potential for ash use.

HNPCL will utilise a part of the fly ash generated at the plant for increasing the height of the bund around the ash pond. The initial bund (about 7-8 m high) will be made with clay and will be sufficient for the first 10 years of operation. To cater for the life of the plant (30 years), a bund with a height of about 18 m with side slopes of 1:2 to 1:3 would be required[5]. The fly ash would need to be compacted to a density of 1.4 T/m^3. While developing this proposal, adequate care will have to be taken to avoid dust nuisance. Approximately 4 years' production of ash could be utilised for increasing height of the ash bund. After the 30-year period of the operation of the plant (design plant life), if the plant is to be scrapped, the ash pond would be reclaimed by planting appropriate species of trees. The land has been provided for the worst-case scenario, i e, no ash is utilised. In case sales of ash pick up, the final height of the ash bund will be less than 18 m. The area not used for the dyke (depending on ash usage) would be converted to greenbelt or given to ash users.

5.5 Greenbelt Development

The main objectives of greenbelt development in and around the proposed HNPCL plant will be:

- mitigation of impact due to fugitive emissions
- attenuation of noise levels
- creation of an aesthetic environment
- Reuse of plant effluent

The greenbelt in and around the HNPCL plant will be developed in harmony with the environmental conditions of the area. It is suggested that drip irrigation be provided to avoid loss of moisture through evaporation. Treated domestic sewage and industrial effluent can be used for irrigation of the greenbelt.

Planting of the greenbelt will commence at the same time as construction of the main plant, with the exception of the areas for access roads and main plant where major earth works are required. Plantation of *Casuarina* and cashew trees already exists in HNPCL site, which will be maintained to the extent possible to avoid disturbance to the natural ecosystem and habitats.

[5]Exact slope can be determined during the detailed engineering phase, only after detailed soil investigation and studying the properties of the material available for constructing the dyke. Space will be provided in the layout for 1:3 slope.

HNPCL has proposed to maintain a greenbelt in an area of about 650 acres (over 260 ha), which is larger than four times the built-up area, as required by APPCB. A 500 m wide greenbelt will be developed from the high tide line (HTL) on the southern boundary of the plant. A greenbelt of around 150-200 m will be developed around the ash pond where it is adjacent to other properties, and around 100 m on the other sides. Apart from this, greenbelt will be developed in the appropriate open spaces surrounding the coal unloading point and stockyard, boiler house, DG sets room, and ETP. Plantation of trees alongside the roads inside the plant and HNPCL's access road from NH5 to the plant site is recommended.

Two principal factors have been considered in the selection of plant species for the proposed greenbelt.

- Plant species should be able to thrive under local agro-climatic conditions.
- Plant species would need minimum level of maintenance including fertilisation and other soil amelioration.

The trees and plants that have been recommended are native and can grow in the coastal climate of Visakhapatnam plant site. In addition, due consideration has been given to the ability of the plant species to tolerate pollution. The trees and plants chosen show "moderate" to "high" levels of tolerance to SO_2, fly ash, and SPM, the major pollutants expected from the proposed TPP. In addition, plant species "sensitive" to pollutants which can act as "biomonitors" have also been suggested to indicate the level of air pollution.

In addition to developing the greenbelt around the boundary of the industrial complex, trees will be planted alongside the roads within the plant premises and inside the colony with a view to provide:

- shade
- protection of roads from erosion
- wind breaks
- mitigation of noise
- mitigation of fugitive emissions

5.6 Community Development Plan

HNPCL has planned to involve the local community during the entire project development. For this purpose, HNPCL and its con-

tractors will recruit local work force to the extent possible during both construction and operational phases. HNPCL will encourage training for the local people to develop skilled manpower required to carry out technical work in the proposed plant during operational phase.

HNPCL will organise a community advisory group that would help HNPCL in finding ways to participate with its neighbours in addressing socio-economic concerns. With the advice of its community advisory panel, local officials, and other key individuals and groups, HNPCL will sponsor appropriate programs and projects to benefit its neighbours and the community as a whole. HNPCL plans to reinforce one of the existing approach roads from NH5 to the site, which would be used during the construction period till its own road is built. Some other community development programmes that could be considered by HNPCL are suggested in this report.

5.7 Post-Project Monitoring Plan

To monitor the extent of environmental impact of the proposed project, pollutant loads generated from the plant will be periodically checked under the post-project monitoring plan. Meteorological data, air quality data, noise levels inside and outside the plant, water quality, soil quality, and solid wastes will be monitored regularly. HNPCL will set up an environmental management cell (EMC) to look after all the environment-related activities in the plant. The capital cost of the EMP and PPMP is expected to be Rs 2500 million. The recurring O&M expenditure is expected to be Rs 50 million per year.

6.0 Evaluation of Impacts

Impact score for the project was calculated for the construction phase as well as the operational phase under different scenarios using the matrix method. Matrices were prepared to represent each of these scenarios.

- Scenario 1: No project, i e, the site near Palavalasa, where the TPP of HNPCL is proposed to be located, remains as it is and the proposed project development does not take place.
- Scenario 2: EIA without EMP, i e, proposed development takes place without any environmental management measures.

- Scenario 3: EIA with EMP, i e, proposed development takes place with the environmental management measures suggested in Chapter 5.

On a scale of ±100, the total project impact score for Scenario 1 was found to be -0.25, -7.1 for Scenario 2, and +0.84 for Scenario 3. For the first two scenarios, the impact is in the "minimally adverse" category, while the impact of project with and EMP in place would be in the "minimally beneficial" category. The impact score of the construction phase was found to be -4.73 on a scale of ± 100.

It is clear from the above discussion that the proposed thermal power project of HNPCL would have some negative impacts without any environmental management strategies. If the EMP, as discussed in Chapter 5, is strictly adopted and implemented, the adverse impact would be nullified and the overall environmental quality of the area would improve. The project would result in the following advantages:

- The power generation capacity would improve, hence the deficit between power demand and supply in Andhra Pradesh will be reduced in the medium term. This will help reduce the impact of the failure of monsoon.

- Acute power shortages have existed in Andhra Pradesh from 1986-87 till date. The demand for power in the year 2001-02 would be about 10500 MW. The corresponding installed capacity required would be about 15000 MW. The additional supply due to the HNPCL plant will partly meet the demand and improve the stability of the APSEB grid system.

- Skilled as well as unskilled manpower will be required for the operation of the plant. It is estimated that about 1000 persons will be working at the plant during the operational phase. In addition, indirect employment is expected to be generated for many more people. Thus employment opportunities will be created in the region.
- Once the HNPCL plant becomes functional, service establishments are expected to come up in and around the plant to cater to the needs of the HNPCL employees. This secondary growth will create self-employment opportunities for the local villagers and thus increase their income level.

- The secondary growth resulting from the setting up of the HNPCL plant would trigger improvements in the basic amenities, particularly transportation, telecommunication, electricity, educational and medical facilities, etc. This would improve the quality of the life of the local people.

- As HNPCL employees would spend more on goods and services available in the area, demand would be created for production of such goods and provision of services. This would give a push to the local enterprises for providing the same which would lead to the creation of more jobs, hence more income. Thus, HNPCL's plant would have a multiplier effect on the local economy.

Thus, having evaluated both positive and negative environmental impacts of HNPCL's proposed power plant, it can be concluded that the project (with the proposed EMP in place) will be a welcome development.

CHAPTER 1

INTRODUCTION

1.1 Background

Hinduja National Power Corporation Limited (HNPCL) is a company promoted by the Hinduja Group through its nominated subsidiary Machen Development Corporation of Panama, National Power PLC of the United Kingdom (UK), and Ashok Leyland Limited of India. HNPCL proposes to build a 1040 MW (2 units of 520 MW each) coal-fired thermal power plant (TPP) at a site between the villages Palavalasa and Thikkavanipalem on the Bay of Bengal coast, about 25 km SW of Visakhapatnam in Andhra Pradesh (AP). The site will be connected by a new road to NH5 near Lankalapalem and by rail to the broad gauge Calcutta-Chennai line via a new spur at Duvvada station. A map showing the plant site and the access road/rail corridor is shown in Exhibit 1.1.

The need for this power plant was originally identified by the Andhra Pradesh State Electricity Board (APSEB) in 1988. With the Government of India's private power initiative in 1992 as a part of its economic liberalisation programme, the development of this project was transferred to the Hinduja Group.

The total land area for the plant site is 2682 acres and that for the rail/road corridor is 1012 acres. Out of this, about 2032 acres are Government agency land and the remaining 1662 acres are private land. Land acquisition procedure in the plant area has been completed by APSEB. Land acquisition procedures in the rail/road corridor are in advanced stage. As per the power purchase agreement (PPA) between APSEB and HNPCL, the land is to be acquired by APSEB and transferred to HNPCL.

1.2 Need for EIA-EMP

Rapid population growth and industrialisation, particularly in developing countries, have resulted in a considerable impact on the environment. During the last few decades there has been a growing realisation that development cannot be sustained unless the environment is preserved. Hence an increasing number of gov-

ernments around the world are making it mandatory for development project sponsors to prepare EIA-EMP reports so that the quality of the environment is not only preserved but in some cases even enhanced.

This power project, when conceived by APSEB, had received environmental clearance from both state and central governments. Nevertheless, since the original EIA had been carried out more than five years earlier, HNPCL felt it appropriate to carry out a fresh EIA reflecting any changes in the background environmental quality, in anticipation of the requirements of either statutory or lending agencies. When the "consent order for establishment" (copy attached in Appendix A) was transferred from APSEB to HNPCL, the Andhra Pradesh Pollution Control Board (APPCB) notified HNPCL that a comprehensive EIA report be prepared on the project. MoEF also requested for an environmental reappraisal before transferring the clearance from APSEB to HNPCL.

Taking the above into consideration, HNPCL requested Tata Consultancy Services (TCS) to carry out a comprehensive EIA of its proposed TPP, review HNPCL's proposed environmental management strategies, and suggest enhancements where appropriate. The resulting EMP would be a comprehensive plan to minimise any adverse impacts on the environment surrounding the plant site. In addition, HNPCL also requested TCS to carry out a detailed industrial risk analysis (RA) of the project and prepare an emergency preparedness plan (EPP).

As a forerunner to this comprehensive EIA, a rapid EIA report was prepared in April 1996 and was submitted to the Ministry of Environment and Forests (MoEF). After a review of this report by the Environmental Appraisal Committee of MoEF on power plant projects, the project received an environmental clearance. A copy of the clearance is attached in Appendix A.

1.3 Objectives of EIA-EMP

The overall objective of any EIA-EMP exercise is to identify and assess the adverse impacts of a project in the planning stages itself, so that necessary mitigation measures to prevent or minimise these adverse impacts can be planned early and cost-effectively. In view of this, the specific objectives of this EIA-EMP project were:

1. to review the current environmental status of the area within a 30 km radius of the proposed TPP site,

2. to estimate the environmental impact of the proposed project on the surrounding environment,
3. to prepare a comprehensive EMP to ensure that the environmental quality of area would be preserved, and
4. to conduct an industrial risk analysis of the proposed project and prepare an EPP.

1.4 Scope of EIA-EMP

The scope of this EIA-EMP project was as follows:

- collection of baseline data on the environmental quality within a 30 km radius of the project area, including air, noise, water, land, biological (terrestrial, aquatic, and marine), and socio-economic environments for four seasons during 1995-96,
- assessment of the potential environmental impacts of the proposed project including the socio-economic benefits, i e, the positive impact on the socio-economic environment,
- preparation of an EMP to minimise the adverse environmental impacts of the proposed project and to ensure that the standards relevant to the industry will be met,
- industrial risk analysis of the project and preparation of an emergency preparedness plan,
- preparation of a post-project monitoring plan (PPMP) to ensure that the environmental management plan achieves its desired objectives, and
- technical assistance to HNPCL officials in presenting the EIA report before statutory and lending agencies.

1.5 Methodology of EIA-EMP

1.5.1 Assessment of Existing Environmental Quality

All components of the environment were taken into account while assessing the existing environmental quality. Selection of monitoring locations and monitoring and analysis of various parameters of interest was conducted according to (i) guidelines of the Ministry of Environment and Forests (MoEF) and (ii) internationally recognised standard methods of sampling and analysis prescribed by the American Society of Testing and Materials (ASTM), American Public Health Association (APHA), and Bureau of Indian Standards (BIS).

a. Meteorology

Monitoring for micrometeorological parameters such as wind speed and direction, ambient temperature, relative humidity, rainfall, and cloud cover was carried out *round the clock for 365 days* between December 1995 and December 1996 at Palavalasa, the location nearest to the plant site appropriate for the purpose (Exhibit 1.2). In addition, the most recent data on these parameters and rainfall for 5 years were collected for the nearest station (Waltair) from the India Meteorological Department (IMD).

All micrometeorological parameters were monitored in the field. The methods and frequencies of measurements were as follows (based on IS 5182):

Parameter	Equipment (Make) /Method of Monitoring	Frequency
Wind speed	Digital anemometer (Lutron AM 4201)	Hourly
Wind direction	Wind vane	Hourly
Relative humidity	Digital Temp/RH meter (Lutron HT 3003) and dry bulb/wet bulb thermometer	Hourly
Maximum/minimum temperature	Maximum/minimum registering thermometer (G H Zeal Ltd, England)	Hourly
Rainfall	Rain gauge (Lawrence & Mayo)	Daily
Cloud cover	Manual observation	Hourly
Atmospheric pressure	Aneroid barometer (Fischer, Germany)	Hourly

b. Ambient Air Quality

Six air quality monitoring locations (see Exhibit 1.2) were selected based on preliminary estimates taking into account the following project-related and meteorological data provided by HNPCL:

- Stack height = 275 m
- Flue internal diameter = 6 m (at exit)
- Flue gas temperature = 146°C
- Flue gas density = 0.84 kg/m^3
- Sulphur content of coal = 0.8 % (max)
- Ash content of coal = 32 - 36 %
- Coal consumption = 335 T/h (per unit) of washed coal
- Flow rate of gas = 3,052,400 (per unit) m^3/h
- Single plume
- Distance of stack from high tide line = 700 m (approx)
- Distance of stack from coast line = 810 m
- 200 m high hillocks exist within 2 - 6 km of plant site
- There will be 2 units of 520 MW each

The key parameters which determine the distance at which maximum ground level concentrations (GLCs) of pollutants from stack emissions would occur are effective stack height, atmospheric stability class, wind direction, wind speed, etc. Effective stack height was calculated using Briggs plume rise equation and estimates were made considering all stability classes.

Preliminary estimates indicated that the plume would touch down around 1.5 to 5 km from the stack under unstable atmospheric conditions and lead to relatively high GLCs of pollutants. Therefore 4 air quality monitoring (AQM) stations were located within 1.5 to 5 km of the proposed stack location.

The directions of AQM stations relative to the stack were selected based on the prevalent wind directions in the area (based on IMD data). Accessibility and security were also considered while finalising the monitoring locations. According to the wind rose diagrams, the predominant wind directions in the area over the year are:

- SW → NE
- NE → SW
- S → N

Therefore one AQM station was selected in each of the three predominant downwind directions (Palavalasa (A1) in NE, Thikkavanipalem (A4) in SW, and Peddapalem (A2) in N) from the proposed stack location.

Since the power plant will be located on the coast, there could be coastal fumigation due to the formation of internal thermal boundary layer. To account for this phenomenon, one AQM location (A3) was selected on the west at Vadachipurapalli (about 5 km W of the plant site).

One AQM station (A5, Deshapatrunipalem) was selected near where HNPCL's proposed road/rail/power transmission line would pass. This location was considered ideal to assess the impacts due to the movement of vehicles on road and railway cargo and high tension power transmission.

To assess the combined impact of the Visakhapatnam Steel Plant (VSP) and HNPCL's proposed power plant, one AQM station was selected at Peddagantyada (A6), about 3-4 km NNE of the steel plant.

After carrying out the rapid EIA, the meteorological data indicated that the locations selected for the background air quality survey were not inappropriate for the purpose.

Ambient air quality was monitored continuously for 48 hours at each location every week for the entire year. At all locations, concentrations of sulphur dioxide (SO_2), carbon monoxide (CO), both respirable and residual particulate matter (PM), nitrogen oxides (NO_x), and hydrocarbons (HC) were measured. PM was measured on an eight-hourly basis (3 samples per day) while SO_2 and NO_x were measured on a four-hourly basis (6 samples per day), as per MoEF norms. CO and HC were monitored hourly for 48 hours, every week. Particulate matter, SO_2, and NO_x were monitored using a high volume sampler in the field. Samples were analysed in the lab using the methods given below. CO and HC were measured in the field. The methods of monitoring and analysis were based on IS 5182 and methods recommended by the Central Pollution Control Board (under MoEF - notification dated 11 April 1994), as follows:

Parameter	Equipment (Make)/Method	Place of Analysis
Particulate matter (both respirable and residual)	Monitoring by respirable dust sampler (Model APM 415, Envirotech, New Delhi) and analysis by gravimetric method	Lab
SO_2	West & Gaeke	Lab
NO_x	Jacob and Hochheiser, sodium arsenate (modified)	Lab
CO	Portable Detector (Model CO-84, Endee Engineers, Mumbai)	Field
HC	Portable Detector (Model GP-200P, Endee Engineers, Mumbai)	Field
Dust fall	Standard dust fall jar	Field

c. Noise Levels

Noise monitoring locations were selected in populated villages likely to be affected by the additional noise due to HNPCL's proposed TPP, including noise due to construction work, and vehicular movement along the proposed railway line and approach road. Noise levels were monitored at all six AQM locations (N1...N6 corresponding with A1...A6) and nine other locations listed below. All noise monitoring locations are indicated in Exhibit 1.3.

1. **N7: Plant site**
2. **N8: Kalapaka**
3. **N9: Pittavanipalem**
4. **N10: Devada**
5. **N11: Lankelapalem**

Exhibit 1.2. Monitoring locations for micrometeorology and air quality

Exhibit 1.3. Monitoring locations for noise

6. N12: Pentaseema Bonangi
7. N13: Niraj Petrochemicals
8. N14: Paravada
9. N15: Pandivanipalem

Noise monitoring frequency was once a month at each location. Noise readings were taken every hour for 24 hours, using a noise level meter (Lutron, Model SL-4001).

d. Water Quality

Water environment typically includes groundwater and surface water environments. To assess the water quality in the area within 30-km radius of the project site, surface water, marine water, and groundwater samples were collected. Sampling locations are shown in Exhibits 1.4 and 1.5. The samples were analysed for physical, chemical, as well as biological parameters, as per standard methods (Table 1.1). Samples were collected twice a month, starting January 1996.

① Ground Topography in Plant area not de

② natural flow wel drainage system effe Plant area not de

③ Availability of Exact ground wat at Lignite depths not dealt.

i. Surface Water

Surface water bodies in the area surrounding HNPCL's proposed TPP were selected on the basis of beneficial use (drinking, bathing/washing, irrigation, fishing, and aquaculture) of the water body and the distance and direction from the TPP site. Only perennial sources were selected to enable study of variation in water quality over the seasons during 1996. A list of selected locations is given below. All directions were covered, to assess the impact, if any, of the proposed TPP.

1. SW1: Palavalasa pond
2. SW2: Borrapeta tank (near Devada)
3. SW3: Kaniti reservoir
4. SW4: Deshapatrunipalem tank
5. SW5: Kalapaka tank
6. SW6: Barinikam tank
7. SW7: Nalla tank
8. SW8: Thikkavanipalem creek
9. SW9: Yeleru canal
10. SW10: Creek near Appikonda (wastewater discharge point of Visakhapatnam Steel Plant)

ii. Groundwater

Groundwater sources (open wells as well as borewells) in the area surrounding the proposed plant site were selected on the basis of beneficial use (drinking, bathing/washing, irrigation, and salt-making) and the distance and direction from the plant site. Only

perennial wells were selected to enable study of variation in water quality over the seasons. A list of selected locations is given below. As in case of surface water quality monitoring, all directions were covered for groundwater quality monitoring as well. (Numbers in parentheses indicate the distance between the plant and the sampling location - less than 5 km from the plant (5), between 5 and 10 km away from plant (5-10), etc):

1. GW1: Open well at Palavalasa Cyclone Shelter (5)
2. GW2: Open well at Palavalasa village (5)
3. GW3: Borewell at Devada (5)
4. GW4: Open well at Deshapatrunipalem (5-10)
5. GW5: Borewell at Kalapaka (5)
6. GW6: Open well at Pittavanipalem (5)
7. GW7: Open well at Chinnapalem (5)
8. GW8: Borewell at Islampeta (5)
9. GW9: Open well at Barinikam (10-15)
10. GW10: Open well at Visakhapatnam Urban Development Authority (VUDA) Colony near Gajuwaka (10-15)
11. GW11: Open well at Raja Reddy Farm on Paravada-Dalaipalem road (5-10)
12. GW12: Borewell near school at Vada Chipurapalli (5-10)
13. GW13: Open well at Utagaddapalem (5)
14. GW14: Borewell at Jalarpeta (5)
15. GW15: Borewell at Mutyalammapalem (5-10)
16. GW16: Raw water supply borewell of Niraj Petrochemicals (5)
17. GW17: Open well at Dalaipalem (5)
18. GW18: Borewell at salt pans near proposed ash pond (5)
19. GW19: Borewell opposite Hindustan Zinc Limited (HZL) gate (15-20)
20. GW20: Open well at Anakapalli (15-20)
21. GW21: Borewell at Madatur (10-15)
22. GW22: Borewell at Ragavanipalem (5-10)
23. GW23: Open well at Lankelapalem (10-15)
24. GW24: Borewell at Duvvada (15-20)
25. GW25: Open well at Appikonda (5)

iii. Marine Water

Marine water quality was monitored at 15 locations, twice a month at each location. The criteria for selection of the sampling locations were:

- distance and direction from the plant site
- habitats for marine flora-fauna
- cooling water discharge from HNPCL through marine outfall

The following locations were identified. The distances from the coast are indicated in parentheses.

Surface water quality monitoring

Rocky outcrop near Appikonda

Exhibit 1.4. Monitoring locations for surface water quality and marine water quality

Exhibit 1.5. Monitoring locations for groundwater quality

Table 1.1. Methods of analysis of water samples

Parameter	Method (ASTM number)	Indian Standard (if any)	Preservation	Holding time	Field/ Lab
pH	pH meter (D 1293-84)		-	-	F
Colour	Comparison with standard colour solution		-	-	F
Odour	D 1292-80		-	-	F
Temperature	Thermometer		-	-	F
Dissolved oxygen	DO analyser, Winkler-sodium azide modification (D 888-81)	IS2488 (Pt I), 1966	-	-	F
BOD	DO analyser, Winkler-sodium azide modification	IS2488 (Pt I), 1966	-	-	F/L
COD	Open reflux (D 1252-83)	IS2488 (Pt IV), 1974	H_2SO_4 to pH 2	7 d	L
Electrical conductivity	Conductivity meter (D 1125-82)		-	-	F
Turbidity	Turbidity meter (D 1889-81)		-	-	F
Chlorides	Argentometric (D 512-81 Reapproved 85)	IS2488 (Pt III), 1968	-	7 d	L
Phosphates	Molybdenum blue, colourimetric (D 515-82)	IS2488 (Pt IV), 1974	4°C	24 h	L
Cyanides	Distillation, colourimetric (D 2036-82)	IS2488 (Pt I), 1966	NaOH to pH 12	24 h	L
NH_3-N	Nesslerisation, colourimetric (D 1426-79)	IS2488 (Pt IV), 1974	H_2SO_4 to pH 2	24 h	L
NO_3-N	Cadmium reduction, diazotisation, colourimetric (D 3867-85)	IS2488 (Pt IV), 1974	H_2SO_4 to pH 2	24 h	L
NO_2-N	Diazotisation, colourimetric (D 3867-85)	IS2488 (Pt IV), 1974	H_2SO_4 to pH 2	24 h	L
Oil & Grease	Partition, gravimetric (D 4281-83)	IS2488 (Pt I), 1966	H_2SO_4 to pH 2	24 h	L
Phenolic compounds	Diazo (D 1783-80)	IS2488 (Pt I), 1966	H_3PO_4 to pH 4 and 1 g $CuSO_4$/L	24 h	L
Total Kjeldahl Nitrogen	Kjeldahl distillation (D 3590-84)	IS582, 1970	H_2SO_4 to pH 2	24 h	L
Total dissolved solids	Gravimetric (D 1888-78)	IS2488 (Pt V), 1976	4°C	7 d	L
Total suspended solids	Gravimetric (D 3977-80)	IS2488 (Pt I), 1966	-	-	L
Total hardness	EDTA titrimetric (D 1126-80)		-	-	L
Hexavalent chromium	S-diphenylcarbazide, colourimetric (D 1687-84)	IS2488 (Pt II), 1968	-	-	L
Sulphates	Gravimetric, turbidimetric (D 516-82)	IS2488 (Pt III), 1968	4°C	7 d	L
Arsenic	Silver diethyl dithiocarbonate (D 2972-84)	IS2488 (Pt II), 1968	HNO_3 to pH 2, 4°C	7 d	L
Calcium	EDTA titrimetric (D 511-84)		HNO_3 to pH 2, 4°C	7 d	L
Magnesium	EDTA titrimetric (D 511-84)	IS2488 (Pt V), 1976	HNO_3 to pH 2, 4°C	7 d	L
Sodium	Flame photometric (D 1428-82)	IS2488 (Pt V), 1976	HNO_3 to pH 2, 4°C	7 d	L
Potassium	Flame photometric (D 1428-82)	IS2488 (Pt V), 1976	HNO_3 to pH 2, 4°C	7 d	L

Table 1.1. Methods of analysis of water samples (continued)

Parameter	Method (ASTM number)	Indian Standard (if any)	Preservation	Holding time	Field/ Lab
Manganese	Persulphate, colourimetric (D 858-84)		HNO_3 to pH 2, 4°C	7 d	L
Barium	AAS (D 4382-84)		HNO_3 to pH 2, 4°C	7 d	L
Mercury	AAS (D 3223-80)		2 mL/L 20% (w/v) $K_2Cr_2O_7$ prepared in 1+1 HNO_3	7 d	L
Silver	AAS (D 3866-82)		HNO_3 to pH 2, 4°C	7 d	L
Selenium	AAS (D 3859-84)		HNO_3 to pH 2, 4°C	7 d	L
Lead	AAS (D 3559-85)		HNO_3 to pH 2, 4°C	7 d	L
Copper	AAS (D 1688-84)	IS2488 (Pt II), 1968	HNO_3 to pH 2, 4°C	7 d	L
Cadmium	AAS (D 3557-84)		HNO_3 to pH 2, 4°C	7 d	L
Iron	AAS (D 1068-84)		HNO_3 to pH 2, 4°C	7 d	L
Zinc	AAS (D 1691-84)		HNO_3 to pH 2, 4°C	7 d	L
Nickel	AAS (D 1886-84)		HNO_3 to pH 2, 4°C	7 d	L
Boron	Surcumin, colourimetric (D 3082-79)	IS2488 (Pt III), 1968	4°C	24 h	L
Coliform organisms	MPN test (F 488-79)		4°C	24 h	L
Total organic carbon	Persulphate-ultraviolet oxidation (D 2579-85)		HCl to pH 2	24 h	L
Pesticides	Liquid-liquid extraction, GLC (D 3086-85)		4°C	24 h	L
Alpha emitters	Geiger-Muller, alpha spectrometer (D 1943-81)		4°C	24 h	L
Beta emitters	Geiger-Muller, beta counter (D 1890-81)		4°C	24 h	L
PAH	Liquid-liquid extraction, GLC (ASTM)		4°C	24 h	L
Acidity	Titrimetric (D 1067-82)		-	-	F
Alkalinity	Titrimetric (D 1067-82)		-	-	F
Residual chlorine	Iodometric (D 1253-76)	IS3025, 1964	-	-	F

Exhibit 1.6. Monitoring locations for soil quality

1. MW1: Visakhapatnam Port outer harbour (1 km)
2. MW2: Yerada beach (1 km)
3. MW3: Gangavaram (1.5 km)
4. MW4: Visakhapatnam Steel Plant Guest House - boundary away from HNPCL (2 km)
5. MW5: Visakhapatnam Steel Plant southwestern boundary, near HNPCL site (1 km)
6. MW6: Appikonda - rocky outcrop (200 m)
7. MW7: HNPCL plant area (500 m)
8. MW8: HNPCL plant area (2 km)
9. MW9: HNPCL plant area (5 km)
10. MW10: Rocky outcrop near Thikkavanipalem (500 m)
11. MW11: Creek mouth near Mutyalammapalem (500 m)
12. MW12: Between Palavalasa and Thikkavanipalem, southeast of plant site (500 m)
13. MW13: Pudimadaka - rocky outcrop (2 km)
14. MW14: Kothapatnam (300 m)
15. MW15: Chepalapalem near Tantadi - near Chauhan Shrimp Farm (1 km)

Sampling was carried out at these locations using a commercial fishing trawler.

e. Soil Quality

Soil sampling locations were selected in all directions from the plant site, based on the following criteria:

- fertility status for greenbelt development
- suitability for ash pond (to check permeability, etc)
- impact on major activities (agriculture, salt-making, and aquaculture) in the area surrounding the plant site

The selected soil sampling locations are given below and are shown in Exhibit 1.6.

1. S1: Deshapatrunipalem
2. S2: Kalapaka
3. S3: Peddapalem
4. S4: Devada
5. S5: Palavalasa (near plant boundary, proposed greenbelt area)
6. S6: Plant Site (cashew plantation)
7. S7: Ash pond area (west)
8. S8: Plant site boundary (near salt pans)
9. S9: Dalaipalem
10. S10: Niraj Petrochemicals
11. S11: Thikkavanipalem (near aquaculture farm)
12. S12: Thikkavanipalem (near coast)
13. S13: Lankelapalem
14. S14: Peddagantyada
15. S15: Ash pond area (near Palavalasa)

At every location, an undisturbed sample was collected at 40-80 cm depth and a disturbed sample was collected from 80-100 cm depth. Undisturbed samples were collected to accurately measure physical parameters such as infiltration capacity, specific gravity, bulk density, and porosity. All soil parameters which were monitored and the methods of analysis followed are listed in Table 1.2. Monitoring was conducted in January 1996.

Besides soil quality, the following baseline data were also collected on the land environment from secondary sources:

- physiographic features of the region
- Landuse pattern within 20-km radius of the project site, e g, forest cover, irrigated land, unirrigated, culturable wasteland, and area not amenable to cultivation (ANAC)

f. Flora-fauna

A detailed field survey was carried out once in each season to identify the native flora and fauna and their distribution within 30 km radius of the HNPCL plant site. The core zone (within 10 km) and buffer zone (10-30 km) surrounding the proposed site fall under the toposheet number 65 O/1, 65 O/2, 65 O/3, 65 K/14 and 65 K/15 of the Survey of India (SOI). In the buffer zone there are sporadic hill ranges of the Eastern *Ghats* (towards north and west) and Bay of Bengal (towards south and east). Terrestrial, aquatic, and marine flora-fauna were studied on the basis of selection of representative samples. Sampling sites were selected by quadrat and transect methods. The study involved collection of samples from each sampling site, preservation of sample, and its transportation to the laboratory for identification.

Both core and buffer zones were surveyed and the various types of habitat existing in the area were identified for detailed investigation. During field visits of the area, an overall checklist of the flora and fauna was prepared. This checklist was later classified according to the various classes, genera, and species of flora and fauna.

For quantitative assessment of plant species in selected forest habitats, 10 m × 10 m quadrats were laid in the forest area. Secondary data on crop yield, forest cover and livestock census of the area were collected from the respective government departments of the district headquarters.

Marsh plants were examined in situ; a checklist was prepared highlighting their distribution pattern in various aquatic habitats.

Table 1.2. Methods of analysis of soil samples

Parameter	Method (ASTM/BS number)	Indian Standard (if any)	Preservation	Holding time	Field/ Lab
Grain size distribution	Sieve analysis (D 422-63)			7 d	L
Textural classification	Chart developed by Public Roads Administration			7 d	L
Specific gravity	Pycnometer (D 854-58)			7 d	L
Infiltration capacity	Infiltrometer				F
Bulk density	Sand replacement, core cutter			7 d	L
Porosity	Void ratio			7 d	L
Organic matter	Walkley & Black (BS 1377-61)				L
Acidity	Titrimetric (D 1067)			7 d	L
Alkalinity	Titrimetric (D 1067)			7 d	L
Sodium absorption ratio	Flame colourimetric (D 1428-82)			7 d	L
pH	pH meter (D 1293-84)				F
Electrical conductivity	Conductivity meter (D 1125-82)				F
Nitrogen	Kjeldahl distillation (D 3590-84)	IS582, 1970	Drying at 105°C	7 d	L
Phosphorus	Molybdenum blue, colourimetric (D 515-82)	IS2488 (Pt IV), 1974	Drying at 105°C	7 d	L
Potassium	Flame photometric (D 1428-82)	IS2488 (Pt V), 1976	Air drying conditions (< 40°C)	7 d	L
Manganese	Persulphate, photometric (D 858-84)		Air drying conditions (< 40°C)	7 d	L
Copper	AAS (D 1688-84)	IS2488 (Pt II), 1968	Air drying conditions (< 40°C)	7 d	L
Iron	AAS (D 1068-84)		Air drying conditions (< 40°C)	7 d	L
Zinc	AAS (D 1691-84)		Air drying conditions (< 40°C)	7 d	L
Boron	Surcumin, colourimetric (D 3082-79)	IS2488 (Pt III), 1968	Air drying conditions (< 40°C)	7 d	L
Chlorides	Argentometric (D 512-81 Rev 85)	IS2488 (Pt III), 1968		7 d	L
Carbonates	Titrimetric (D 1067)			7 d	L

The life cycles of major sea-weeds of the coastal areas were also examined in situ.

In aquatic habitats, plankton were collected by filtering 100 L of the sample through a net (mesh size 40 μ). The samples were preserved in formalin acetic alcohol solution and brought to the laboratory for examination under the microscope. Benthic algae were collected from both freshwater and inter-tidal coastal habitats, preserved in 4% formalin, and brought to the laboratory for examination.

Terrestrial invertebrate fauna specimens were collected by hand, traps, and insect net. An aquatic net and sampler were used for collecting aquatic forms. Lower groups of vertebrate fauna, fish, and amphibian specimens were also collected using nets.

For the survey of birds and large mammals, a 25×30 telescope and extra wide (8×40) binoculars were used. For crepuscular and nocturnal fauna, detailed survey was conducted at night using filamentless headlight and maglite.

Marine samples were collected at selected locations along the Visakhapatnam coast. Five locations were selected for this purpose: Lawson's Bay, Palm Beach, Gangavaram, Kuttukonda, Mutyalammapalem, and Pudimadaka. These stations cover both rocky and sand-dwelling macrofauna of the intertidal zone. Intertidal fauna were collected during low tide when part of the coast was exposed. A sample of each of the organisms which needed close scrutiny was preserved for the study.

For collecting marine benthic biota, two transects off Gangavaram and Pudimadaka were selected (Exhibit 1.7). On each transect, four different stations were identified at depths of 50 m, 30 m, 20 m, and 10 m. All observations were made between 0630 and 1200 hours. Locations in the sea were fixed using a mariner's compass, in relation with permanent landmarks on the coast. A naturalist's dredge with steel frame (90 cm × 180 cm) was used for the collection of samples. In the sea, the dredge was towed along the bottom in circular path for 10 minutes while maintaining the boat speed between 4 and 5 knots. On the deck, the samples were sorted, and those of interest were thoroughly washed with sea water and preserved in polythene bags in 10% formaldehyde. The collected samples were further screened in the laboratory, thoroughly washed, and preserved in rectified spirit. The collections were then classified groupwise and identified.

Quantitative samples were collected with a Peterson Grab lowered vertically from the boat. As soon as the grab reached the bottom, the brake was released and trawling commenced immediately. Once off the bottom, the grab was hauled as fast as possible. The grab sample was washed through a 500 μ sieve.

After the detailed survey, a checklist of flora-fauna in the area was prepared and checked for rare and endangered species against the Schedule of Indian Wildlife Protection Act (1972, amended till 1991). Secondary data on flora-fauna of the region were collected from ZSI, BSI, CMFRI, Andhra University, State Departments of Forests and Agriculture.

g. Socio-economic Parameters

To assess the existing quality of the socio-economic environment of the region, the following information was collected through secondary sources:

- Demographic Characteristics: break-up of population according to various age groups, male:female ratio, educational level and literacy rate, occupational structure, etc.
- Health Status: The general health status of the population was assessed from district level health records. Incidents of endemic and epidemic diseases in the area was noted.
- Basic Amenities: drinking water resources and water supply, medical facilities, educational facilities, sanitation facilities, recreational facilities, power supply, etc.
- Transport: Information on transportation and communication systems of the area including the frequency of the vehicle movements on adjacent roads were collected. Details of transport study conducted by TCS are given separately.
- Miscellaneous: landuse, major industrial and commercial activities, fishing and agriculture, archaeological monuments, monuments of cultural and historical importance, etc.

A socio-economic survey was conducted by the TCS team within a 30 km radius of the project site to gather public opinion about the project. The questionnaire used for the survey is given in Appendix - B. The following villages were surveyed:

- Thikkavanipalem, Jalarpeta, Dalaipalem, Devada, Palavalasa, and Appikonda
- Mutyalammapalem, Vada Chipurapalli, Kalapaka, Deshapatrunipalem, Steel Plant Colony, Islampeta, Yathapalem, Paravada, Lankelapalem, and Peddagantyada

- Pudimadaka, Atchutapuram, Koppakar, Sheelanagar, Rambilli, Kasimkota, Batajangalapalem, Visakhapatnam, Dimili, Somalingapalem, Sabbavaram, and Chinagadila

h. Traffic Study

To quantify the impact of the additional traffic load on the existing roads leading to the project site, a traffic study was carried out. The main objectives of this study were:

1. to establish the existing hourly and daily average traffic,
2. to determine the existing peak hour traffic,
3. to establish the existing directional split of traffic along with its composition, and
4. to determine the level of congestion on the existing roads leading to the project site.

Traffic surveys were carried out to estimate the classified traffic volume count surveys for 16 hours at important locations in the study area. These surveys were conducted on a normal working day from 6 a m to 10 p m. The locations selected for the traffic survey are given below, along with justification. The recommendations made by Rail India Technical and Economic Services (RITES) for HNPCL on approach road planning were taking into consideration for selection of the locations for the TCS survey. These locations are shown in Exhibit 1.8.

1. Deshapatrunipalem (Gajuwaka - Yelamanchili Road): This road is the major traffic carrier passing close to the HNPCL site. The road provides an alternative to the already congested NH5.

2. Paravada (Lankelapalem - Paravada Road, near MRO office): This is the main artery providing access to the project site from NH5.

3. Kalapaka (Deshapatrunipalem - Kalapaka - Palavalasa Road): This is a major junction on the recommended (RITES) approach road from NH5 at Lankelapalem to the site during the construction phase.

4. Nimma Doddi, Mammusahebpeta (Steel Plant - Palavalasa Road): The road connecting this village with Palavalasa is the stretch common for all alternative alignments considered by RITES.

In order to assess the worst case impact, the traffic count surveys were conducted during January 1996, the harvest season. Traffic is normally at its peak during this season. In addition to these surveys, traffic data for NH5 were collected from the Public Works Department (PWD) of Andhra Pradesh in Visakhapatnam. Traffic data collected from the surveys were coded and analysed to established the hourly and daily traffic composition and directional split.

Traffic volume on the existing roads was projected for the construction phase of the power plant. From past trends based on the PWD counts, an average growth factor was estimated and applied to the results of the traffic survey to obtain the projected traffic during the construction phase.

1.5.2 Identification and Assessment of Impacts

Current background levels of pollution in the various components of environment were measured or estimated as described above. Pollution expected after the TPP becomes operational was estimated. Based on these estimates, changes in the ambient environmental quality was assessed using computer models. Details of models used are given in Chapter 4. Impacts were assessed for construction as well as operational phases. During operational phase, three scenarios - No Project, EIA with EMP, and EIA without EMP - were considered. Assessment and evaluation of impacts are described in greater detail in Chapter 6.

1.5.3 Environmental Management Plan

The environmental protection strategies proposed by HNPCL were reviewed by TCS. After quantifying the pollution potential of the project and studying the effectiveness of HNPCL's environmental protection strategies, enhancements were suggested wherever appropriate to reduce the potential adverse impacts of the project. While developing this EMP, focus was on the following:

- integrated approach to pollution control
- waste minimisation
- waste reuse and resource recovery
- housekeeping practices
- waste segregation to make the treatment and disposal cost-effective

Besides meeting the objectives listed above, the EMP was geared towards meeting the relevant regulatory standards.

Exhibit 1.7. Offshore collection transects along Visakhapatnam coast

Exhibit 1.8. Traffic survey locations

In addition to pollution control strategies, long-term environmental management strategies were proposed including the formation of an environmental management cell. A plan for the development of a greenbelt was suggested to improve both physical and biological environments.

1.5.4 Post-Project Monitoring Plan

The EMP is only as effective as the implementation. To determine the effectiveness of the EMP, a PPMP was suggested to monitor the changes in the surrounding environmental quality after the implementation of the TPP project.

1.5.5 Risk Analysis

A detailed industrial risk analysis of all potential hazardous operations in HNPCL's proposed TPP was carried out using the latest assessment tools. Details of the methodology are presented in Chapter 7.

1.5.6 Emergency Preparedness Plan

Based on the risks identified during the risk assessment, an emergency preparedness plan was prepared. Details of the emergency preparedness plan are given in Chapter 8.

1.6 Structure of This Report

This report is divided into eight chapters including this introduction.

- Chapter 2 gives the power plant details and utilities.
- Chapter 3 describes the existing environmental scenario within a 30 km radius of the proposed plant site.
- Chapter 4 assesses the impact potential of the project without any measures to mitigate adverse impacts.
- Chapter 5 describes the environmental management plan including long-term environmental management options.
- Chapter 6 evaluates the environmental impact of the proposed plant under different scenarios.
- Chapter 7 details the risk analysis study carried out on the HNPCL plant and recommends measures to minimise risk.
- Chapter 8 describes the emergency preparedness plan of HNPCL.

POWER PLANT DETAILS AND UTILITIES

This chapter describes the power plant details and utilities proposed by HNPCL. Source of fuel, transportation, and storage/handling of fuel at site are also described.

Modern steam power plants are variations of the Rankine steam power cycle, which consists of a boiler, a turbine, a generator, and a condenser. The steam from the boiler, when expanded through a turbine, turns the turbine shaft, which is coaxially coupled to an electric power generator. The spent steam is passed through the condenser for reuse.

HNPCL's proposed CBTPS will use washed coal as fuel. A desalination plant will be set up for meeting the sweet water requirement. Sea water from the Bay of Bengal will be used for once-through cooling, desalination, and ash handling.

2.1 Fuels

2.1.1 Source

a. Coal

Coal for the HNPCL plant will be mined from the existing Ananta and Bharatpur open-cast mines of Mahanadi Coalfields Limited (MCL), a subsidiary of Coal India Limited, in the Talcher coal field of Orissa. Both mines have sufficient mineable reserves to supply the proposed power plant for future need. HNPCL has initialled an agreement with the Mahanadi Coalfields Limited (MCL) for the supply of washed coal. The coal will be transported by Indian Railways (IR) in bottom-opening (BOBR-type) wagons under the "own your wagon" (OYW) scheme from the washery at the mine head to the power plant.

HNPCL will use about 4.8 million tonnes[1] of washed coal annually. The coal will have the following characteristics (as per agreement initialled with MCL):

[1] Calculated using a gross calorific value of 4150 kcal/kg, as per agreement initialled with MCL

Parameter	Contracted value	Cut-off value
Ash*	≤ 34 ± 2 %	> 36 %
Total moisture	9.5 - 15 %	> 15 %
Size	≤ 75 mm	> 75 mm
Sulphur	0.6 - 0.8 %	> 0.8 %

*Annual average ash content will not exceed 34%

b. Oil

Light fuel oil (LFO) will be used as fuel for the auxiliary boiler, the emergency generator, and the engine-driven fire pumps. LFO will also be used as fuel for one steam generator during main fuel ignition and warm-up. One of the heavy fuel oils (HFOs), as specified in the table below, may be used as secondary fuel for both steam generators up to 30% maximum continuous rating (MCR) load during main fuel ignition, warm-up, and flame stabilisation at low firing rates. Fuel oil will be procured on a spot contract basis from local suppliers such as Hindustan Petroleum Corporation Limited (HPCL), Indian Oil Corporation Limited (IOCL), etc. The following table shows the characteristics of the alternate fuel oils to be used in HNPCL's TPP.

Parameter	Light fuel oil IS1460-1974	Heavy furnace oil Grade HV IS 1593-1982	Low sulphur heavy stock (LSHS)	Heavy petroleum Stock (HPS)
Sulphur content (max)	1.8%	4.5%	1%	4.5%
Gross cal value (kcal/kg)	10,600	10,200	10,500	10,000
Flash Point (min)	66°C	66°C	66°C	73°C
Water content by vol (max)	0.1%	1%	1%	1%
Sediment by weight (max)	-	0.25%	0.25%	0.25%
Asphaltene by weight (max)	-	2.5%	2.5%	2.5%
Kinematic viscosity in centistokes (max)	2.5-15.7 (at 38°C)	180 (at 15°C)	30 (at 100°C)	500 (at 50°C)
Ash content by weight (max)	0.02%	0.1%	0.1%	0.1%
Acidity (inorganic)	-	Nil	Nil	Nil
Pour point (max in winter)	12°C	8°C	60°C	72°C
Pour point (max in summer)	18°C	27°C	60°C	72°C

2.1.2 Transport

a. Coal

Coal will be transported by rail to the project site. The distance between the proposed coal source, the Ananta and Bharatpur mines, and Visakhapatnam is about 600 km. These two mines are connected to Visakhapatnam by the South-Eastern Railway, out of which the first approximately 80 km of the route from the mines is a spur line to Talcher which then joins the main Calcutta-Chennai

line at Barang near Bhubaneshwar. From Barang, the proposed rail routing (for transportation of coal to Visakhapatnam) is connected up to Duvvada near Visakhapatnam along the Calcutta-Chennai line. The route from Duvvada to the TPP will consist of a single track rail spur with passing places constructed as part of the project works and owned by HNPCL.

HNPCL is discussing a transportation agreement with the Indian Railways (IR) who will be responsible for transporting the required quantity of washed coal every year from the washery to the unloading point at the power station. Coal will be transported in dedicated bottom-discharge wagons, each wagon having a carrying capacity of 55.8 T.

To ensure timely and reliable delivery of coal, HNPCL plans to subscribe to the "Own Your Wagon (OYW)" scheme, under which HNPCL will be responsible for the procurement of new wagons, which will then be operated and maintained by the IR and dedicated for the exclusive use of transporting coal to HNPCL's TPP. This will ensure availability of dedicated rolling stock to the project and reduce the risks in relation to transportation of coal.

b. Oil

Oil will be delivered by rail and/or road to the power plant from Visakhapatnam. Off-loading facilities will be provided to receive both LFO and HFO by road or rail.

2.1.3 Storage and Handling

a. Coal

The coal handling system will consist of rail unloading system with back-up road unloading facility, coal stockyard, and fill system. This will have the following major components :

- Coal unloading system
- Coal stocking/reclaiming system
- Coal dust control system
- Coal handling ancillary systems

About 4-5 trains per day will deliver the coal to the site in a typical wagon rake of 55-60 bottom discharge wagons (type BOBR). This coal will be unloaded into two track hoppers by a merry-go-round system. An emergency truck unloading system will also make use of the same hopper. A 1,500 T/h conveying

system will then take the coal from the rail unloading hopper via an automatic sampling system to the stockyard where a stacker/reclaimer will stock out the coal as required. Two stackers/reclaimers of 1500 T/h will be provided.

Uncrushed coal from the stockyard or wagon unloading facility will be taken to a crusher house and incorporated into the bunker feed stream and transferred to the coal bunkers. Each coal bunker will have twelve-hour storage capacity. There will be six coal bunkers for each steam generator. Fully automated samplers will also be incorporated into the bunker feed streams to facilitate the sampling of "as fired" coal.

b. Oil

LFO will be stored in two tanks, each of 500 m^3 capacity. These will provide fuel for operating the auxiliary boiler for about ten days with two shifts per day and start up of one main steam generator, for running the emergency diesel generator set, and diesel-operated fire pumps.

HFO will be stored in two tanks, each of 1,400 m^3 capacity, with steam coil heaters in the floor. Each HFO tank will have sufficient capacity to store fuel for the main boiler from ignition to 30% MCR load for sixty days' operation, with two shifts per day.

All the tanks will be constructed within a bunded area capable of containing a minimum of 110% of the tank capacity. The bunded area will be adequately drained and equipped with collection sump and interceptors to prevent escape of oil.

Fuel oil will be unloaded into the storage tanks from oil tankers by unloading pumps. Fuel oil from storage tank will be transferred to the burner by transfer pump.

2.2 Unit Process Details

This section briefly describes the important unit operations at the HNPCL plant. Process flow diagram is given in Exhibit 2.1.

2.2.1 Steam Generation

Coal from each bunker will be transported to coal furnace via feeders and coal mills. Each steam generator (steam capacity 1705 T/h MCR) will be furnished with pulveriser-feeder combinations.

Exhibit 2.1. Schematic flow diagram of HNPCL's power plant

Two coal feeders will be provided for each pulveriser. There will be six ball tube pressurised double-ended type pulverisers for each steam generator. The steam generator system of the boiler will transfer the heat released during the combustion of fuel (coal) to the feed water and steam. Heat transfer will also take place in the reheater to increase the temperature of the cold reheat steam, required by the intermediate pressure turbine.

Each of the two boilers in the proposed plant will consist of the following major components:

- Furnace : Welded wall, water cooled, hopper bottom type
- Super heaters : Steam-cooled (roof and rear pass), horizontal spaced type (primary), and pendant panel type (secondary and tertiary)
- Reheaters : Radiant wall type (primary), and pendent space type (secondary and tertiary)
- Economiser : Horizontal continuous loop type

The steam generator type will be a balanced draft, forced circulation, top supported, subcritical unit, corner fired, single re-heat, designed to operate satisfactorily within the whole range of coal characteristics and able to meet the steam requirements of steam turbine. Twelve oil burners and 24 coal burners will be provided with each steam generator.

The HFO firing plant will have a capacity of 30% MCR and the LFO firing plant will have a capacity of 15% MCR. The steam generator will be capable of start-up using LFO in case HFO is not available. Burners, ducts, and other equipment will be designed to permit operation with excess air as high as 20% at MCR when firing the specified coal.

The main steam system will convey superheated steam from the steam generator superheater outlet to the main turbine stop valves. The reheat steam system will provide a flow path for cold reheat steam from the high pressure turbine exhaust to the steam generator and for hot reheat steam from the reheater outlet to the intermediate pressure turbine inlet. Hot reheat steam will be routed from the steam generator reheater outlet to the combined reheat and intercept valves at the intermediate-pressure turbine.

2.2.2 Turbine

The steam turbine will be standard Mitsubishi two-cylinder, tandem-compound, double-exhaust, condensing re-heat turbine designed for high operating efficiencies and maximum reliability.

The high pressure (HP) and intermediate pressure (IP) turbines will be combined in one cylinder. This design will reduce the overall turbine length and result in a compact plant layout.

The turbine will be provided with two separate steam chests which will be connected to HP-IP casing through flexible pipes in such a way that the high temperature parts from the HP-IP casing will be isolated. This will reduce the temperature gradients in the elements, thereby facilitating hot and cold starts free from casing cracking.

Steam from governing valves will enter at the centre of HP-IP casing through four inlet pipes, two in the top half and two in the bottom half, and will pass into four nozzle chambers. The steam will then pass through reaction stages of HP turbine and exhausts to the re-heater through two exhaust openings in the outer casing bottom half. The steam will return to IP turbine (after reheat in steam generator) through two stop valves and two interceptor valves, which will be located on either side of the turbine. Interceptor valves will be connected by flexible steam inlet pipes with IP cylinder, thereby reducing the stresses on each part. The steam exhausting from IP turbine will leave the turbine through the openings in the outer casing cover. The exhaust openings will be connected through crossover pipes to the low pressure (LP) turbine. The LP turbine will incorporate high-efficiency blading, diffuser-type exhaust and liberal exhaust hood design. The steam will then be exhausted into a condenser which is cooled by sea water (once-through system).

Openings will be provided in the casings through which steam will be extracted for feed water heating and for providing steam for the desalination plant.

2.2.3 Generator and Excitation System

The generator and excitation system will convert turbine mechanical energy to electrical energy. The excitation system will provide control of generator terminal voltage by controlling current supplied to the generator field. The generator will be a two pole 50 Hz machine, consisting of cooling systems (hydrogen and water

cooled). It is proposed that each generator's output will be connected to the 400 kV grid system via a generator circuit breaker, transformer, and a grid circuit breaker. Unit transformers will be "teed" off the generator output bus-bars at a point between the circuit breaker and the generator transformer.

2.2.4 Substation

A 400 kV substation with one-and-half breaker configuration is proposed for connecting two 520 MW generators to four transmission circuits for feeding power to the grid.

2.2.5 Instrumentation and Control

The HNPCL plant will be equipped with a state-of-the-art "DIASYS-UP" digital control and instrumentation system (DCIS) of Mitsubishi Heavy Industries (MHI). The system is based on proven hardware. The 32 bit microprocessor in the system assures high data processing capability and permits the use of advanced software technology available for real time data processing. The DCIS will provide high-level automation capability including single-push hot-mode start-up capability. The DCIS will also monitor and log data from the various on-line monitors provided for various pollution control equipment and operators will be provided with alarms whenever pollution exceeds stipulated limits.

The DCIS is designed for allowing the plant to start up safely and allows the plant to be operated reliably and efficiently by the operators. The system will provide automatic plant start-up and shutdown. It will also ensure that the normal start-up/shutdown sequences are maintained.

The integrated DCIS will provide power plant control, monitoring, data logging, and protection and interlocking of the units.

The central control room will be furnished with all necessary control equipment, including unit control desks, unit back panels, printers, and electrical control panels. The plant is designed to operate under all normal conditions through the "CRT-based" "soft" man-machine interface.

2.2.6 Auxiliary Boiler

One factory-assembled auxiliary boiler (38 T/h - 14 atg - saturated), complete with its auxiliaries, fired by light oil, will be provided for ensuring the start-up of one of the main boilers. The

boiler will be sized so as to also start (in addition to one main steam generator) one stream of the desalination plant to ensure that in the event of shutdown of both the main units, enough sweet water will be available to meet the drinking water and other service water requirement.

2.2.7 Emergency Diesel Generator

Two 776 kVA emergency diesel generator (DG) sets will be provided to meet the load requirement for the safe shutdown of the plant during an emergency and for emergency lighting.

2.3 Access

A new all-weather motorable access road will be constructed from NH5 to the site to cater to the traffic to and from the proposed TPP. The road will be one lane each way, each lane being 3.65 m wide with kerbs. Parts of the existing roads may be improved to facilitate passage of construction traffic till the proposed access road is built. The proposed access road is shown in Exhibit 1.1.

In addition to the access road, a new railway spur (about 18 km) will be built from Duvvada station to the HNPCL site. This will be single track with a passing place. The route will follow the land corridor being acquired by the APSEB. The spur will leave the main line at the Duvvada station, run parallel to the existing main line for about 5 km, turn south, detour the hillock, turn SE, and then again south to reach the TPP site. The spur will pass by the Visakhapatnam steel plant boundary along its route. The proposed access railway alignment is shown in Exhibit 1.1.

2.4 Water Requirement

Over 99% of HNPCL's total water requirement will be for cooling. Apart from cooling, 0.042% of the total water requirement will be for process (boiler make-up), 0.02% for service water, 0.01% for coal handling, 0.02% for bottom ash handling, and 0.01% for domestic use. Exhibit 2.2 shows the water requirement of HNPCL.

The total daily water requirement of the plant is expected to be 5862981 m^3/d, which will be met by drawing water from the Bay of Bengal. Out of this, 80,421 m^3/d of sea water will be desalinated for meeting the sweet water requirement of 6064 m^3/d. The

What is the cost ?

brine (74,357 m^3/d) generated from the desalination unit will be discharged along with cooling water discharge through the marine outfall.

The sweet water requirement will be for boiler make-up, potable water (canteen, sanitary, and colony), service water, coal handling, and bottom ash handling. To yield 2440 m^3/d of boiler make-up water, 2464 m^3/d of sweet water will be passed through a mixed bed polisher (demineralisation unit).

The distribution of HNPCL's water requirement is tabulated below.

Water requirement of HNPCL for	Quantity (m^3/d)
Process (boiler makeup)	2440
Domestic (canteen, sanitary and colony)	625
Service water	1175
Coal handling	600
Bottom ash handling	1200
Cooling (once-through)	5782560

0409

The cooling water system will provide cooling water to the condensers for condensing turbine exhaust steam and to the closed-cycle cooling water heat exchangers. The system will be a once-through design to comply with the condition in the MoEF clearance requiring that the rise in temperature be maintained within 5°C of the ambient sea water temperature. From the condenser and heat exchangers, heated circulating water will flow to the seal well. Heated water will be discharged through an outfall structure in the Bay of Bengal.

The cooling water will be chlorinated, before being used, to prevent any biological growth. The chlorination system (liquid chlorine cylinders with dosing equipment) will meet the need of continuous (1 ppm) and impact chlorine addition (3 ppm) for the entire quantity of cooling water. The storage capacity for bottled chlorine will have an endurance of approximately 7 days, consistent with O&M norms. The chlorination system will consist of two sets of chlorination units with 230 kg/h capacity each, comprising one set of evaporator and automatic chlorinator. Chlorine solution will be injected through diffusers at cooling water inlet channel and intake pump pit. The residual chlorine will be continuously monitored at the outfall to meet the CPCB standard of < 0.5 ppm.

The total sweet water requirement of HNPCL will be met from a steam distillation desalination plant. This plant will treat the readily available sea water to generate fresh water, compatible with the site uses or suitable for further treatment to produce demineralised and potable water.

The water desalination process will be based on the multiple-effect distillation (MED) technique, which will use a multi-stage thermo-compression process operating at low temperature and pressure. Adequate plant capacity and redundancy will be maintained to ensure that the plant's water demand be met at all times. Belgard EV will be used as the anti-scale agent and Belite E8 will be used as the anti-foam agent. The desalination plant will provide water of the following quality:

- Sodium (as Na) : <1.7 mg/L
- Silica (as SiO_2) : ≈0.15 mg/L
- Conductivity : <12 μmho/cm
- Free CO_2 : ≈0.6 ppm
- pH : 5.8-6.5
- Total dissolved solids (TDS) : ≈0.6 ppm

A demineralisation plant (mixed bed polishing unit), based on ion-exchange technology, will be used to treat the distillate from the desalination plant to produce the high quality process water required as a boiler feed. The quality of the demineralised water will satisfy the following:

- Sodium (as Na) :<10 μg/L
- Chloride (as Cl) :<6 μg/L
- Sulphate (as SO_4) :<6 μg/L
- Silica (as SiO_2) :<20 μg/L
- Conductivity :<0.15 μSiemens/cm
- Total organic carbon :<300 μg/L

The boiler feed water will be dosed with hydrazine, ammonia, and phosphate to remove oxygen and prevent scaling.

Water to be used for domestic/drinking purpose will be remineralised to meet the WHO drinking water standard. A schematic of the raw water treatment is given in Exhibit 2.2 as a part of the water balance diagram.

Exhibit 2.2. Water utilisation at HNPCL's plant

(ALL FLOWS ARE IN m^3/d)

CHAPTER 3

EXISTING ENVIRONMENTAL SCENARIO

The TCS team surveyed the area surrounding the HNPCL plant site near Palavalasa in December 1995. During this field visit, the physical features of the area including the structures and major activities were surveyed, and sampling locations for background environmental quality monitoring were selected. Primary data collection was started on 17 December 1995. Besides primary data, secondary data were collected from the District Census Handbook, District Industries Centre, Primary Health Centres surrounding the site and other central and state government offices. It is on these data that the existing environmental scenario presented in this chapter is based.

The HNPCL site is located between 17°32'42"N-17°35'N Latitude and 83°6'45"E-83°10'E Longitude. The maximum elevation of the proposed plant area is about 5 m above mean sea level (MSL). The proposed ash pond site would be mostly on a mud flat area, whose elevation ranges from sea level up to a maximum of 1.1 m above MSL. Most of the plant area is flat, dry, and barren land at present.

Towards the south of site, cashew and casuarina plantations exist. The area surrounding the HNPCL site is essentially rural, bound by hillocks on three sides except S and SE where the Bay of Bengal exists. The proposed site is located about 2 km SW of Visakhapatnam Steel Plant (VSP) boundary.

3.1 Air Environment

The description of the existing air environment surrounding the HNPCL plant site is based on actual monitoring during December 1995 - December 1996 carried out under the supervision of TCS. Past meteorological data pertaining to the area were obtained from the India Meteorological Department (IMD), for the nearest IMD station, Waltair (Visakhapatnam). The data collected by TCS were compared with the data obtained from IMD.

3.1.1 Meteorology

Air quality of a region depends to a large extent upon the local micrometeorological conditions and sources of air emissions. Dilution and dispersion of pollutants is determined by the wind speed and direction, and rainfall, which are regulated by the variation in temperature. Thus micrometeorology plays a vital role in determining the baseline air quality of any region.

To determine the micrometeorological conditions [temperature, relative humidity (RH), rainfall, cloud cover, and wind speed and direction] at the HNPCL plant site, a monitoring station was set up at the Palavalasa cyclone shelter. This was the most appropriate location, being adjacent to the site and safe. The data collected at this site are presented in this section. Data Collected from IMD for the Waltair Station for 1989-93 are also presented for comparison.

a. Temperature

Temperatures recorded at the Palavalasa cyclone shelter are presented in Exhibit 3.1. Data Collected from IMD for the Waltair Station for the period 1989-93 are given in Table 3.1. The minimum temperature at Palavalasa varied between 14.4°C (February 1996) and 25°C (September 1996) and the maximum temperature ranged between 31°C (January 1996) and 38.0°C (September 1996). As shown in Exhibit 3.1, average temperatures increased from January to May, decreased slightly during the monsoon, and again increased slightly during September before gradually decreasing again. Winter season temperatures were moderate. Data from Waltair Station of IMD indicate a similar trend with an average minimum temperature ranging between 19°C and 28°C and average maximum temperature ranging between 26.5°C and 33.1°C for the period 1989 to 1993 (Table 3.1).

b. Relative Humidity

The minimum RH at Palavalasa varied between 16% (February 1996) and 65% (July 1996). During the entire monitoring period, the maximum RH was found to be more than 95% (Exhibit 3.2). The average RH varied between 75% and 85%. These figures are comparable with those recorded at the Waltair Station of IMD; during the period between 1989 and 1993, the Waltair Station recorded average RH ranging from 61% to 82% (Table 3.1).

Exhibit 3.1. Monthly variation of temperature at Palavalasa from December 1995 to November 1996

Table 3.1. Monthly mean surface meteorological data for Waltair (1989-93)
(Source : India Meteorological Department)

Year	Month	Max temp (C)	Min temp (C)	Rainfall (mm/month)	Wind speed (km/h)	Evaporation (mm/d)	Rel humidity %
89	May	32.1	27.7	070.5	15.9	06.0	78
89	Jun	32.0	27.5	070.5	15.4	05.7	75
89	Jul	30.6	26.2	241.9	14.8	04.2	81
89	Aug	31.5	25.9	207.7	11.6	04.6	79
89	Sep	30.8	25.7	236.3	09.5	04.5	80
89	Oct	31.7	25.3	002.6	06.6	05.1	69
89	Nov	30.0	23.3	000.0	07.6	05.6	64
89	Dec	27.4	21.3	013.2	07.8	05.2	61
90	Jan	28.2	21.0	000.1	07.3	04.3	71
90	Feb	29.0	22.5	075.1	08.3	04.7	78
90	Mar	30.4	24.5	138.2	12.5	05.3	77
90	Apr	31.0	25.3	084.1	16.3	06.0	78
90	May	31.4	26.3	341.0	12.6	05.5	78
90	Jun	32.4	27.0	047.0	12.5	05.0	76
90	Jul	30.5	25.9	098.8	13.5	04.2	80
90	Aug	31.2	26.0	235.2	11.7	04.8	80
90	Sep	31.5	26.1	095.0	09.0	04.9	81
90	Oct	30.1	24.9	137.4	09.1	04.5	77
90	Nov	29.4	23.7	171.6	10.9	04.5	71
90	Dec	27.9	21.7	008.8	09.0	04.1	69
91	Jan	27.3	21.4	056.8	07.8	03.3	76
91	Feb	30.0	22.7	000.0	08.7	03.9	68
91	Mar	31.3	25.1	000.0	12.6	05.0	74
91	Apr	32.5	27.3	000.0	15.1	05.5	73
91	May	33.1	28.3	014.0	19.4	05.5	74
91	Jun	32.2	27.0	193.3	13.3	04.1	81
91	Jul	30.7	26.4	142.6	13.8	03.9	78
91	Aug	32.2	26.9	013.8	11.1	04.3	74
91	Sep	31.8	26.1	161.7	09.4	04.5	80
91	Oct	30.5	24.9	228.6	07.4	03.0	77
91	Nov	28.0	22.5	129.1	09.8	03.2	71
91	Dec	27.0	20.4	000.2	07.7	03.3	66
92	Jan	26.6	19.2	000.6	06.0	02.9	70
92	Feb	29.0	22.8	001.0	11.4	04.1	74
92	Mar	29.5	23.7	000.0	13.0	04.8	74
92	Apr	30.5	25.9	000.0	13.5	05.2	76
92	May	32.1	27.1	033.9	14.0	06.0	75
92	Jun	33.0	28.0	077.3	12.4	05.5	75
92	Jul	31.0	26.3	234.5	12.2	03.9	80
92	Aug	31.1	25.8	192.6	10.4	03.8	81
92	Sep	30.9	25.9	122.2	08.2	03.7	79
92	Oct	31.3	25.1	234.5	07.3	05.0	74
92	Nov	28.6	23.3	433.6	00.0	04.0	77
92	Dec	27.7	20.2	000.0	07.0	03.4	65
93	Jan	28.2	21.0	000.0	07.1	03.2	73
93	Feb	29.0	22.2	001.0	09.1	04.2	70
93	Mar	30.5	24.6	000.0	11.2	04.9	78
93	Apr	31.4	26.0	088.6	15.3	05.3	77
93	May	32.2	27.1	104.0	17.6	05.5	76
93	Jun	32.7	27.6	112.1	12.0	05.4	74
93	Jul	30.9	26.7	071.1	12.1	03.8	79
93	Aug	31.9	26.8	191.4	11.7	04.2	75
93	Sep	30.6	25.6	181.0	09.8	03.4	82

Exhibit 3.2. Monthly variation of relative humidity at Palavalasa from December 1995 to November 1996

c. Rainfall

The monthly total rainfall recorded at Palavalasa is shown in the following graph. During the monitoring period (1995-96), no rainfall was recorded from December 1995 to March 1996. October was the wettest month, receiving 445 mm of rainfall. During monsoon, June was the wettest month, receiving 130 mm of rainfall. The heavy rainfall during October was due to the occurrence of depressions in the Bay of Bengal.

IMD data from the Waltair Station (Table 3.1) indicate that that this region receives considerable amount of precipitation due to cyclonic activity during pre-monsoon and post-monsoon periods. The pattern observed during 1995-96 was consistent with this.

d. Cloud Cover

Cloud cover was monitored at Palavalasa during 1995-96. During winter, December was comparatively cloud-free; January and February were relatively more cloudy. During pre-monsoon, March was relatively cloud-free. From April to June, the sky was partly cloudy, especially during the afternoon hours. From the second half of July to the second week of September, overcast conditions prevailed on many days. This was due the active monsoon during this period. After the monsoon, the first half of October was cloudy due to depressions in the Bay of Bengal. The second half of October was relatively less cloudy than the first half. Most of the days in November were comparatively cloud-free except for a day, due to a depression in the Bay of Bengal.

The temperature, RH, rainfall, and cloud cover data at Palavalasa are typical of moderate sub-tropical climate.

b. Wind Speed and Direction

Wind roses for December 1995 to November 1996 based on hourly readings of wind speed and direction collected at site are presented in Exhibits 3.3 through 3.14. These exhibits indicate that southwesterly winds were predominant from March to September. From October to December, predominant wind direction changed to northeast. In February, June, September, October, and November, the wind was multi-directional. Relatively higher wind speeds (more than 10 knots) were recorded during summer. Wind speeds were lower and calm conditions were prevalent during the winter months. Winds were mainly from the southwesterly quadrant during March, May, July, and August. Frequency of winds from the northwesterly to southeasterly quadrants and vice versa was very low in all months except February 1996 and November 1996.

Wind roses collected from IMD for the Waltair Station for the period 1981-1990 are given in Exhibits 3.15 and 3.16. During January, north-northeasterly and northeasterly winds are predominant with wind speeds ranging between 4 and 6 knots at 0830 hours. At 1730 hours, southerly wind predominates, followed by easterly and northeasterly. The predominant wind speed is 4-6 knots. During February, the predominant wind is southwesterly with dominant wind speed ranging between 4 and 6 knots at 0830 hours. South-southwesterly wind predominates at 1730 hours, with dominant wind speed in the range of 7-10 knots. From March to September, the predominant wind direction is southwesterly. More than 70% of the time, both at 0830 and at 1730, winds are from the southwesterly quadrant. Winds from the southeasterly quadrant are almost absent during this period. During October, winds are generally from all directions except from the southeasterly quadrant. During November and December, winds from the northeasterly quadrant are predominant. During December, north-northeasterly and northeasterly winds predominate, with dominant wind speed between 7 and 10 knots at 0830 hours and 1730 hours.

In general, the wind pattern at the HNPCL site was similar to that observed at the Waltair IMD station. The predominant wind direction in the area is from the southwestern to the northeastern quadrant.

Exhibit 3.3. Wind rose for Palavalasa during December 1995

CALM WINDS 47.69%

NOTE: Frequencies indicate direction from which the wind is blowing.

WIND SPEED (KNOTS)

Exhibit 3.4. Wind rose for Palavalasa during January 1996

Exhibit 3.5. Wind rose for Palavalasa during February 1996

Exhibit 3.6. Wind rose for Palavalasa during March 1996

Exhibit 3.7. Wind rose for Palavalasa during April 1996

CALM WINDS 3.65%

NOTE: Frequencies indicate direction from which the wind is blowing.

WIND SPEED (KNOTS)

Exhibit 3.8. Wind rose for Palavalasa during May 1996

CALM WINDS 2.32%

NOTE: Frequencies indicate direction from which the wind is blowing.

Exhibit 3.9. Wind rose for Palavalasa during June 1996

Exhibit 3.10. Wind rose for Palavalasa during July 1996

CALM WINDS 0.00%

NOTE: Frequencies indicate direction from which the wind is blowing.

WIND SPEED (KNOTS)

Exhibit 3.11. Wind rose for Palavalasa during August 1996

CALM WINDS 2.32%

NOTE: Frequencies indicate direction from which the wind is blowing.

WIND SPEED (KNOTS)

Exhibit 3.12. Wind rose for Palavalasa during September 1996

Exhibit 3.13. Wind rose for Palavalasa during October 1996

CALM WINDS 30.43%

WIND SPEED (KNOTS)

NOTE: Frequencies indicate direction from which the wind is blowing.

Exhibit 3.14. Wind rose for Palavalasa during November 1996

Exhibit 3.15. Wind roses for Waltair at 0830 hours
(1981-90 data collected from India Meteorological Department)

Exhibit 3.16. Wind roses for Waltair at 1730 hours
(1981-90 data collected from India Meteorological Department)

3.1.2 Ambient Air Quality

Air quality was measured nearest to and surrounding the proposed plant site at six locations (Exhibit 1.2). As discussed in Chapter 1, the locations were decided based on preliminary estimates (using Gaussian air dispersion modelling) of the distance from the plant where maximum ground level concentrations (GLCs) of pollutants emitted by HNPCL would occur under the prevalent meteorological conditions, including coastal fumigation effects. Apart from the various pollutants, dust fall rates were also measured at the six locations.

Seasonal maximum, minimum, 95th percentile values, and 98th percentile values of concentrations of SPM, SO_2, NO_x, and CO at each monitoring location are given in Table 3.2. Standards specified by the Central Pollution Control Board (CPCB) are also given for comparison.

The ambient SPM concentrations (98th percentile values) in the area surrounding the HNPCL site varied from 51 $\mu g/m^3$ at Deshapatrunipalem (monsoon) to 117 $\mu g/m^3$ at Palavalasa (winter). SO_2 concentrations (98th percentile values) varied between 14 $\mu g/m^3$ at Thikkavanipalem (monsoon) and 31 $\mu g/m^3$ at Palavalasa (winter). NO_x concentrations (98th percentile values) ranged between 12 $\mu g/m^3$ at Thikkavanipalem (monsoon) and 39 $\mu g/m^3$ at Palavalasa (winter). CO concentrations (98th percentile values) varied between 0.9 mg/m^3 at Chipurapalli (pre-monsoon) and 2.8 mg/m^3 at Palavalasa (winter and pre-monsoon). Thus, in general, higher concentrations were observed during winter. During monsoon, pollutant concentration were comparatively lower. This is likely due to the washout of pollutants by precipitation.

As expected in a rural area, the concentrations of SPM, SO_2, NO_x, and CO were observed to be low and well within the limits prescribed by CPCB for not only residential and rural areas, but industrial/mixed use areas as well. No standards exist for ambient HC concentrations; nevertheless, the HC levels in the ambient air were relatively low, averaging less than 2 mg/m^3.

Presence of CO and HC in the ambient air surrounding the proposed project site could be attributed to the traditional shell-burning for lime preparation, brick-making, and preparation of molasses in village *chulhas* (country stoves) using firewood.

The dust fall rates observed in the project area are given in the following table.

Location	Dust fall rate ($g/m^2/month$)
Palavalasa	1.14
Peddapalem	1.06
Vadachipurapalli	1.03
Thikkavanipalem	0.99
Deshapatrunipalem	1.16
Peddagantyada	0.54

The dust fall rates during 1995-96 varied between 0.54 and 1.16 $g/m^2/month$. The highest dust fall rate was observed at Deshapatrunipalem, which could be attributed to the proximity of this monitoring location to the Gajuwaka-Yelamanchili road.

3.2 Noise Environment

Equivalent noise levels (L_{eq}) for day and night at and around the HNPCL plant site during 1995-96 are given in Exhibit 3.17. The following salient observations can be made from the exhibit:

- L_{eq} at and around the project site varied between 49 dBA and 70 dBA during day time and between 40 dBA and 59 dBA during night time, which were well within the standards specified for industrial areas.
- Noise levels were found to be highest at Desapatrunipalem and lowest at the plant site throughout the year during both day and night. This could be attributed to the traffic plying on the busy Gajuwaka-Yelamanchili Road which passes very close to this location.
- At most of the locations where monitoring was undertaken, the highest L_{eq} values were found to have occurred during the first three months of the year. During the latter part of the year, the L_{eq} values were found to be fairly uniform at most of the locations. At some locations, however, the L_{eq} values were found to be slightly higher during August and September. These months coincide with harvesting time, when a great deal of activity takes place in these rural areas.

Table 3.2. Ambient air quality around HNPCL plant site

All units are in $\mu g/m^3$ except for CO which is in mg/m^3

Station	Distance*	Direction*	Season	SPM 8 hourly Max	SPM 8 hourly Min	SPM 24 hourly Max	SPM 24 hourly Min	SPM 24 hourly 95 **	SPM 24 hourly 98 **	SO_2 8 hourly Max	SO_2 8 hourly Min	SO_2 24 hourly Max	SO_2 24 hourly Min	SO_2 24 hourly 95 **	SO_2 24 hourly 98 **	NO_x 8 hourly Max	NO_x 8 hourly Min	NO_x 24 hourly Max	NO_x 24 hourly Min	NO_x 24 hourly 95 **	NO_x 24 hourly 98 **	CO 8 hourly Max	CO 8 hourly Min	CO 8 hourly 95 **	CO 8 hourly 98 **
Palavalasa	3 km	NE	Winter	213	13	132	37	120	127	36	14	33	19	29	31	57	11	39	15	38	39	3.4	0.3	2.5	2.8
			Pre-monsoon	105	34	97	57	89	94	32	8	26	17	24	25	23	10	19	14	19	19	2.3	0.0	2.2	2.2
			Monsoon	94	24	77	34	70	73	32	9	24	14	24	24	29	9	23	13	22	22	2.0	0.0	1.6	1.9
			Post-monsoon	98	25	81	39	79	81	43	9	26	13	25	26	31	9	23	12	22	22	1.4	0.0	1.3	1.3
			Annual	213	13	132	34	98	112	43	8	33	13	27	29	57	9	39	12	30	36	3.4	0.0	2.0	2.2
Peddapalem	6 km	N	Winter	111	29	102	33	99	101	37	9	28	14	26	27	47	10	36	12	35	36	2.0	0.0	1.4	1.6
			Pre-monsoon	118	39	94	48	89	92	33	9	24	17	23	24	32	9	25	16	22	24	1.7	0.0	1.4	1.5
			Monsoon	101	25	83	39	77	80	25	7	19	13	18	19	22	7	18	12	16	17	2.0	0.0	1.4	1.7
			Post-monsoon	112	33	84	40	79	82	35	6	30	13	26	28	28	7	25	12	25	25	1.7	0.2	1.3	1.3
			Annual	118	25	102	33	89	98	37	6	30	13	26	27	47	7	36	12	24	32	2.0	0.0	1.4	1.6
Chipurupalli	6 km	WNW	Winter	227	22	124	30	107	117	42	9	27	16	27	31	30	11	18	13	18	18	0.9	0.0	0.8	0.9
			Pre-monsoon	106	50	90	64	90	90	32	10	26	19	23	24	22	8	18	12	17	17	2.3	0.0	1.7	2.1
			Monsoon	108	34	93	43	89	92	22	6	27	14	19	20	23	5	19	10	17	18	2.0	0.0	1.4	1.6
			Post-monsoon	93	43	76	51	72	74	26	11	28	14	19	19	24	9	19	12	18	18	1.7	0.0	1.3	1.4
			Annual	227	22	124	30	91	102	42	6	28	14	25	27	30	5	19	10	18	18	2.3	0.0	1.6	1.7
Thikkavanipalem	3 km	SW	Winter	216	19	121	46	94	110	42	5	33	14	24	28	22	11	20	13	19	20	1.4	0.0	1.1	1.3
			Pre-monsoon	137	28	99	47	95	97	26	7	24	16	20	20	23	5	17	13	17	17	2.7	0.0	1.9	2.0
			Monsoon	66	27	55	38	51	53	19	5	20	12	13	14	17	5	12	9	12	12	2.0	0.0	1.6	1.7
			Post-monsoon	65	32	59	41	57	58	21	6	19	14	17	17	22	5	15	9	15	15	1.6	0.0	1.3	1.3
			Annual	216	19	121	38	89	96	42	5	33	12	20	23	23	5	20	9	17	17	2.7	0.0	1.6	1.8
Deshapatrunipalem	9.5 km	N	Winter	253	17	128	35	103	118	42	9	31	10	28	29	34	9	24	15	21	23	1.7	0.0	1.4	1.7
			Pre-monsoon	98	46	87	51	86	87	31	7	20	14	21	22	22	7	18	11	17	17	2.5	0.2	2.0	2.4
			Monsoon	73	21	52	31	49	51	32	7	14	9	19	20	19	7	15	11	14	15	2.2	0.0	1.7	2.1
			Post-monsoon	80	21	65	34	63	65	35	8	17	9	19	20	25	7	20	12	17	19	1.6	0.0	1.4	1.4
			Annual	253	17	128	31	81	87	42	7	31	9	24	27	34	7	24	11	19	21	2.5	0.0	1.7	2.0
Peddagantyada	14 km	NE	Winter	166	18	120	36	117	119	37	5	29	16	25	26	34	9	24	14	22	24	1.4	0.0	0.9	1.1
			Pre-monsoon	106	39	93	46	84	89	37	11	23	13	24	25	28	10	23	17	23	23	2.5	0.0	2.2	2.3
			Monsoon	82	25	68	32	66	68	36	8	21	11	25	26	27	7	22	12	19	20	2.0	0.0	1.6	1.9
			Post-monsoon	81	26	69	33	68	69	37	10	21	12	27	27	37	7	27	11	26	26	1.9	0.0	1.4	1.7
			Annual	166	18	120	32	97	110	37	5	29	11	26	27	37	7	27	11	24	26	2.5	0.0	1.7	2.0
CPCB Standard for industrial areas									500						120						120				5.0

* With respect to stack

** Percentile

Exhibit 3.17. Monthly variation in day and night Leq values around HNPCL site

Peddapalem

Thikkavanipalem

Chipurupalli

Exhibit 3.17. (Contd...) Monthly vatiation in day and night Leq values around HNPCL site

Exhibit 3.17. (Contd...) Monthly variation in day and night Leq values at and around HNPCL site

Exhibit 3.17. (Contd...) Monthly variations in day and night Leq values around HNPCL site

Exhibit 3.17. (Contd...) Monthly variation in day and night Leq values around HNPCL site

3.3 Water Environment

Surface water, groundwater, as well as marine water quality was monitored during the four seasons of 1995-96 in a 30 km radius around the HNPCL plant site. These are discussed separately in this section.

3.3.1 Surface Water

Several tanks exist in the villages in a 30 km radius of the HNPCL plant site. The major uses of these village tanks are bathing, washing, and irrigation. Most of these tanks get dried up during summer months. To enable assessment of the surface water quality throughout the year, only perennial tanks were selected for the purpose of this EIA. Samples were also collected from some perennial streams. Results of the analysis of samples collected from these surface water bodies are presented in Appendix C. The salient features of the analysis are as follows:

- Water quality was found to be generally acceptable except for BOD which exceeded recommended limits at all locations. Appikonda creek was found to be the most polluted of all surface water bodies monitored, which could be attributed to the discharge of effluents into the creek. As expected, Kaniti reservoir water quality was found to be best. This reservoir is the raw water source for VSP.
- The concentrations of most parameters tested were higher during pre-monsoon than in the other seasons.
- pH was found to be highly alkaline during pre-monsoon. In other seasons, it was in the slightly alkaline range.
- Water from all the village tanks was found to be *moderately hard* to *hard* but that from the Thikkavanipalem and Appikonda creek was found to be *very hard*. During monsoon, hardness was relatively lower than in other seasons.
- Dissolved oxygen (DO) content was high, indicating good aeration of the water. During pre-monsoon, DO concentrations were lower at some locations than during other seasons, possibly due to relatively higher ambient temperatures.
- Concentrations of nutrients - phosphates, nitrates, nitrites, TKN, and ammoniacal nitrogen - were low.
- Heavy metals were generally present in low quantities. Mercury concentrations, however, were found to be fairly high in all samples during winter.
- Coliform organisms were found in all samples, indicating faecal contamination.

- Pesticides were absent from all samples during winter, but could be detected during other seasons, making the water unsuitable for public water supplies or bathing. The water from most of these water bodies, however, is used for irrigation, for which no standard is specified under IS 2296.
- Polyaromatic hydrocarbons were absent from all samples during all seasons.
- Radioactivity could not be detected in any sample.

3.3.2 Groundwater

A number of groundwater (GW) sources (open wells and borewells) were observed in the villages surrounding and adjacent to the HNPCL plant site. Major uses of these GW sources are drinking, washing, bathing, and irrigation. Most of these wells go dry during the summer months.

Depth of the GW table was measured in the open wells from which samples were collected for water quality analysis. The groundwater table in the area was found to be generally between 0.5 m and 10.5 m below ground level, depending upon the season (Table 3.3).

GW samples were collected from 25 perennial wells (open wells as well as borewells) in the area. The quality of water in these wells is presented in Appendix C. No significant seasonal variation was observed in the groundwater quality in the area. The salient features of this analysis are as follows:

- GW quality was found to be generally acceptable as per IS 2296, except for BOD (at GW1 and GW13) which marginally exceeded the standard for public water supplies and bathing *ghats* during winter. In other seasons, the BOD was found to be within acceptable limits. Water from GW18 is used for salt farming, hence IS 2296 limits are not strictly applicable to it. At most locations from where water is drawn for drinking, the water quality was found to conform to drinking water standards (IS 10500) except for total dissolved solids.
- pH was in the neutral to slightly alkaline range.
- Heavy metals were either absent or were present in traces.
- Water at all locations was found to be *moderately hard* to *hard.*
- Phosphates and TKN concentrations were relatively low.
- Oil and grease, phenolic compounds, polyaromatic hydrocarbons and pesticides were absent.

Table 3.3. Depth of groundwater table in open wells around HNPCL plant site

Location	Depth of water table below ground level (m)			
	Winter	Pre-monsoon	Monsoon	Post-monsoon
Palavalasa (Cyclone shelter)	1.6	4.2	1.7	1.4
Palavalasa (near site)	1.4	2.7	1.4	1.3
Deshapatrunipalem	2.0	6.7	1.8	1.2
Pittavanipalem	3.0	6.8	5.3	1.5
Chinnapalem	2.2	3.2	5.2	1.4
Baranikam	1.3	4.5	0.9	1.1
VUDA colony	2.4	4.5	3.2	1.9
Raja Reddy Farm	6.5	9.7	5.5	2.5
Utagaddapalem	2.9	4.1	3.4	2.0
Dalaipalem	10.5	11.5	5.0	4.2
Anakapalli	1.1	3.7	1.4	0.5
Lankelapalem	2.0	4.2	2.0	0.5
Appikonda	2.0	3.9	2.2	0.8

- Coliform organisms was either absent or low, indicating low levels of faecal contamination.
- Radioactivity could not be detected in any sample.

Thus the water was found to be non-polluted and acceptable for washing, bathing, and irrigation. For drinking, it is advisable to boil the water to protect against diseases due to faecal contamination.

3.3.3 Marine Water

The coastal area near Visakhapatnam is associated with the "Eastern *Ghat*" hill ranges, which run nearly parallel to the east coast from southern parts of Andhra Pradesh up to about middle of Orissa with intervening undulating valleys, low lying mounds, and hillocks. A status report prepared by Masula Marine Services has indicated, based on earlier bathymetric surveys, that the continental shelf in the offshore region of Visakhapatnam extends up to 35 - 40 km from the coast. The depth of the sea at the shelf edge is 120-130 m.

Marine water samples from 2.5 m depth were collected from fifteen locations in a 30 km radius of the proposed TPP. The results of the analysis are given in Appendix C. The salient features of this analysis are as follows:

- Marine water quality was generally found to be good as per "Primary Water Quality Criteria for Class SW-I Waters" of the Central Pollution Control Board, except for lead, cadmium, and oil and grease.
- pH was in the alkaline range (8.1-8.5) except at MW14 (near Kothapatnam), where pH was found to be slightly acidic during winter.
- Dissolved oxygen (DO) content was generally found to be high (6-7 mg/L). This could be attributed to good mixing of the sea surface with air and planktonic growth resulting in photosynthetic oxygen production.
- As expected in marine water, conductivity values, total hardness, and concentrations of total dissolved solids, chlorides, and sulphates were very high at all locations. During post-monsoon, values of these parameters were lower than in the other three seasons.
- Concentrations of nutrients - phosphates, TKN, nitrates, nitrites, and ammoniacal nitrogen were low.

- BOD and COD were low at all locations, indicating relatively low degree of organic pollution. BOD levels during pre-monsoon were higher than in the other seasons.
- Heavy metals were generally present in low quantities, except cadmium and lead. Cadmium exceeded the CPCB's recommended criteria during pre-monsoon. In other seasons, however, cadmium levels were within acceptable limits except at MW1. Lead exceeded recommended criteria at most locations throughout the year.
- Phenolic compounds, polyaromatic hydrocarbons, radioactivity, and pesticides were absent at all locations.

Thus the marine water quality in a 30 km radius of the proposed site was generally found to be good as per "Primary Water Quality Criteria for Class SW-I Waters" of the CPCB.

3.4 Land Environment

HNPCL's proposed project site is more or less flat and gently sloping towards south and southwest. Major part of the area is covered by mud flat and coastal sand dunes. The elevation of the mud flat ranges from sea level up to a maximum of 1.1 m above MSL. The mud flat is barren and bound by a creek towards the west and salt pans towards north and northwest. There are no major rivers in and around the area except few seasonal stormwater drains which drain into a creek near Thikkavanipalem.

3.4.1 Landuse

The landuse classification in 12 *Mandals* in a 30 km radius of the HNPCL plant site is given in Table 3.4. The data were collected from the Handbook of Statistics, Visakhapatnam District, 1992-93. The total landuse is pictorially presented in Exhibit 3.18. It is clear from the exhibit that the area is dominated by agricultural land (over 65,000 ha, amounting to 36% of the total area). This is followed by non-agricultural land, amounting to a total of over 42,000 ha (23% of the total area). A large fraction (over 16%) is barren and uncultivable. Forest land covers about 12% of the land.

3.4.2 Hydrogeomorphology

The land area surrounding the HNPCL site can be classified into the following major types:

Table 3.4. Landuse around HNPCL plant site (area in ha)

Mandal	Geographical area	Forests	Barren and uncultivable land	Non-agricultural land	Culturable wasteland	Pastures and other grazing land	Land under miscellaneous plantation	Other fallow lands	Current fallow land	Net area sown
Yelamanchili	11707	2499	1541	1027	50	0	51	146	0	6393
Atchutapuram	15101	1788	1701	1422	376	0	1409	661	178	7566
Rambilli	14711	1419	2166	1044	171	4	1034	235	15	8623
Anakapalli	18360	227	1764	3250	103	0	670	83	2595	9668
Munagapaka	9292	486	394	832	71	85	492	609	849	5474
Kasimkota	19695	4027	3498	1733	65	43	751	173	2142	7263
Sabbavaram	19347	2709	4155	1891	404	244	908	104	563	8369
Paravada	15090	358	4158	1460	673	140	2275	536	180	5310
Visakhapatnam (R)	27048	5913	2853	15637	411	59	63	735	52	1325
Pendurthi	12019	1019	2984	3027	214	30	708	100	70	3867
Gajuwaka	8952	335	2863	4697	139	20	93	390	65	350
Peddagantyada	10487	484	1389	6761	62	24	970	0	0	857
Total of 30 km radius	181809*	21264	29466	42781	2739	649	9424	3772	6709	65065

Exhibit 3.18. Landuse around HNPCL plant site

- beach
- coastal sand dunes
- mud flat
- salt flat
- moderately weathered pediplain
- shallow weathered pediplain
- residual hill
- structural hill

Beach is a narrow strip of land bordering the sea between high and low tide lines. It is composed of sand, cobbles, and shingle. Coastal sand dunes are composed of aeolian deposit of fine grade moist sand grains, originated from the beach, to a depth of 3-5 m. The mud flat is a low-lying flat land, formed in depressions along the coast that is inundated by stormwater during monsoon.

A study carried out by Black and Veatch International observed that the overburden stratigraphy at the mud flat area is divided into marine clay and residual soil. The salt flat is a land form similar to mud flat encrusted with salt. Many of the salt flats are located in the mud flat. Pediplains are flat, have smooth surface with varying degree of weathered material, and are normally covered with red soil. Moderately weathered pediplain is composed of 5-15 m weathered material and located along the border of the proposed site, whereas shallow weathered pediplain is composed of 0-5 m weathered material and is located near the hills away from the sea.

Besides the above areas, residual hills, an isolated low relief relict hill, and structural hill with linear to arcuate structure, are also present around the proposed project site.

3.4.3 Soil Quality

Soil samples were collected and analysed to assess the existing quality of the soil around the HNPCL plant site. Representative soil samples were collected from fifteen locations. The results of soil quality analysis are given in Table 3.5.

The soil at and surrounding the HNPCL plant site varies in textural classification. Predominant textural class is silty-clay and silty except the locations near the coast, where soil is sandy. Soil at the plant site near cashew plantations is sandy, whereas the soil from the mud flat area (proposed ash pond) is silty to silty-clay. Infiltration rates at most locations were found to be low (1-5 cm/h) except at Thikkavanipalem, Peddagantyada, and near cashew plantations on the plant site, where the soil is predominantly sandy. In-

filtration rates in the ash pond area (Dalaipalem and Palavalasa) were also found to be low.

The pH of the soil in the area was found to be in the neutral range during winter and pre-monsoon seasons whereas during monsoon and post-monsoon seasons, the pH was in the alkaline range. The nutritional status of the soil was found to be moderate with fairly high amounts of organic matter, moderate NPK content, and adequate quantities of the micronutrients B, Mn, Cu, and Zn except during pre-monsoon. The soil was non-saline with low electrical conductivity (less than 350 μmhos/cm). In the ash pond area, however, conductivity was found to be higher (900-1500 μmhos/cm). At all the locations the soil was characterised by low concentrations of NaCl and absence of Na_2CO_3. This type of soil can be made suitable for agricultural purposes with adequate soil amelioration and water management practices.

3.5 Biological Environment

To assess the existing status of the biological environment of the area within a 30 km radius of the HNPCL plant site, a detailed flora-fauna survey, covering four seasons, was carried out during 1995-96. Terrestrial, marine, and aquatic flora-fauna, as well as avi fauna were studied during this survey. Details of the survey observations are presented in Appendix F. The salient features of the survey are presented in this section.

Within a 30 km radius of the HNPCL plant site, about 30-40% of the area is under water (primarily Bay of Bengal). About 10-20% of the area is under settlements, industries, aquaculture farms, and hilly tracts.

3.5.1 Terrestrial

The various terrestrial habitats in the area around the HNPCL site are (a) hill forest, (b) swamps with thorny forest, (c) urban settlement, (d) village settlement with orchards, (e) agricultural plantation, (f) coastal dune vegetation, (g) mud flat, and (h) salt pans and aquaculture. No reserve forests exist within the core zone (10 km) of the HNPCL plant site. The nearest reserve forest, at Pudimadaka, is 12 km away.

The coastal vegetation is mainly of three types (a) vegetation of open coast, (b) vegetation of saline marshes, and (c) vegetation of the rocky coast. The vegetation of hilly regions has mainly thorny

Table 3.5. Soil quality around HNPCL plant site

Location	Deshapatrunipalem		Kalapaka		Peddapalem		Devada		Palavalasa		Plant Site (cashew plantation)		Ash pond area	
Location code	S1		S2		S3		S4		S5		S6		S7	
Winter														
Undisturbed or Disturbed	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Sand (%)	0		20		5		10		40		95		0	
Silt (%)	45		85		60		80		55		5		60	
Clay (%)	55		5		35		10		5		0		40	
Textural class	Silty clay		Silty		Silty clay		Silty		Loamy		Sandy		Silty clay	
Infiltration capacity (cm/h)	5.4		7.2		12.6		9.0		10.8		22.0		10.8	
Specific gravity	2.64		2.66		2.64		2.61		2.63		2.66		2.66	
Bulk Density (g/cc)	1.76		1.71		1.76		1.78		1.78		1.8		1.71	
Porosity (%)	45		55		48		58		45		46		50	
Electrical conductivity (micromhos/cm)	258.4	172	204	184	489.6		68.54	81	197.2	190	240.2		1115	884
Sodium absorption ratio	5.25	4.99	8.1	4.12	4.62	3.99	4.22	4.17	6.21	5.65	5.11	4.86	8.25	4.52
pH (pH units)	7.84	7.9	8.12	8.05	7.21	7.14	7.35	7.28	8.04	8.1	7.33	7.25	7.55	7.48
Organic matter (%)	1.13	1.18	1.12	1.04	1.55	1.48	0.992	0.86	1.012	1.08	0.981	0.88	1.001	1.02
Acidity (mgCaCO3/L)	0	0	0	0	0	0.005	0	0.002	0	0	0	0.004	0	0.002
Alkalinity (mgCaCO3/L)	0.04	0.038	0.06	0.054	0.021	0.025	0.022	0.028	0.051	0.044	0.019	0.015	0.025	0.027
Nitrogen (%)	0.104	0.112	0.102	0.106	0.099	0.014	0.1	0.12	0.085	0.078	0.098	0.086	0.109	0.104
Phosphorus (%)	0.005	0.0034	0.008	0.0065	0.006	0.0058	0.001	0.0026	0.004	0.0038	0.003	0.0024	0.1	0.014
Potassium (%)	0.023	0.02	0.025	0.022	0.022	0.025	0.03	0.028	0.035	0.03	0.024	0.025	0.032	0.028
Manganese (%)	0.0035	0.0028	0.003	0.0034	0.005	0.0048	0.003	0.0025	0.0029	0.0036	0.002	0.0032	0.0002	0.0017
Copper (%)	0.00069	0.00027	0.00071	0.00053	0.00076	0.00066	0.00075	0.00032	0.00069	0.00038	0.00059	0.00041	0.00072	0.00074
Iron (%)	0.02712	0.0248	0.02721	0.0206	0.0235	0.205	0.02135	0.0188	0.02552	0.0289	0.0232	0.0237	0.02521	0.0264
Zinc (%)	0.00106	0.0008	0.00105	0.0075	0.00103	0.0008	0.00107	0.0025	0.00108	0.0014	0.00102	0.00098	0.00101	0.0016
Boron (%)	0.0085	0.0094	0.0048	0.0063	0.012	0.0098	0.0034	0.0022	0.0076	0.0095	0.0034	0.0046	0.0064	0.0058
Sodium chloride (%)	0.015	0.019	0.012	0.014	0.092	0.088	0.013	0.01	0.011	0.016	0.021	0.02	0.0073	0.089
Sodium carbonate (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.5. (Contd…)

Location	Salt pan boundary		Dalaipalem		Niraj Petrochemicals		Thikkavanipalem (aquafarm)		Thikkavanipalem (coast)		Lankelapalem		Peddagantyada		Ash pond area (near Palavalasa)	
Location code	S8		S9		S10		S11		S12		S13		S14		S15	
Winter																
Undisturbed or Disturbed	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Sand (%)	0		10		45		30		92		0		35		45	
Silt (%)	65		65		55		68		8		40		60		55	
Clay (%)	35		25		0		2		0		60		5		0	
Textural class	Silty clay		Silty clay		Silty sandy		Silty		Sandy		Clayey silty		Silty clay		Clayey sandy	
Infiltration capacity (cm/h)	6.1		6.8		10.1		9.5		23.4		6.1		12.6		5.0	
Specific gravity	2.66		2.62		2.66		2.62		2.64		2.62		2.65		2.61	
Bulk Density (g/cc)	1.75		1.74		1.7		1.75		1.81		1.73		1.78		1.48	
Porosity (%)	41		48		43		50		50		45		52		53	
Electrical conductivity (micromhos/cm)	268	176	197.8	190	261.2	210	202	180.8	261.2	269	222.4	240	220	168	1405	1482.8
Sodium absorption ratio	5.9	4.99	4.95	4.982	6.43	5.32	5.88	4.85	5.26	5.108	4.82	4.17	6.28	5.23	7.65	7.12
pH (pH units)	6.95	7.1	7.36	7.38	7.28	7.32	6.18	6.3	6.94	6.98	7.22	7.16	7.38	7.24	7.59	7.5
Organic matter (%)	0.811	0.84	1.38	1.46	0.92	1.1	0.912	0.98	1.12	1.14	0.99	0.88	0.975	0.98	0.97	1.1
Acidity (mgCaCO3/L)	0.01	0.008	0	0.001	0	0.006	0.007	0.028	0.01	0.012	0	0.007	0	0.003	0	0
Alkalinity (mgCaCO3/L)	0	0.01	0.01	0.014	0.018	0.015	0	0.006	0	0.01	0.013	0.014	0.017	0.012	0.021	0.038
Nitrogen (%)	0.097	0.095	0.103	0.114	0.105	0.116	0.093	0.108	0.101	0.112	0.93	0.98	0.112	0.0118	0.0995	0.096
Phosphorus (%)	0.009	0.0082	0.005	0.0044	0.007	0.0056	0.006	0.0045	0.043	0.038	0.012	0.016	0.013	0.018	0	0
Potassium (%)	0.042	0.036	0.012	0.01	0.034	0.024	0.028	0.031	0.031	0.032	0.019	0.024	0.023	0.016	0.027	0.0242
Manganese (%)	0.0041	0.0024	0.004	0.0055	0.0052	0.0047	0.0039	0.0028	0.0021	0.0036	0.0052	0.0042	0.0061	0.0074	0.0021	0.0028
Copper (%)	0.00068	0.00069	0.00073	0.00057	0.00058	0.00023	0.00059	0.00031	0.00052	0.00044	0.00051	0.00068	0.00055	0.00035	0.00059	0.00054
Iron (%)	0.0194	0.0252	0.0292	0.0326	0.0352	0.038	0.042	0.0344	0.0312	0.0355	0.0301	0.0284	0.0292	0.0279	0.0231	0.0243
Zinc (%)	0.00106	0.0022	0.00109	0.0034	0.00107	0.0018	0.00101	0.0009	0.00103	0.0007	0.00106	0.00074	0.00103	0.0006	0.00101	0.0015
Boron (%)	0.0076	0.007	0.08	0.0086	0.0092	0.0108	0.0068	0.0072	0.016	0.019	0.021	0.017	0.0074	0.0066	0.0094	0.013
Sodium chloride (%)	0.011	0.018	0.021	0.025	0.0198	0.02	0.018	0.016	0.013	0.011	0.02	0.014	0.0113	0.012	0.13	0.17
Sodium carbonate (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.5. (Contd…)

Location	Deshapatrunipale		Kalapaka		Peddapalem		Devada		Palavalasa		Plant site		Ash pond near Dailaipalem	
Location code	S1		S2		S3		S4		S5		S6		S7	
Pre-monsoon														
Undisturbed or Disturbed	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Sand (%)	17		15		15		15		44		97		0	
Silt (%)	53		65		60		55		46		3		65	
Clay (%)	30		20		25		30		10		0		35	
Textural Class	Silty clay		Silty clay		Silty clay		Silty clay		Silty sandy		Sandy		Silty clay	
Infiltration Capacity (cm/h)	1.44		1.98		1.62		1.08		2.16		21.6		0.18	
Specific gravity	2.61		2.64		2.61		2.62		2.64		2.61		2.64	
Bulk Density (g/cc)	1.83		1.72		1.85		1.82		1.79		1.81		1.77	
Porosity (%)	39		47		43		53		40		43		52	
Electrical Conductivity (μ mho/cm)	214.2		95.0		61.2		68.0		260.0		74.8		1462.0	
Sodium Absorption Ratio	5.26	4.69	8.33	3.99	5.37	4.21	6.73	5.33	5.86	4.97	7.18	6.85	8.35	5.63
pH (pH units)	7.9	8.0	7.3	7.3	7.5	7.0	7.3	7.2	7.8	7.6	7.3	7.2	7.3	7.1
Organic Matter (%)	0.4128	0.42	0.33	0.31	0.49	0.36	0.46	0.36	0.42	0.51	0.115	0.102	0.186	0.175
Acidity (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Alkalinity (%)	0.325	0.259	0.125	0.102	0.12	0.11	0.106	0.124	0.27	0.24	0.069	0.059	0.109	0.114
Nitrogen (%)	0.0646	0.0985	0.062	0.074	0.015	0.009	0.019	0.023	0.0024	0.0017	0.0016	0.0013	0.001	0.0009
Phosphorus (%)	$4.6x10^{-6}$	$5.4x10^{-6}$	$1.1x10^{-7}$	$1.5x10^{-7}$	$6.7x10^{-7}$	$7.1x10^{-7}$	$2.1x10^{-7}$	$3.5x10^{-7}$	$2.0x10^{-8}$	$7.0x10^{-8}$	$8.0x10^{-8}$	$6.0x10^{-8}$	$1.6x10^{-8}$	$1.1x10^{-7}$
Potassium (%)	0.42	0.34	0.11	0.08	0.11	0.16	0.18	0.1	0.032	0.024	0.08	0.09	12.17	10.85
Manganese (%)	$4.1x10^{-6}$	$3.4x10^{-6}$	$1.9x10^{-6}$	$2.2x10^{-6}$	$0.37x10^{-5}$	$2.1x10^{-6}$	$2.9x10^{-6}$	$1.4x10^{-6}$	$2.1x10^{-6}$	$3.0x10^{-6}$	$3.6x10^{-6}$	$4.1x10^{-6}$	$1.8x10^{-6}$	$2.1x10^{-6}$
Copper (%)	0.00027	0.0001	0.00057	0.0004	0.0004	0.0002	0.0003	9E-05	0.0003	0.0003	0.0004	0.0003	0.0002	0.0001
Iron (%)	0.011	0.009	0.026	0.019	0.018	0.025	0.031	0.011	0.0321	0.0362	0.046	0.043	0.036	0.037
Zinc (%)	0.0031	0.0003	0.0039	0.0063	0.0026	0.0014	0.002	0.0008	0.0013	0.0013	0.0014	0.0023	0.0002	0.0001
Boron (%)	$1.8x10^{-6}$	$2.1x10^{-6}$	$2.1x10^{-6}$	$1.5x10^{-6}$	$1.8x10^{-6}$	$1.3x10^{-6}$	$2.0x10^{-6}$	$1.0x10^{-6}$	$1.0x10^{-6}$	$8.0x10^{-7}$	$2.0x10^{-6}$	$1.2x10^{-6}$	$1.0x10^{-6}$	$9.0x10^{-7}$
Chloride (%)	0.021	0.012	0.019	0.013	0.078	0.063	0.021	0.015	0.021	0.032	0.027	0.022	0.085	0.082
Sodium Carbonate (%)	NIL	NIL	<0.001	<0.001	NIL	NIL	NIL	NIL	<0.001	<0.001	NIL	NIL	NIL	NIL

Table 3.5. (Contd...)

Location	sh pond boundar near saltpans		Dalaipalem		Niraj petrochemic		Tikkavanipalem		Tikkavanipalem co		Pedagantyada		Ash pond near Palavalasa	
Location code	S8		S9		S10		S11		S12		S14		S15	
Pre-monsoon														
Undisturbed or Disturbed	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Sand (%)	20		5		40		5		96		65		0	
Silt (%)	70		65		55		80		3		30		40	
Clay (%)	10		30		5		15		1		5		60	
Textural Class	Silty sandy		Silty clay		Silty sandy		Silty		Sandy		Sandy Silt		Clayey silt	
Infiltration Capacity (cm/h)	1.62		1.58		7.2		1.44		21.6		21.6		0.14	
Specific gravity	2.65		2.66		2.61		2.66		2.64		2.62		2.65	
Bulk Density (g/cc)	1.84		1.81		1.79		1.79		1.77		1.80		1.83	
Porosity (%)	44		52		47		53		50		55		50	
Electrical Conductivity (μ mho/cm)	95.3		54.4		70.0		85.6		65.0		106.3		1530.0	
Sodium Absorption Ratio	5.82	4.78	6.52	5.98	7.19	6.39	7.41	7.14	4.19	3.99	7.19	6.98	6.18	5.85
pH (pH units)	7.9	7.3	7.3	7.1	7.4	7.4	7.0	7.1	7.3	7.2	7.5	7.2	7.5	7.2
Organic Matter (%)	0.386	0.395	0.583	0.567	0.29	0.99	0.215	0.226	0.632	0.653	0.537	0.513	0.231	0.359
Acidity (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Alkalinity (%)	0.039	0.04	0.11	0.1	0.123	0.146	0.112	0.105	0.086	0.086	0.218	0.208	0.021	0.038
Nitrogen (%)	0.045	0.039	0.008	0.007	0.029	0.027	0.039	0.04	0.101	0.112	0.008	0.009	0.0018	0.0014
Phosphorus (%)	$4.2x10^{-7}$	$3.7x10^{-7}$	$3.0x10^{-8}$	$2.0x10^{-8}$	$4.0x10^{-7}$	$3.4x10^{-7}$	$1.8x10^{-7}$	$1.2x10^{-7}$	$1.6x10^{-7}$	$1.3x10^{-7}$	$8.1x10^{-7}$	$7.3x10^{-7}$	$1.1x10^{-7}$	$7.0x10^{-8}$
Potassium (%)	0.08	0.074	0.09	0.06	0.1	0.08	0.12	0.09	0.36	0.43	0.19	0.21	11.42	9.85
Manganese (%)	$6.6x10^{-6}$	$6.3x10^{-5}$	$1.2x10^{-6}$	$1.9x10^{-6}$	$6.1x10^{-6}$	$7.3x10^{-6}$	$1.8x10^{-6}$	$2.3x10^{-6}$	$3.4x10^{-6}$	$3.9x10^{-6}$	$6.3x10^{-6}$	$7.2x10^{-6}$	$1.1x10^{-7}$	$7.0x10^{-8}$
Copper (%)	0.0005	0.0005	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0003	0.0002	0.0001	0.0001	0.0001
Iron (%)	0.018	0.021	0.023	0.03	0.011	0.014	0.028	0.032	0.033	0.027	0.026	0.03	0.0126	0.015
Zinc (%)	0.002	0.003	0.0016	0.0025	0.0012	0.002	0.004	0.004	0.0011	0.0008	0.00016	0.0001	0.0011	0.0008
Boron (%)	$1.8x10^{-6}$	$1.4x10^{-6}$	$2.6x10^{-6}$	$2.0x10^{-6}$	$3.1x10^{-6}$	$2.6x10^{-6}$	$3.2x10^{-6}$	$2.9x10^{-6}$	$1.7x10^{-6}$	$1.8x10^{-6}$	$6.4x10^{-6}$	$5.5x10^{-6}$	$3.0x10^{-6}$	$2.5x10^{-6}$
Chloride (%)	0.023	0.031	0.027	0.033	0.021	0.024	0.022	0.019	0.017	0.015	0.0216	0.0196	0.37	0.22
Sodium Carbonate (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

Table 3.5. (Contd…)

Location	Deshapatrunipalem		Kalapaka		Peddapalem		Devada		Palavalasa		Plant site		Ash pond near Dalaipalem	
Location code	S1		S2		S3		S4		S5		S6		S7	
Monsoon														
Undisturbed or Disturbed	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Sand (%)	20		8		18		65		2		95		2	
Silt (%)	32		77		75		35		58		5		80	
Clay (%)	48		15		7		0		40		0		18	
Textural Class	Clayey silt		Silty		Silty		Sandy silt		Silty clay		Sandy		Silty	
Infiltration Capacity (cm/h)	1.44		2.16		1.98		10.8		0.108		21.6		2.52	
Specific gravity	2.86		2.63		2.64		2.66		2.66		2.65		2.65	
Bulk Density (g/cc)	1.72		1.82		1.86		1.79		1.79		1.78		1.82	
Porosity (%)	48		52		46		50		51		44		52	
Electrical Conductivity (μ mho/cm)	316.4	228.6	381.6	189.2	411.2		109.3	70.24	214.31	228.31	316.4	190.0	897.2	1214.6
Sodium Absorption Ratio	6.11	4.18	10.21	5.26	7.82	4.56	5.11	3.28	8.66	6.12	7.18	9.32	5.36	9.16
pH (pH units)	8.12	8.00	8.48	8.12	8.05	8.21	7.82	8.12	8.67	9.12	7.18	8.84	7.25	8.12
Organic Matter (%)	1.18	2.10	1.06	1.02	1.86	1.72	1.18	1.60	1.42	1.25	1.20	1.40	1.12	1.26
Acidity (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Alkalinity (%)	0.07	0.048	0.08	0.046	0.038	0.042	0.018	0.031	0.038	0.067	0.032	0.024	0.042	0.039
Nitrogen (%)	0.218	0.118	0.314	0.031	0.028	0.031	0.121	0.124	0.038	0.047	0.063	0.052	0.128	0.142
Phosphorus (%)	0.007	0.0082	0.004	0.0031	0.004	0.0031	0.0024	0.0018	0.006	0.0041	0.0017	0.002	0.007	0.028
Potassium (%)	0.016	0.028	0.018	0.031	0.019	0.032	0.01	0.023	0.037	0.035	0.029	0.02	0.032	0.03
Manganese (%)	0.0029	0.0032	0.0002	0.0039	0.0030	0.0052	0.0010	0.0029	0.0025	0.0041	0.0038	0.0010	0.0021	0.0001
Copper (%)	0.00029	0.0002	0.0005	0.0011	0.0006	0.0003	0.00048	0.0006	0.00061	0.0005	0.0008	0.0012	0.0006	0.0005
Iron (%)	0.03182	0.0315	0.0242	0.0232	0.0242	0.2831	0.03624	0.0242	0.01848	0.0256	0.0182	0.0318	0.0273	0.0316
Zinc (%)	0.00086	0.00073	0.00121	0.00036	0.00084	0.00067	0.00071	0.00086	0.00212	0.00260	0.00063	0.00024	0.00340	0.00637
Boron (%)	0.0018	0.0061	0.0041	0.0031	0.0042	0.0068	0.0041	0.0016	0.0041	0.0062	0.0021	0.0084	0.0041	0.0048
Chloride (%)	0.024	0.038	0.031	0.007	0.051	0.043	0.026	0.025	0.002	0.008	0.023	0.041	0.032	0.048
Sodium Carbonate (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

Table 3.5. (Contd...)

Location	Ash pond boundary near saltpans		Dalaipalem		Niraj petrochemica		Thikkavanipalem		Thikkavanipalem coast		Lankelapalem		Peddagantyada		Ash pond near Palavalasa	
Location code	S8		S9		S10		S11		S12		S13		S14		S15	
Monsoon																
Undisturbed or Disturbed	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Sand (%)	9		16		60		30		95		20		83		15	
Silt (%)	79		78		38		65		5		10		15		70	
Clay (%)	12		6		2		5		0		70		2		15	
Textural Class	Silty		Silty		Sandy silt		Silty sand		Sandy		Clayey sand		Sandy		Silty	
Infiltration Capacity (cm/h)			3.06		10.8		0.72		21.6		2.88		14.4		2.52	
Specific gravity	2.65		2.64		2.66		2.68		2.66		2.65		2.66		2.67	
Bulk Density (g/cc)	1.87		1.86		1.86		1.86		1.77		1.87		1.77		1.82	
Porosity (%)	44		50		46		52		51		47		49		51	
Electrical Conductivity (μ mho/cm)	214.0	314.8	218.0	214.0	314.0	287.2	207.2	282.4	207.4	314.1	284.0	216.0	248.0	232.0	1180.6	1284.0
Sodium Absorption Ratio	7.12	8.16	5.25	6.14	7.18	6.32	3.62	7.18	5.25	6.12	6.36	5.19	10.21	7.82	6.67	8.48
pH (pH units)	7.21	7.12	8.12	8.34	8.12	6.16	6.98	7.13	7.21	8.21	8.18	6.25	9.17	8.18	7.83	8.28
Organic Matter (%)	0.719	0.917	1.260	1.410	0.54	0.82	1.40	1.80	1.32	1.30	0.67	0.32	0.81	0.67	1.10	0.56
Acidity (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Alkalinity (%)	0.020	0.064	0.040	0.030	0.024	0.026	0.021	0.031	0.030	0.018	0.024	0.018	0.031	0.041	0.039	0.031
Nitrogen (%)	0.124	0.108	0.114	0.108	0.082	0.063	0.041	0.028	0.108	0.121	0.418	0.316	0.218	0.218	0.042	0.034
Phosphorus (%)	0.0038	0.0047	0.0042	0.0039	0.0080	0.0031	0.0031	0.0041	0.0042	0.0036	0.021	0.038	0.024	0.028	0.004	0.008
Potassium (%)	0.042	0.038	0.02	0.012	0.037	0.028	0.037	0.023	0.039	0.028	0.011	0.027	0.018	0.02	0.021	0.028
Manganese (%)	0.0027	0.0035	0.0030	0.0061	0.0049	0.0052	0.0032	0.0035	0.0039	0.0017	0.0047	0.0049	0.0058	0.0082	0.0033	0.0016
Copper (%)	0.0008	0.00114	0.00028	0.0007	0.0005	0.0005	0.00086	0.0011	0.0003	0.0009	0.0008	0.0006	0.0003	0.0005	0.0004	0.0006
Iron (%)	0.03164	0.01782	0.02816	0.02532	0.02638	0.02368	0.03672	0.03824	0.02631	0.02682	0.03216	0.03683	0.03184	0.03184	0.03164	0.04182
Zinc (%)	0.00063	0.00062	0.00086	0.00046	0.00045	0.00028	0.00181	0.00214	0.00062	0.00261	0.00384	0.00061	0.00082	0.00038	0.00026	0.00086
Boron (%)	0.0041	0.0039	0.0064	0.0049	0.0073	0.0081	0.0028	0.0042	0.0082	0.0041	0.0182	0.0082	0.0046	0.0028	0.0026	0.0063
Chloride (%)	0.012	0.026	0.036	0.042	0.0482	0.038	0.032	0.026	0.024	0.036	0.008	0.024	0.0123	0.036	0.034	0.031
Sodium Carbonate (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

Table 3.5. (Contd…)

Location	Deshapatrunipalem		Kalapaka		Peddapalem		Devada		Palavalasa		Plant site		Ash pond near Dalaiplem	
Location code	S1		S2		S3		S4		S5		S6		S7	
Post-monsoon														
Undisturbed or Disturbed	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Sand (%)	22		6		19		63		3		91		1	
Silt (%)	31		75		74		36		56		6		82	
Clay (%)	47		19		7		1		41		3		17	
Textural Class	Clayey loam		Silty		Silty		Sandy silt		Silty clay		Sandy		Silty	
Infiltration Capacity (cm/h)	1.80		0.29		2.52		0.13		0.18		27.00		1.80	
Specific gravity	2.75		2.69		2.58		2.67		2.65		2.7		2.72	
Bulk Density (g/cc)	1.79		1.8		1.84		1.81		1.75		1.77		1.84	
Porosity (%)	48		48		45		51		53		47		55	
Electrical Conductivity (μ mho/cm)	314.3	229.6	379.6	185.1	417.1	187.9	105.2	68.79	212.33	221.52	321.3	215.7	1312.5	917.3
Sodium Absorption Ratio	5.72	4.31	11.1	5.31	8.53	3.89	6.59	4.28	9.67	7.82	8.32	7.18	8.25	6.38
pH (pH units)	8.36	8.2	7.76	7.22	8.53	8.12	8.78	8.1	8.24	9.05	8.82	7.73	8.67	7.53
Organic Matter (%)	0.97	1.05	0.85	0.83	0.95	1	0.98	1.03	1.03	0.99	0.93	0.9	0.97	0.95
Acidity (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alkalinity (%)	0.06	0.035	0.07	0.032	0.041	0.033	0.021	0.035	0.04	0.059	0.021	0.033	0.035	0.051
Nitrogen (%)	0.215	0.109	0.317	0.022	0.034	0.028	0.109	0.113	0.032	0.045	0.048	0.056	0.153	0.121
Phosphorus (%)	0.005	0.0071	0.002	0.0028	0.004	0.0033	0.0028	0.0013	0.0003	0.0039	0.004	0.0018	0.021	0.003
Potassium (%)	0.019	0.025	0.017	0.028	0.013	0.034	0.03	0.021	0.042	0.04	0.018	0.027	0.025	0.041
Manganese (%)	0.0023	0.0034	0.0003	0.0029	0.0002	0.0048	0.002	0.0031	0.0024	0.0039	0.002	0.0029	0.0002	0.0018
Copper (%)	0.00018	0.0001	0.0005	0.002	0.0007	0.0003	0.00039	0.0005	0.00053	0.0004	0.0015	0.0008	0.00043	0.0007
Iron (%)	0.03212	0.032	0.0238	0.0222	0.0215	0.1635	0.02413	0.2635	0.01134	0.0164	0.0242	0.0211	0.02432	0.0199
Zinc (%)	0.00052	0.0007	0.0008	0.0002	0.0006	0.0004	0.00049	0.0007	0.00382	0.0022	0.0002	0.0005	0.00527	0.0026
Boron (%)	0.0027	0.0082	0.0035	0.0018	0.0079	0.0052	0.0027	0.0059	0.0026	0.0081	0.0082	0.0056	0.0067	0.0023
Chloride (%)	0.037	0.055	0.056	0.032	0.072	0.029	0.019	0.031	0.004	0.008	0.055	0.013	0.069	0.044
Sodium Carbonate (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

Table 3.5. (Contd…)

Location	Salt pan boundary		Dalaipalem		Niraj Petrochemical		Thikkavanipalem (aquafarm)		Thikkavanipalem (coast)		Lankelapalem		Peddagantyada		Ash pond area (near Palavalasa)	
Location code	S8		S9		S10		S11		S12		S13		S14		S15	
Post-monsoon																
Undisturbed or Disturbed	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Sand (%)	7		19		58		33		90		17		80		18	
Silt (%)	77		75		40		63		9		76		19		69	
Clay (%)	16		6		2		4		1		7		1		13	
Textural Class	Silty		Silty		Sandy silt		Silty sandy		Sandy		Silty		Sandy		Silty	
Infiltration Capacity (cm/h)	28.80		2.70		0.72		1.26		1.80		32.40		18.00		2.16	
Specific gravity	2.71		2.59		2.65		2.69		2.62		2.61		2.67		2.71	
Bulk Density (g/cc)	1.89		1.82		1.83		1.88		1.76		1.85		1.79		1.81	
Porosity (%)	42		49		49		55		48		45		52		53	
Electrical Conductivity (µ mho/cm)	326.5	212.75	225	213.5	319	287.2	287.9	205.7	327.3	211.5	287	225.9	257.3	235.7	1032	978.56
Sodium Absorption Ratio	9.31	8.56	7.6	5.23	8.55	7.23	8.81	4.28	7.25	6.69	7.56	6.81	11.25	8.66	9.93	7.54
pH (pH units)	7.72	7.15	8.53	8.79	8.23	6.92	7.35	6.5	8.89	7.25	8.58	6.93	8.94	8.15	8.35	7.21
Organic Matter (%)	0.99	0.84	1.01	1.17	0.63	0.75	1.03	1.09	0.99	1.07	0.63	0.48	0.87	0.65	0.51	0.99
Acidity (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alkalinity (%)	0.069	0.028	0.039	0.028	0.017	0.023	0.029	0.017	0.015	0.028	0.021	0.013	0.037	0.044	0.027	0.035
Nitrogen (%)	0.101	0.119	0.111	0.103	0.079	0.064	0.029	0.039	0.129	0.101	0.422	0.309	0.222	0.219	0.039	0.044
Phosphorus (%)	0.0042	0.0031	0.0038	0.0032	0.005	0.0028	0.0039	0.0028	0.0038	0.004	0.0018	0.04	0.029	0.027	0.005	0.002
Potassium (%)	0.035	0.045	0.017	0.016	0.032	0.023	0.027	0.039	0.023	0.042	0.015	0.031	0.015	0.022	0.023	0.027
Manganese (%)	0.0034	0.0028	0.001	0.0048	0.0047	0.0048	0.0041	0.0029	0.0023	0.0045	0.0055	0.0043	0.0028	0.0065	0.0011	0.0046
Copper (%)	0.001	0.0007	0.0001	0.0007	0.00035	0.0003	0.0009	0.0007	0.0007	0.0004	0.0007	0.0008	0.0002	0.0005	0.00057	0.00039
Iron (%)	0.0216	0.0248	0.0413	0.0313	0.02145	0.0293	0.02354	0.0284	0.0316	0.0286	0.0246	0.1783	0.0252	0.0214	0.04652	0.02987
Zinc (%)	0.0005	0.0004	0.0005	0.0003	0.00036	0.0007	0.00196	0.0016	0.0033	0.0021	0.0049	0.0014	0.0006	0.0002	0.00097	0.00036
Boron (%)	0.0062	0.0043	0.0079	0.0053	0.0082	0.0038	0.0059	0.0037	0.0063	0.0029	0.0015	0.0077	0.0097	0.0066	0.0075	0.0018
Chloride (%)	0.033	0.025	0.052	0.027	0.068	0.0267	0.032	0.024	0.042	0.063	0.021	0.051	0.035	0.026	0.019	0.052
Sodium Carbonate (%)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL NIL	NIL	NIL	NIL	NIL	NIL	NIL

bushes with isolated trees. The undergrowth comprises herbs and undershrub and also woody climbers. In addition, there are several species of grasses, which grow in the thorny forest and swamps. Most of the flora are of tropical type with wide range of distribution. Endemic species were not encountered during in the TCS survey. Towards the coast, the HNPCL project site is covered with a fair growth of cashew and *Casuarina* plantations. A part of the proposed ash pond area harbours swampy vegetation predominated by *Prosopis juliflora*.

Most of the plant species recorded during this survey commonly occur in other habitats as well. Only a few plants could be considered rare in these habitats. None could be found in the core zone.

Agriculture in the area around the HNPCL site is primarily monsoon food crops with few Rabi crops. The major crops are rice, jowar, bajra, ragi, various types of grains, cotton, sugarcane, groundnut, castor, tapioca, tobacco, etc.

During the TCS survey, insects from the order diptera, odonates (Zygoptera, Anisozygoptera), ephinuroptera, lepidoptera, hemiptera, coleoptera, etc, and other invertebrates such as spiders were observed. Among vertebrates, congregations of frogs were observed in water pools at many places. Snakes, both terrestrial and aquatic, were also commonly observed. Consequently, the area also has waders and marsh-dwelling birds. Mud flats and salt pans were observed to harbour migratory waders.

The accumulated leaf litter in the forests around the HNPCL site offers the necessary micro-climate for many soil-inhabiting forms including arthropods, annelids, and molluscs, which were observed during the TCS survey. At more humid patches, sandflies and biting midges were found to predominate.

The dense cover of cashew and *Casuarina* forest offers adequate protection to the wildlife that inhabits the area. Among vertebrates, *Bufo stomaticus*, *Varanus flavescens*, cobra, krits, Russel's viper, mabuia, *Calotes versicolor*, *Hemidactylas brooki*, etc were observed. Among mammals, blacknaped hare, civet, jackal, Bengal fox, jugle cat, and pugmarks and droppings of hyena were observed. A number of jackals were seen at dusk on the southeastern boundary of the HNPCL plant site. A part of the proposed ash pond area harbours swampy vegetation predominated by *Prosopis juliflora*. Due to its periodic inundation by stormwater, this habitat attracts wading and marsh birds, and mammals such as jackals and civets, for foraging as well as nesting and roosting.

Buffalo and poultry birds are the most common livestock in almost all of the *Mandals* surrounding the HNPCL plant site.

3.5.2 Aquatic

The common aquatic habitats in the area around the HNPCL site are (a) freshwater reservoirs, (b) coastal subtidal zones, and (c) coastal littoral zones.

The planktonic load in freshwater, brackish water, and saline water was found to vary widely with respect to species composition and diversity.

The Bay of Bengal coast near Visakhapatnam is one of the important habitats for marine algae, with rocky outcrops scattered along the coastline on which benthic algae grow.

Both freshwater and brackish water bodies in the area around the HNPCL site were found to harbour a number of macrophytic plants. In addition, a number of marsh plants were also noticed in this area.

Data on freshwater fish collected from local fish markets and examination of catches during field visits indicated that none of the species belongs to to rare or endangered categories as per Indian Board of Wild Life (IBWL).

Various marine and coastal avi fauna were recorded during the TCS team's visit. Flocks of migratory ducks such as the common teal, garganey, shoveller, tufted pochard, and other waders were regularly seen along the coast (100-300 m off the coast).

Several species of invertebrates were recorded off the Visakhapatnam coast. The interstitial sands harbour a rich variety of protozoans, nematodes, annelids, gastrotrichs, kinorhynchs, crustaceans, and molluscus. The tidal fauna also include micro-, meio-, and macrofaunal species of invertebrates.

Benthic fauna plays a crucial role in the trophic relationships of continental shelf. Demersal fish mainly depend for their food on benthic fauna. Macrobenthic fauna off Visakhapatnam, collected from various depths during the TCS survey indicated that about 68% of benthic biomass was found to occur within a depth range of 0-200 m. The zone between 20 m and 30 m depth appeared to be the most productive zone. The mean faunal density was found to be maximum at 40-50 m depth. The benthic fauna at 10 m depth was almost negligible. The benthic fauna comprises

predominantly *Polychaets* (about 68%) followed by *Crustacea* (22%), and *Mollusca* (3%). Offshore fauna near Gangavaram and Pudimadaka indicated that the overall density varied from a single individual to as many as 150 per litre.

Visakhapatnam coast is mostly rocky with sandy beaches in certain stretches. The intertidal region is narrow and does not exceed 100 m. The rocky outcrops at Appikonda/Kuttukonda and Pudimadaka offer ideal habitats for invertebrates such as molluscs, crustaceans, sea anemonas, echinoderms, sponges, etc. The sandy beaches support only sand-burrowing forms such as crustaceans (crabs) and molluscs (gastropods and bivalves).

Although no sea turtle nesting was located in the area during the survey, local residents reported steady catch of Olive Ridley turtle during the turtle breeding season. A fresh carcass of a turtle was seen near the coast at Palavalasa.

A specimen of the whale shark *Rhineodon typhus* was stranded on the coast near the HNPCL site during the TCS survey in winter. According to the local fishermen, whale sharks are common in the area during winter, which also indicates abundance of plankton in the coastal zones of this region.

Among marine mammals, only the plumbeus dolphin, *Sousa plumbea*, was seen in the area. Another common species along the east coast, the finless black porpoise, *Neameris phocaenoides*, was also reported in the area.

Andhra Pradesh has a coastline of 974 km and continental shelf area of 33,247 sq km, and ranks fifth in marine fish landings among all coastal states in India. Visakhapatnam district is an important marine fishing centre in the state, with 59 coastal villages and a population of 75,000 fishermen. Most of the fishing is carried out north of Visakhapatnam. Five fishing villages, including Pudimadaka and Mutyalammapalem, are located within a 20 km radius of the HNPCL plant site. The fish catches off the shore near the HNPCL site have been reported to be poor by the local fishermen.

The major commercial marine fisheries are composed of sharks, seerfish, pomfrets, thread fish, ribbon fish, and prawns. These contribute nearly 50% of the total marine catches from the area. Ribbon fish is the largest contributor to the total catch.

The low saline reservoirs in the adjacent salt factory form the potential ground for the collection of prawn seed. A few prawn

farms exist near the salt farms towards the northwestern side of the HNPCL plant site.

3.6 Socio-economic Environment

3.6.1 Demographic Features

The area in a 30 km radius of the proposed project site falls under thirteen *Mandals* of Visakhapatnam district. A total of 284 villages and 11 towns exist in the area. The *Mandal*wise description of demographic features is given in Table 3.6. The population of the area according to the 1991 census was 1683515, out of which 864689 (51.4%) were males and 818826 (48.6%) were females. Of the total population, 8% belonged to the scheduled castes (SC) and less than 1% belonged to the scheduled tribes (ST) categories (Exhibit 3.19). Literacy rates were moderate (about 52%).

3.6.2 Amenities

Data on existing amenities in the *Mandals* surrounding the HNPCL plant site are given in Table 3.7. These data were collected from the Handbook of Statistics 1992-93, Visakhapatnam District.

All thirteen *Mandals* have good facilities for primary and secondary education, while facilities for higher education are inadequate. There are no facilities for technical education in the rural area. The nearest medical and engineering colleges are located at Visakhapatnam, about 23 km from the HNPCL site.

Most of the thirteen *Mandals* surrounding the HNPCL plant site have primary health centres. Other *Mandals* have Government hospitals or allopathic/*Ayurvedic*/homoeo dispensaries. Other services such as maternity and family welfare centres, and tuberculosis (TB) clinics are not available in most of the *Mandals* except Visakhapatnam urban area. All the *Mandals* have veterinary hospitals and dispensaries facilities. Main livestock are poultry, cattle, buffaloes, sheep, and goats.

All *Mandals* have potable drinking water, mostly from dug wells and tubewells. Tap water supply is available only in Visakhapatnam urban area and VSP colony. Minor irrigation tanks are available in all rural *Mandals*.

Table 3.6. Demographic features around HNPCL plant site

Mandal	Area in sq km	Number of villages	Number of towns	Population	Population density (per sq km)	Male population	Female population	Scheduled caste population	Scheduled tribe population	Literates
Yelamanchili	105	15	1	64515	614	32010	32505	5325	347	24888
Atchutapuram	145	34		55012	379	27637	27375	3271	105	14891
Rambilli	129	31		47895	371	24235	23660	3741	113	13027
Anakapalli	184	35	1	162652	884	80800	81852	10605	1560	72962
Munagapaka	93	28		49238	529	24544	24694	4241	549	16129
Kasimkota	171	28		68486	342	38900	29586	4322	109	17783
Sabbavaram	162	34		51861	320	26189	25672	3282	90	16496
Paravada	138	24		48824	354	24669	24155	2154	27	15675
Visakhapatnam (U)	266		1	752037		387784	364253	72298	3392	488856
Visakhapatnam (R)	& R)	10	3	105248	2827	54067	51181	11953	1301	54633
Pendurthi	112	23	2	69122	617	35100	34022	4654	157	30559
Gajuwaka	84	18	2	143073	1703	74461	68612	7307	856	85031
Peddagantyada	100	4	1	65552	655	34293	31259	2933	339	26772
Total of 30 km radius	1689	284	11	1683515	9595	864689	818826	136086	8945	877702

Exhibit 3.19. Population distribution around HNPCL plant site

Table 3.7. Amenities around HNPCL plant site

	edical Facilities							Veterinary			Communication					Tele-communication				Rural Electrification				Recreation	
Mandal	Govt. Hospitals	Public Health Centres	Allopathic dispensaries	Ayurvedic dispensaries	Homeo dispanseries	Number of Doctors	Number of beds	Veterinary Doctors	Livestock Doctors	Veterinery Hospitals & Dispensaries	Bus stop	Railway station	Villages on Main road	Pucca road	Katcha road & Footpaths	Post Offices	Telegraph and Post Office (Combined)	Telephone Exchange	Public Phone	Total Inhavited Villages	Number of Villages electrified	Number of agricultural connections	Number of industries connections	Community Radio sets	Cinema Halls
Yelamanchili	1			1	1	4	30	1		2	5	2	3	11		10	10	2	20	14	14	1041	91	15	3
Atchutapuram		2		1	1	3	6	1		3	15		5	8	20	16	6		12	33	33	589	53	27	2
Rambilli		1				2	6	2		4	23		29			13	3	2	9	29	29	95	17	27	2
Anakapalli	1			1		9	32	2	4	7	23	1	23		12	28	13	1	37	35	35	143	169	35	9
Munagapaka		1				1	3	1	3	4	11		9	2	16	10	7	1	14	27	27	1325	95	13	1
Kasimkota		1	2	1		5	6	1	3	4	24		10	17		12	7	1	19	27	27	1275	150	27	3
Sabbavaram		1				3	30		4	5	27		30	4		14	6	1	16	34	34	1180	178	19	1
Paravada		1		1		2	3	1	1	2	19	1	18	1	3	14	3	3	21	22	22	350	400	24	2
Visakhapatnam (U)	6		1	2	1	327	1917	4		4	10	2	10			121	15	5	370					23	28
Visakhapatnam (R)			1			1	3	19	3	2						15	10	2	8	10	10	8	156		5
Pendurthi		1			2	3	9	1	2	3	21	1	7	12	4	13	1	1	10	23	23	165	280	24	3
Gajuwaka		2			2	4	6	1	1	2	18	1	17		1	8	3	3	58	18	18	32	630	15	9
Peddagantyada		1				3	30	2		2	4	1	4			8			3	4	4	6	89	9	1
Total of 30 km radius	8	11	4	7	7	367	2081	36	21	44	200	9	165	55	56	282	84	22	597	276	276	6209	2308	258	69

The communication system of the region is moderately good. All *Mandals* are connected by *kuchcha* (unpaved) or *pucca* (paved) roads. Bus is the main mode of public transport. Yelamanchili, Anakapalli, Paravada, Visakhapatnam (U), Pendurthi, Gajuwaka, and Peddagantyada have railway station as well. Good post and telegraph services are available in all the *Mandals*.

As on 31.3.93, the installed capacity and generation of hydro/thermal power stations in the Visakhapatnam district were as follows:

Power station	Installed Capacity
Upper Sileru Hydro Electric Power Station	2×60 MW
Machkund Hydro Power Station (Joint Project)	3×17 + 3×23 MW
Andhra Pradesh Share 70% = 84 MW	
Orissa State Share 30% = 36 MW	

Source : Superintending Engineer, APSEB.

*Mandal*wise rural electrification status is shown in Table 3.8. It can be observed from the table that all the villages in thirteen *Mandals* in a 30 km radius of the proposed project site are electrified. Nevertheless, after surveying the area, power cuts were observed to be common for about 8-10 hours in rural areas and for about 6-8 hours in urban areas. In rural areas, electricity is used mostly for agriculture (lift irrigation), and to a smaller extent for domestic consumption and industrial use.

Recreational facilities such as stadia, community halls, auditoria, and public libraries do not exist in most of the *Mandals*. These facilities are, however, available in nearby towns and cities. All *Mandals* have cinema halls.

3.6.3 Occupational Pattern

The occupational pattern in villages surrounding the HNPCL plant site is given in Table 3.9. Exhibit 3.20 shows the percentage distribution of the population based on the categories of workers. A majority (about 65%) of the population in the villages surrounding the HNPCL plant site are non-workers, 1.5% are marginal workers, and only a third are main workers. Thus there is potential for HNPCL to hire local persons during both construction and operational phases.

The sector-wise distribution of main workers is depicted in Exhibit 3.21. About 15.6% of the main workers are engaged in agricultural labour and about 15.5% are cultivators. Thus almost a third of the population in the region is engaged in agriculture. The

other major sectors in which the main workers are engaged are manufacture and processing (other than household); transport, storage, and communications; construction; and trade and commerce.

3.6.4 Industries

Visakhapatnam district hosts a number of large- and medium-scale industries. The district has 565 registered factories under the Factories Act with a total work force of about 50415. The area in a 30 km radius of the proposed project site houses about 32 large- and medium-scale industries. These include engineering, chemical and allied, electrical and electronics, mineral and ceramic, and miscellaneous industries. The large- and medium-scale industries surrounding the HNPCL plant site (in 30 km radius) are listed in Table 3.10. Proposed industries in the area are listed in Table 3.11.

3.6.5 Places of Historical and Cultural Importance

The area in a 30 km radius of HNPCL plant site has few monuments of historical and cultural importance. The monuments protected by Andhra Pradesh state Government and Government of India that exist within 30 km from the plant site are given in Table 3.12. The famous Simhachalam temple is about 26 km from the HNPCL site.

3.6.6 Traffic

To determine the existing traffic on approach roads from NH5 to the HNPCL plant site, a traffic survey was conducted by TCS at key locations in the area. The locations have been given in Chapter 1. Traffic data collected from various locations were summarised and hourly and daily traffic compositions were determined. The results of the exercise are presented in this section.

a. Traffic Composition

The composition of traffic at various locations is given in the following table. The numbers in the table indicate the number of vehicles observed at the locations during the entire day of sampling. The traffic data are also presented as pie-charts in Exhibits 3.22 through 3.25.

Table 3.8. Electrification in villages around HNPCL plant Site

Mandal	Total inhabited villages	Number of villages electrified	Number of agricultural connections	Number of industrial connections
Yelamanchili	14	14	1041	91
Atchutapuram	33	33	589	53
Rambilli	29	29	95	17
Anakapalli	35	35	143	169
Munagapaka	27	27	1325	95
Kasimkota	27	27	1275	150
Sabbavaram	34	34	1180	178
Paravada	22	22	350	400
Visakhapatnam (U)				
Visakhapatnam (R)	10	10	8	156
Pendurthi				
Gajuwaka				
Peddagantyada				

Table 3.9. Occupational pattern around HNPCL plant site

Mandal	Main workers	Marginal workers	Non-workers	Cultivators	Agricultural labourers	Manufacturing, processing, service, repairs	Manufacturing, processing other than household	Construction	Trade and commerce	Transportation, storage, communication	Other services	Livestock, forestry, fishing	Mining, quarrying
Elamanchili	27689	1095	35731	6955	12169	1439	1073	191	1899	800	2914	245	4
Atchutapuram	23935	3551	27526	10607	7528	1080	279	55	988	235	1282	1879	2
Rambilli	20239	2872	24784	8360	7612	774	110	83	668	154	1097	1380	1
Anakapalli	58329	2235	102088	12003	12282	829	6458	1059	10129	3841	9246	755	1727
Munagapaka	22292	2368	24578	9083	7996	560	428	273	1163	574	1671	530	14
Kasimkota	26677	2527	29282	11361	9174	908	613	179	1145	634	1982	375	8
Sabbavaram	23056	2862	25943	10784	6598	552	441	143	912	1351	1490	709	76
Paravada	18916	2916	26992	7275	5683	536	1273	276	665	482	1169	1176	381
Visakhapatnam (U)	215700	977	535360	318	1460	1232	31881	16614	36611	38291	83229	5606	458
Visakhapatnam (R)	30689	891	73668	1213	5301	446	3089	3081	3716	4289	8212	738	612
Pendurthi	23805	959	44358	4874	5979	544	2192	854	2137	2621	3451	412	748
Gajuwaka	43027	409	99629	1497	3407	689	15993	3014	3991	2938	10674	419	432
Pedagantyada	19992	538	45022	1431	1310	144	8025	2647	1310	583	3073	1178	301
Total of 30 km radius	554346	24200	1094961	85761	86499	9733	71855	28469	65334	56793	129490	15402	4764

Exhibit 3.20. Occupational Pattern around HNPCL project site

Exhibit 3.21. Sectorwise distribution of main workers around HNPCL plant site

Table 3.10. Existing large- and medium-scale industries around HNPCL plant site

Name of Industry	Location	Products	Employment
Marine Fish Processing Industry			
Sreenivasa Enterprises	DA, Mindi	Processed prawns,	858
Navabharat Ferro Alloys Limited	Fishing Harbour, cold storage	Shrimp export, cold storage	106
Phoenix India Marine (P) Limited	Visakhapatnam	Marine foods	192
Crouthani Construction & Fisheries (P) Limited	Vallanki, Peddipalem	Processing of marine products	65
Oriental Highson's Fisheries	Visakhapatnam	Fish Products	125
Engineering Industries			
Visakhapatnam Steel Plant	Ukkunagaram	Rolled, structural & Liquid steel	17454
Visakha Wire ropes Limited	E.E.I.E., Visakhapatnam	Steel wire rope	117
Usha Iron and Steel Alloy Limited	I.D.A., Visakhapatnam	MS rods, CTD bars billets and tubes	150
AKC Steel Industries Limited	Malkapuram	MS ingots, rerolling rounds, bars, squares and angles	169
Hindusthan Shipyard Limited	Gandhigram	Ship building and repairing	7688
BHPV Limited	Visakhapatnam	Process plant equipment, cryogenic plants, storage systems, boiler, special process systems	4602
Hast Alloy Casting Limited	Anakapalli	Alloy steel castings	150
Hindusthan Zinc Limited	Visakhapatnam	Zinc, Pb, Ag, Cd and Sulphuric acid	1515
Chemical and Allied Industries			
Pragathi Fertilisers Limited	Industrial Development Area, Mindi	Single super phosphate, sulfuric acid	478
Hindusthan Polymers	Venkatapuram	Polystyrene, styrene ethyl alcohol	644
Hindusthan Petroleum Corporation Limited	Visakhapatnam	Crude oil processing	1148
Indian Oxygen (P) Limited	Nakkavanipalem	Industrial oxygen, dissolved acetylene	57

Table 3.10. Existing industries around HNPCL plant site (continued)

Name of Industry	Location	Products	Employment
Andhra Pradesh Industrial Gases (P) Limited	IDA, Visakhapatnam	Industrial oxygen, dissolved acetylene	30
Electrical and Electronics Industries			
Southern Electrodes Limited	New IDA, Visakhapatnam	Oxygen, Nitrogen & dissolved acetylene gas	34
B.E. Pumps	IDA, Visakhapatnam	Power driven Pumps	36
Marine & Communication Electronic (I) Limited	APIE, Visakhapatnam	Electronic and telecom-munication equipments	NA
Petrochemical Industry			
Andhra Petrochemicals Limited	Visakhapatnam	Ethyl alcohol, butanol	250
Niraj Petrochemicals Limited	Vada Chipurapalli	Maleic Anhydride	60
Miscellaneous Industry			
The Anakapalli Co-operative Sugar Limited	Thummapala, Anakapalli	Sugar, rectified spirit, tablets, liquid CO_2 gas	893
Andhra Pradesh Dairy Develop-Cooperative Federation	Mindi	Milk	NA
Vijaya Prestressed Products (P) Limited	Pendurthi	Concrete sleepers	75
IDL Salzbau Limited	Pedagantyada	Marble tiles, ceiling boards, partition panels boarding plaster	70
Ferro Serap Nigam (P) Limited	Visakhapatnam	Processing of soap	NA

Table 3.11. Proposed large- and medium-scale industries aropund HNPCL plant site

Name of Industry	Location	Products	Investment (Rs in lakh)
Marine Fish Processing Industry			
Prel Magnet (P) Limited	Visakhapatnam	Processing of fish and shrimp	105
Oriental High Sea Fisheries Limited	Visakhapatnam	Processing of marine fish	1250
Engineering Industries			
Ferro Scrap Nigam Limited	Visakhapatnam	Processing of scrap	1545
Chemical and Allied Industries			
Alu Flouride (P) Limited	Visakhapatnam	Aluminium flouride	1292
Himadri Chemicals & Indus-tris Limited	Pedagantyada	Dehydrated coal tar & coal tar products	433
Ballarpur Industries Limited	Paravada	Para-nitro-chloro-bnenzene	7680
DCM Shriram Industries Limited	Visakhapatnam	Urea	18150
Pronmagnet (P) Limited	Vadlapudi, Gajuwaka	Para-nitro-chloro-benzene	546
Industrial Gases Limited	Gajuwaka	Oxygen gas	23.36
UB Petro Limited	Visakhapatnam	Caustic soda & chlorine	2800
The Bombay Dyeing & Manufacturing Company Limited	Visakhapatnam	Paraxylene, benzene propine, hydrogen, and sulphur compounds	37500
T.R. Datla Limited	Paravada	LPG, light and heavy naptha	55100
Petrochemical Industry			
Niraj Petrochemicals Limite	Vada Chipurpalli	Maleic anhydride, lubricating oil, butanol, tetrahydro furan	1728
UB Petrochemicals Limited	Paravada	Polypropylene & Polymers, PVC & high density polythene	11922

Table 3.11. Proposed industries aropund HNPCL plant site (continued)

Name of Industry	Location	Products	Investment (Rs in lakh)
Reddy Petroproducts Limited *Miscellaneous Industry*	Gajuwaka	Urea and LAB	43000
Indian Rayons & Industries Limited	Visakhapatnam	Sea water magnesia	12464
Bhuvnagiri (P) Limited	Paravada	Containers for transport of fluid	684
Visakha Wiro Ropes Limited	Autonagar, Visakhapatnam	Standard wire	210
Suneetha Levels (P) Limited	Autonagar,	Woven levels	227.45

Table 3.12. Monuments around HNPCL plant site

Monument and Location (distance from HNPCL site in km)	Protection Authority
Varaha Lakshmi Narasimha Swamy Temple Simhachalam (Adivaram) (26 km)	Government of Andhra Pradesh
Group of Temples called: • Dharmalingeswara • Radha Madhava Swamy • Visweswaraswamy varu Panchadarla, Elamanchili (28 km)	Government of Andhra Pradesh
Sri Nilakanteswara Temple, Tadi, Anakapalli (13 km)	Government of Andhra Pradesh
Budhist Complex, Madusavada, Visakhapatnam (23 km)	Government of Andhra Pradesh
Someswaraswamy Temple, Appikonda (7 km)	Government of Andhra Pradesh
Sankaram Buddhist Caves, Anakapalli (22 km)	Government of India

*Source: Department of Archaeology, Government of Andhra Pradesh and Government of India

Exhibit 3.23. Traffic on Lankelapalem-Paravada road at Paravada

Exhibit 3.22. Traffic on Gajuwaka-Yelamanchili road at Deshapatrunipalem

Exhibit 3.24. Traffic on Deshapatrunipalem-Kalapaka road

Exhibit 3.25. Traffic on VSP-Palavalasa road at Nimma Doddi

Type of vehicle	Deshapatrunipalem (Location 1)	Paravada (Location 2)	Kalapaka (Location 3)	Nimma Doddi (Location 4)
Car	305	20	6	30
Scooter/motor-cycle	1433	209	101	179
Auto-rickshaw	34	1	10	14
Bus	227	39	19	34
Goods	78	617	26	10
Total (fast moving)	2077	886	162	267
Bicycles	897	186	404	791
Cycle-rickshaw	1	0	0	1
Animal-drawn	13	7	23	24
Total (slow moving)	911	193	427	816
Grand total	2989	1079	588	1084

The following salient features can be observed from the data presented in the above table.

- While 70-80% of traffic on Gajuwaka - Yelamanchili Road and Lankelapalem - Paravada Road is motorised, the remaining two roads mainly carry slow-moving traffic (about 75%), mainly bicycles.
- Scooters and motor-cycles (two-wheelers) are the popular mode of transport among fast-moving private vehicles. On all roads except Lankelapalem - Paravada Road, two-wheelers accounted for over 60% of the fast-moving vehicles.
- Lankelapalem - Paravada Road, intersecting Gajuwaka - Yelamanchili Road at Paravada, provides an alternative to NH5 for truck traffic, indicated by trucks making up 70% of fast-moving traffic on this road.
- Composition of traffic at Kalapaka and Nimma Doddi indicates that roads in these localities carry only local traffic of people going for work and other business. About 75% traffic on this road was observed to be slow-moving.
- Except on Gajuwaka - Yelamanchili Road, all other roads carry bus traffic which connects the villages in the area to Visakhapatnam. About 11% of fast-moving vehicles on this road are buses, which connect Yelamanchili with other districts and important towns in the state.

b. Daily Traffic Flow

The daily traffic flows at all locations are given in the following table.

Location	Direction Towards	Average Daily Traffic	
		(Vehicles)	(PCU)
Deshapatrunipalem (Location 1)	Gajuwaka	1559	1287
	Yelamanchili	1430	1133
Paravada (Location 2)	Paravada	582	1165
	Lankelapalem	497	1016
Kalapaka (Location 3)	Deshapatrunipalem	324	271
	Kalapaka	263	253
Nimma Doddi (Location 4)	Islampeta	613	419
	Palavalasa	471	366

The data in the above table indicate that:

- Gajuwaka - Yelamanchili Road carries the highest amount of traffic while Kalapaka Road the least.
- On Lankelapalem - Paravada Road, even though the vehicular traffic volume is less, traffic flow in terms of PCUs is higher due to the heavy truck traffic.
- Almost all roads carry approximately equal traffic in either direction.

c. Peak-Hour Traffic Flow

Hourly variation in traffic flows at all survey locations were observed and peak-hour traffic flows were determined. These are given in the following table.

Location	Peak Hour	Peak Hour Traffic		
		Vehicles	PCU	% of daily traffic
Deshapatrunipalem	0730-0830	208	243	10.0
Paravada	1000-1100	153	172	7.9
Kalapaka	1630-1730	74	79	15.1
Nimma Doddi	0800-0900	129	84	10.7

The above table shows that all survey locations have morning peak hour except Kalapaka Road. While planning to bring heavy equipment to the plant site, this observation must be taken into account. Peak hour traffic varied between 7% and 15% of the total traffic.

d. Level of Service

From the peak hour traffic flow, the level of service (LOS) on existing roads was determined, and is shown in the following table.

Location	Peak Hour PCU	Road Width (m)	Capacity PCU/h	Volume/ Capacity	Level of Service
Deshapatrunipalem	243	5.5	600	0.40	B
Paravada	172	3.6	200	0.86	D
Kalapaka	79	3.4	200	0.39	B
Nimma Doddi	84	3.6	200	0.42	B

Almost all the roads providing access to the project site at Palavalasa carry much less traffic compared with their respective capacities. On Lankelapalem - Paravada Road, the volume to capacity ratio is 0.86, indicating a fairly high congestion level. This is due to the large volume of truck traffic on this road.

3.6.7 Health Status

The existing health status surrounding the proposed plant site was assessed based on the information collected from the following Primary Health Centres (PHC) and through interviews with doctors in the areas surrounding the plant site. The population covered under the PHCs in the area around the HNPCL plant site is given in the following table:

Name of PHC	Population covered
Paravada	55000
Atchutapuram	30000
Haripalem	24000
Munagapaka	54000
Aganampudi	35500
Vadlapudi	62000

a. Paravada

Anemia, influenza, and allergic diseases such as skin rashes, itching, and sinusitis are commonly reported in this area. The likely cause of anemia is poor living standards and lack of awareness of balanced diet. In addition, loss of immunity, frequent fever, and TB symptoms are also reported. During the rainy season, diarrhea and gastroenteritis are the most common diseases in the fishing villages Vadachipurapalli, Mutyalammapalem, Dibbapalem, Jalarpeta, and Thikkavanipalem.

Health and sanitation awareness has been increasing among the people in the recent years due to increased job opportunities, and literacy and health campaigns conducted by the government. The response to these campaigns is generally good.

b. Atchutapuram

Scabies, diarrhea, amoebiosis, polio, and anemia are the common diseases in this area. Diarrhea and fever are common during the rainy season. High occurrence of TB is reported in the areas near the cement plant. Forty patients out of total 30000 people are continuously undergoing treatment for TB in this PHC area, which could be due to poor living conditions.

Sanitation awareness is very poor in the fishing villages Pudimadaka, Tantadi, Vadapalem, etc. High occurrence of polio is reported in these villages. Villagers attribute these human ailments and death to mythical causes, which is a reflection on the poor literacy in this area. There has been a gradual improvement in the sanitation awareness after the National Literacy Campaign was initiated by the government in this area. Family planning awareness is generally good except among fishermen and some other communities.

c. Haripalem

Scabies, viral fever, and arthritis are the common ailments in this area. Anemia and other diet-related diseases are generally not found, due to high living standards of the people, and also fairly good awareness about sanitation. Diarrhea, cold, and cough are generally observed during the rainy season.

d. Munagapaka

Anemia, worm infection, and nutritional disorders are common in this area. Scabies was a common ailment among schoolchildren in the past, but its occurrence has decreased after the implementation of the School Health Program by the government. Sanitation awareness is good in this region. Family planning awareness is poor in some communities, but has increased during the last two years.

e. Aganampudi

Diarrhea, dysentery, sexually transmitted diseases such as gonorrhoea and syphilis, and worm infection are common in this area. Malaria is occasional, and goiter is rare. Sexually transmitted diseases are believed to be transmitted by highway truck drivers in transit. TB is another common disease in this area which is likely caused by malnutrition. Apart from the above diseases, dental diseases related to betel leaf/nut chewing are also reported. Anglus

stumatitis (vitamin B deficiency) and vitamin A deficiency are the other common problems in this area.

Sanitation and family planning awareness is generally good in this region. All the communities except one or two are responding positively to the government's Family Planning campaign.

f. Vadlapudi

Malaria and diarrhea are common, and filaria occurs occasionally in this area. Population migration during steel plant construction, and poor sanitation habits of the migrants caused high malaria occurrence in the past. But there was a gradual decrease in malaria cases as a result of health campaigns conducted. TB cases were rarely reported.

Awareness of sanitation, environmental pollution, and family planning is generally good in this area. This PHC is ranks first in the district in meeting its family planning targets.

3.6.8 Project Awareness

Awareness about the HNPCL project among the people living within a 30 km radius of the plant site was assessed by conducting a survey of the population. The results of the survey are presented in this section.

During the field survey, it was observed that most of the individuals surveyed in the nearby villages were aware of the proposed project. Seventy two percent of the people expressed a positive attitude towards the project, hoping that it would bring about the economic development of the area which would lead to an improvement in the basic amenities, hence quality of life. Sixteen percent of the people indicated that the HNPCL project was not welcome in the area (Exhibit 3.26), whereas 12 percent of the people did not express any opinion. Most of the respondents, whether in favour or not, stressed the need for stringent pollution abatement measures to be adopted at the HNPCL plant, including development of a greenbelt in the surrounding villages. They also expressed the opinion that local people be employed during both construction and operational phases of the plant.

Most of the people who were against the HNPCL project, believed that the project would impair the air quality and increase noise levels. Some people expressed the opinion that the project would bring about a combination of various environmental problems like water pollution and consequent reduction in fish catch;

health related problems; and impairment of soil quality and a consequent reduction in crop production.

The negative opinion was stronger near the HNPCL plant site; as one went further away from the site, the response was more and more positive. Nevertheless, the positive response exceeded the negative response even in the areas close to the HNPCL plant site.

The ratio of positive:negative response was higher in the younger population (<45) than that of the older population (Exhibit 3.27). Service class and fishermen in the region overwhelmingly welcomed the HNPCL project (Exhibit 3.28). The ratio of positive:negative response was the higher for respondents with graduate and post graduate qualification and uneducated people (Exhibit 3.29). Respondents whose family income was between Rs 500 and Rs 1000 per month expressed maximum positive response towards the project (Exhibit 3.30). This could be attributed to the hope of the lower income group people for the possibility of getting jobs expected to be created in the area by the proposed HNPCL project.

An observation which merits mention here is that respondents in Palavalasa expressed the opinion that they should be given more compensation than that recommended at present by the Revenue Department of the Government of Andhra Pradesh. For this reason, respondents in this village expressed strongly negative opinion about the project.

In general, people with positive opinion about the project expressed a sense of relief, considering their experience of regular power cuts in Visakhapatnam. Some of them even demanded that power generated by the HNPCL's proposed TPP should be distributed only within the state and not shared with any other state.

Exhibit 3.26. Public opinion about proposed project around HNPCL plant site

Exhibit 3.27. Public opinion around HNPCL plant site according to age groups

Exhibit 3.28. Public opinion around HNPCL plant site according to occupational

Exhibit 3.29. Public opinion around HNPCL plant site acoording to educational status

Exhibit 3.30. Public opinion around HNPCL plant site according to income level

CHAPTER 4

IMPACT POTENTIAL

This chapter discusses the pollution potential of HNPCL's power plant and its possible impacts on the surrounding environment without considering the environmental management measures and proposals of HNPCL. The power plant will have impacts of varying magnitude on different environmental components. These impacts could be categorised as

- primary impacts, i e, impacts which occur as a direct result of the project activities, and
- secondary and tertiary impacts, i e, impacts which occur as a result of primary and secondary impacts, respectively.

Impacts could occur during the construction phase as well as the operational phase. Impacts during construction and operational phases are discussed separately.

4.1 Construction Phase

The major activities during the construction phase of the project will be:

- excavation
- cut and fill operations including levelling
- preparation/processing of construction materials
- loading and unloading of construction materials
- construction of approach road/railway and roads inside the plant area
- erection of plant/buildings and other civil structures
- transportation of construction materials and workers to and from the proposed project location
- disposal of liquid and solid wastes

Impacts of these activities on various components of the environment are discussed in the following subsections. It must be noted that most of the impacts during the construction phase are temporary and localised. Most of the impacts will not be felt at the end of the construction phase. These impacts will not be felt in areas which are not in the immediate vicinity of the proposed plant site.

Besides the power plant, HNPCL plans to build an approach road from NH5 as well as a railway spur from Duvvada to the site. According to the present schedule, the construction phase is slated to start by the middle of 1997. The approach road will be built by the middle of 1999. After this road is ready, construction-related traffic will be able to use the road to reach the site from NH5. Until then, however, existing roads will have to be used. Thus, the maximum impacts due to construction-related traffic will be limited to the first two years of the phase. Traffic on existing roads is expected to decrease once the HNPCL approach road is built.

4.1.1 Air Environment

Air quality can be affected by dust and particulate matter emitted from cut and fill operations, construction activities (buildings, roads, and other civil structures), site clearing, emissions from vehicles transporting minerals and materials to and from construction sites, and handling of fine particulate materials. Gaseous emissions containing CO, HC, NO_x, and lead may be released from vehicular movement and construction equipment in operation.

a. Air Quality Modelling

The construction phase will involve transportation of men and materials for construction to and from the HNPCL site. This increased traffic would lead to vehicular exhaust emissions. The impact of these emissions on the ambient air quality is presented in this section.

According to the traffic study conducted by TCS, the projected traffic that will ply on various approach roads from NH5 to the site will be as follows (details of computations involved in predicting traffic growth are given in Section 4.1.6):

Name of Road (Location)	Traffic Flow (Total number of vehicles)		
	1996 (monitored)	1997 (estimated)	1998 (estimated)
Gajuwaka-Yelamanchili (Deshapatrunipalem)	2989	3214	3455
Lankelapalem-Paravada (Paravada)	1079	1160	1247
Deshapatrunipalem-Kalapaka-Palavalasa (Kalapaka)	588	632	679
Visakhapatnam Steel Plant-Palavalasa (Nimma Doddi)	1084	1165	1253

The figures given in the above table take into account the expected natural increase in the traffic (without consideration to the project) as well as construction-related traffic.

To estimate the increases in ambient concentrations of various pollutants due this traffic, the CALINE-III model (developed by the California Department of Transportation) was used. The basic concept of the CALINE-III model is Gaussian dispersion of pollutants from automobile exhaust. The model assumes (i) steady state meteorological conditions, (ii) no decomposition or decay of pollutants, and (iii) no chemical transformation of pollutants. For assessing the worst-case impact, peak-hour traffic flows were considered (10% of the daily traffic flows). Meteorological data collected at Palavalasa during December 1995 - February 1996 were used for the model. Receptor location was considered as 10 m from the centre of the road.

Emissions from different kinds of vehicles were obtained from emission factors used by the Central Pollution Control Board (CPCB). The following emission factors were considered:

Type of vehicle	Emission rate (kg/vehicle/1000 km)				
	SPM	SO_2	NO_x	CO	HC
Light vehicles (petrol operated)	0.33	0.08	3.2	6.0	4.0
2- and 3-wheelers (petrol operated)	0.2	0.02	0.07	10.0	10.0
Buses and lorries (diesel operated)	0.75	1.5	21.0	2.1	12.5

Based on the above emission factors, the resulting increase in ambient concentrations of pollutants were computed by the CALINE-III model. These results are tabulated below.

Road (Location)	Increase in concentration ($\mu g/m^3$)				
	SPM	SO_2	NO_x	CO	HC
Gajuwaka-Yelamanchili (Deshapatrunipalem)	-	-	1.9	5.2	4.4
Lankelapalem-Paravada (Paravada)	-	-	3.8	3.0	1.0
Deshapatrunipalem-Kalapaka-Palavalasa (Kalapaka)	-	-	-	-	-
Visakhapatnam Steel Plant-Palavalasa (Nimma Doddi)	-	-	-	-	-

The results in the above table indicate that the increases in concentrations of all pollutants would be negligible. Thus, the increased traffic during the construction phase of HNPCL's power plant would have negligible impact on the air quality.

Once HNPCL's approach road is ready, the construction traffic will be diverted through this road. This will have some impact on the air quality of the area in the immediate vicinity of the new road, but to a very small extent. On the other hand, the air pollution near existing roads will decrease since traffic will be diverted to the new road.

4.1.2 Noise Environment

Mechanical operations during construction could generate noise. General noise level in and around the project site will be higher due to vehicles transporting men and material, operation of construction equipment, and excavation/drilling/construction activities. Loading and unloading of building and other materials, movement and operation of cranes, and bending and bolting of steel rods and sheets can also contribute to noise pollution during construction. This impact, however, will be temporary and localised.

a. Noise Modelling

Impact on noise environment due to traffic depends on type and number of vehicles plying on the road and the terrain and physiography surrounding the road. As discussed earlier, HNPCL proposes to build a two-lane access road from NH5 to the site to cater to the traffic to and from the proposed TPP. During the construction phase, until the access road is built, parts of the existing roads may be improved to facilitate passage of construction traffic. The possible approach roads to the site during the construction phase are as follows:

- Visakhapatnam Steel Plant-Palavalasa road
- Gajuwaka-Yelamanchili road
- Lankelapalem-Paravada road
- Deshapatrunipalem-Kalapaka-Palavalasa road

As discussed in Chapter 3, traffic surveys were conducted on all these routes to determine the existing levels of traffic on these roads, to predict the increase in traffic on these roads during the construction phase, and to suggest the most suitable alignment to reach the proposed plant site.

A traffic noise survey was conducted and noise generated by different classes of vehicles was recorded. From these, impact of traffic on noise environment during construction period were predicted using Federal Highway Administration (FHWA) model. HNPCL's own approach road to the plant site from NH5 will be ready by the middle of 1999; thereafter construction-related traffic will be diverted from the existing roads to the new road. The impact of traffic noise on the existing roads was predicted till the end of 1998. While predicting the impact, both the natural growth of traffic and construction traffic (maximum 250 trucks per day as assessed by HNPCL) were taken into account.

FHWA model predicts hourly equivalent noise level, L_{eq} *(h)* for different class of vehicles as follows:

$$L_{eq}(h)_i = L_{OE} + 10\log\left(\frac{N_i}{S_i T}\right) + 10\log\left(\frac{15}{d}\right)^{1+\alpha} + \Delta_s - 13$$

where:

- $L_{eq}(h)_i$ is the hourly equivalent noise level for the ith vehicle type, e g, two-wheelers, cars, jeeps, trucks, buses, etc.
- L_{OE} is the reference mean energy level (noise emission level) for the ith vehicle type
- N_i is the number of class *i* vehicles passing during the time T.
- S_i is the average speed for the ith vehicle class in km/h. In the present exercise, average speed of all classes of vehicles was assumed to be 30 km/h.
- T is the duration for which L_{eq} is desired. In the present case it is one hour.
- D is the perpendicular distance (m) from the centreline of the traffic lane to the location of the observer.
- α is a factor which relates to the absorption characteristics of the ground cover between the roadway and the observer. In this case α=0, since there was clear unobstructed view of the highway in absence of any intervening structure, the ground between the highway and the observer was hard, and the height of line of sight was less than 3 m.[1]
- Δs is the shielding factor provided by a noise barrier. For the condition described above, Δs=4.5dB/DD, DD is doubling of distance between the source and the observer.

For each alternate route, the preceding equation was used five times for each different class of vehicles, as described below, to estimate $L_{eq}(h)$ value for each class. The final total $L_{eq}(h)$ for each alternate route was calculated by logarithmically adding those values. Different classes of vehicles with their noise levels, as actually monitored, and the calculated L_{OE} are given in the following table.

Type of vehicle →	a	b	c	d	e
Noise levels	88.8	78.0	86.2	85.5	91.6
	88.0	79.8	84.0	88.0	92.8
	91.0	81.0	86.0	86.0	93.2
	87.0	79.0	85.0	87.7	92.0
	88.0	76.5	84.5	87.2	90.5
L_{OE}	88.78	79.12	85.22	86.98	92.12

a=car/jeep/van, b=scooter/motorcycle, c=autorickshaw, d=bus, e=goods vehicle

The calculated total $L_{eq}(h)$ for each alternate alignment is given in the following table.

[1] Rau and Wooten, 1980, Environmental Impact Analysis Handbook, McGraw Hill.

Alignment	$L_{eq}(h)$ for each vehicle class (dBA)					Total $L_{eq}(h)$
	a	b	c	d	e	
A	65.16	71.16	66.15	71.78	85.19	85.63
B	72.92	77.92	67.74	77.78	84.05	86.04
C	63.33	71.83	54.10	72.40	90.84	90.96
D	58.49	69.01	65.22	69.61	85.80	86.03

A : Steel plant-Palavalasa road, B : Gajuwaka-Yelamanchili road
C : Lankelapalem-Paravada road, D : Paravada-Kalapaka road

From the above table it can be observed that $L_{eq}(h)$ value would be highest on Lankelapalem-Paravada road. This was expected, since this was the busiest of the four roads surveyed, with a number of heavy trucks plying on the road. On the other three alternate routes, $L_{eq}(h)$ values would be similar, and lower than on the Lankelapalem-Paravada Road. It must be noted that the above traffic noise will be temporary and limited to the period required (18-19 months) to construct HNPCL's own access road to the site. Once this new road becomes operational, all the construction traffic of HNPCL will be diverted through this road, resulting in significant reduction in noise levels on all existing roads.

4.1.3 Water Environment

During the construction phase, surface water quality can deteriorate due to runoff of loose exposed soil and sanitary wastes of the labour force. HNPCL will need to take adequate steps to collect the sanitary wastewater of the labour force and dispose of it appropriately.

Construction of a bund around the ash pond will have an impact on the local stormwater drainage pattern. The ash pond area is presently a low-lying mud flat. This serves as a drainage basin for stormwater runoff from the nearby higher areas. Bunding of this area will disturb the local stormwater drainage pattern. This will have to be taken into account by HNPCL while finalising the overall stormwater management/drainage system.

4.1.4 Land Environment

The landuse of the area will change once the construction begins. The land which APSEB/HNPCL have acquired and propose to acquire is currently (i) mud flats, (ii) sand dunes with cashew and casuarina plantations. The landuse at these places will change to industrial and transportation (approach road/rail). This will be a permanent impact of the proposed development.

All the activities during construction phase may affect the characteristics of top soil. This can affect the nutrient status of the top soil in addition to infiltration rate/permeability, bulk density, porosity, water-holding capacity, soil texture and structure. These effects, however, will be limited mostly to the proposed plant site.

4.1.5 Biological Environment

Site clearing, and cut and fill operations during the construction phase can affect the terrestrial flora and fauna on the project site by disturbing their natural habitat. Along the southern boundary of the site, cashew and *Casuarina* plantations exist. The felling of these plantations will be kept to a minimum; thus the impact on these habitats will be minimal.

If no precautions are taken, stormwater runoff from the site during construction may temporarily increase turbidity in nearby surface water bodies. This may, in turn, lead to a decrease in the depth of the euphotic zone, thereby affecting planktonic productivity. This may also affect the aquaculture in the area. Appropriate mitigative measures will be necessary to prevent these impacts.

Several jackals were observed on and in the immediate vicinity of the plant site during the TCS survey. These will be disturbed due to the noise generated by the construction activities. In addition, construction of civil structures will result in an encroachment on their habitat to a limited extent due to selective cutting of trees.

The existing forest under the reserve forest category (not in the core zone - the nearest forest is 12 km from the site) could be classified as open-mixed forest dominated by perennial species. It contains a few species of vulnerable or endangered plants (as identified in Red Data Book of Botanical Survey of India), but HNPCL's project activities will not have any impact on such species; no felling or removal of such species is envisaged as they fall within the buffer zone and not in the core zone.

No migratory route of terrestrial macrofauna is known within the proposed study area. The study area, however, comes within the range of migratory path of avian species from the Siberian region during winter. The proposed plant site, however, is unlikely to affect the migration route in view of large air corridor used by the migrant species and their continued use of same route in spite of rapid industrialisation of Visakhapatnam area during past few years.

4.1.6 Socio-economic Environment

During the construction phase, employment opportunities will be created for the local people. About 6700 persons will be employed at the site during construction at its peak. This will be beneficial for the unemployed population of the nearby area who can work as construction workers and labourers. If the construction work force is not local, however, a number of workers may migrate to the proposed plant site, which can exert additional pressure on the existing infrastructure and could possibly lead to social tension.

Since the land acquired or proposed to be acquired for the plant and the road/rail/transmission corridors is not inhabited, there will be no need for rehabilitation and resettlement of families.

Aesthetics could be affected by the fugitive emissions (mainly dust) and noise generated by the various construction phase activities. These emissions, however, will be temporary and can be mitigated through good management practices.

a. Traffic

Traffic volume on the existing approach roads from NH5 to the HNPCL site was projected for a period of 2 years which is approximately the construction period of the approach road planned by HNPCL. For estimating an average growth factor, traffic census data were collected from PWD. Growth factor for traffic was computed based on PWD census available on NH5 near Gajuwaka. Traffic data obtained from PWD, NH circle of Visakhapatnam are presented in the following table.

Type of vehicle	Number of vehicles		
	July 1994	January 1995	July 1995
Car/Jeep/Van	4679	4679	4686
Bus	3324	3324	3329
Truck	12522	12522	13320
Scooter/Motor-cycle	5857	5881	5890
Tractor with trailer	1180	1180	1177
Bullock cart	582	582	582
Cycle-rickshaw	458	458	458
Bicycle	4167	4167	4173
Total	32769	32793	33615

The figures in the preceding table indicate that traffic grew at 7% per annum. Indian Roads Congress code IRC 34:1984 recom-

mends a growth of 7.5% per annum for traffic projection exercises, in the absence of reliable data for previous years. To estimate worst case impacts, a growth rate of 7.5% per annum was assumed for the purposes of this project. The projected traffic on roads leading to the HNPCL site is shown in the following table.

Name of Road (Location)	Traffic Flow (Total number of vehicles)		
	1996 (monitored)	1997 (estimated)	1998 (estimated)
Gajuwaka-Yelamanchili (Deshapatrunipalem)	2989	3214	3455
Lankelapalem-Paravada (Paravada)	1079	1160	1247
Deshapatrunipalem-Kalapaka-Palavalasa (Kalapaka)	588	632	679
VSP-Palavalasa (Nimma Doddi)	1084	1165	1253

According to the RITES report, the estimated traffic during the construction phase would be about 200-250 trucks per day, corresponding to 750 PCU/h. Taking these values into account and the projected traffic flows, the expected level of service (LOS) on the project roads was calculated and is tabulated below.

Name of Road	Traffic in 1998 (PCU)	Constr'n Traffic (PCU)	Total Traffic (PCU)	Road Width (m)	Capacity (PCU/d)	Vol/ Capacity	LOS
Gajuwaka-Yelamanchili	2797	750	3547	5.5	6000	0.59	C
Lankelapalem-Paravada	2520	750	3270	3.6	2000	1.64	F
Desha'palem-Kalapaka	606	750	1356	3.4	2000	0.68	C
VSP-Palavalasa	907	750	1657	3.6	2000	0.83	D

The following salient observations can be made from the results shown in the above table.

- LOS will get adversely affected with the projected traffic growth together with the construction traffic in 1998, assuming that the road widths will not increase. This is clear from the volume to capacity ratios obtained.
- Lankelapalem - Paravada Road would be worst affected, with a projected LOS category F. This road, however, is being widened, which will lead to an improvement in the LOS.

Thus, unless roads are widened, the level of service of existing approach roads to the HNPCL plant site will deteriorate.

4.2 Operational Phase

The major activities involved in the operational phase of the HNPCL project will be as follows:

- transportation of raw materials (coal/oil) to plant
- storage/handling of raw materials (coal/oil)
- desalination of sea water
- steam generation
- power generation and transmission
- cooling water discharge (into Bay of Bengal)
- ash disposal
- disposal of other wastewater(s)

The impacts of these activities on various components of the environment of the area are discussed in this section.

4.2.1 Air Environment

a. Fugitive Emissions

Fugitive emissions in the plant could result from openings and leaks in ducts and valves. Fugitive emissions could also occur from the coal and ash handling operations at unloading and transfer points. The impacts of these emissions, however, would be limited to the workers at the HNPCL's plant; the emissions are not likely to affect the area outside the plant premises. Nevertheless, proper management actions should be taken to minimise the fugitive emissions to protect HNPCL's employees.

b. Stack Emissions

HNPCL will have one stack through which emissions from both units will be let out into the atmosphere through two flues, one for each unit.

Nature and quantity of pollutants in the stack emission depend on the type of burner and nature and quality (ash and sulphur content) of the fuel used. At the HNPCL plant, coal (670 T/h) will be used as the fuel for the boilers. When coal burns, SPM, SO_2, CO, and NO_x will be emitted.

The washed coal to be used at the HNPCL plant will have an ash content of 34±2%. Part of this will be emitted as fly ash (SPM) in the exhaust gas. The maximum sulphur content of coal will be 0.8%. This will be emitted as SO_2. Generation of NO_x will

be relatively lower, since low-NO_x burners will be used for burning the coal. Flue gases will be emitted only after passing through electrostatic precipitators (ESPs). The SPM emissions considered here are those which would result after the ESP.

Besides the boiler stack, additional emissions would arise from the auxiliary boiler and occasionally from the emergency diesel generator (DG) sets during their testing or operation. These emissions, however, would be occasional, hence their impact on the air environment would be insignificant.

c. Air Quality Modelling

The Industrial Source Complex - Short Term (ISCST) model (USEPA, 1987)[2] was used to predict changes in air quality, i e, maximum ground level concentrations (GLCs) of various pollutants, due to the emissions from HNPCL's plant. The model uses the steady state Gaussian Plume Equation for continuous sources and can be applied to a variety of sources encountered in industrial areas. The model is recommended by the USEPA for the following applications:

- industrial source complexes
- rural or urban areas
- flat or rolling terrain
- transport distances less than 50 km
- one hour to annual averaging times
- continuous toxic air emissions and fugitive emissions from various area sources

Salient Features of ISCST Model

The ISCST model can account for:

- settling and dry deposition of particles
- downwash
- area, line, and volume sources
- plume rise as a function of downwind distance
- separation of point sources
- limited terrain adjustment

The input requirements for the model are:

- hourly meteorological data

[2] USEPA, 1987, Industrial Source Complex - Short Term (ISCST) Model, United States Environmental Protection Agency, EPA-450/4-88-002a.

- source data
- receptor data
- programme control parameters

Meteorological inputs required for the model include hourly estimates of the wind speed and direction, ambient temperature, Pasquill stability category, mixing height, wind profile exponent, and vertical temperature gradient.

The Gaussian plume equation in the general form may be expressed as:

$$\chi = \frac{Q}{2\pi\mu\sigma_y\sigma_z}\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left[\exp\left\{-\frac{(z-h_e)^2}{2\sigma_z^2}\right\}+\exp\left\{-\frac{(z+h_e)^2}{2\sigma_z^2}\right\}\right]$$

where Q is the source strength, σ_y and σ_z are the dispersion coefficients, h_e is the effective stack height and μ is the wind speed at stack level.

The ISCST model applies user-specified locations for point, line, area, and volume sources and user-specified locations for receptor rings. User input topographical evaluation for each receptor can be used.

Briggs (1975)[3] plume rise formula is used in the ISCST model for computing the effective plume height

$$\Delta h = \frac{1.6\,F^{1/3}x^{2/3}}{\mu}$$

where Δh is the plume rise, F is the buoyancy flux parameter, x is the distance from the stack, and μ is the wind speed at stack level.

For rolling terrain (terrain not above stack height), plume centre line is horizontal to at the height of final rise above source.

Chemical transformations with exponential decay and physical removal by settling and dry deposition can be used in the ISCST model. GLCs are calculated corresponding to each meteorological period. These values are arithmetically averaged to obtain concentrations over user-specified periods.

[3] Briggs G A, 1975, Plume Rise Prediction, Chapter 3 in Lectures on Air Pollution and Environmental Impact Analysis, American Meteorological Society, 59-111.

Methodology

Hourly data on wind speed and direction, and temperature collected at the HNPCL site during December 1995 - November 1996 were used for the model. The mixing height for the area for this period was assumed to be 1500 m (maximum).

To estimate the GLC due to N number of identical sources at the same location, the GLC obtained considering emission from one source can be multiplied by a factor of $N^{0.8}$ as follows[4]:

$$\chi_{total} = \chi_1 \times N^{0.8}$$

Since HNPCL will have two identical flues in the stack, in the present case, N = 2.

The air quality simulation exercise was carried out assuming the worst case conditions, for conservative assessment. The following assumptions were made:

- Maximum anticipated emissions from the stack
- Worst sulphur (0.8%) content acceptable to HNPCL from the coal supplier (as per HNPCL's coal supply agreement, coal containing sulphur beyond 0.8% will be rejected)
- All sulphur in the coal would be converted to SO_2 and released through the stack; none would be retained in the ash (in practice, some amount of sulphur may be retained in the ash, as observed at Vijaywada Thermal Power Station of APSEB where coal from Talcher is used as the fuel)
- Maximum anticipated coal consumption and ash content (coal consumption is expected to range between 570 T/h and 670 T/h depending upon the ash content and calorific value)

The source data and model options used for the air quality simulation are given below. Modelling was carried out for SPM, SO_2, NO_x, and CO since the emissions of these pollutants are expected to have some impact on the surrounding air quality.

Model	: ISCST v.2
Simulation area	: 60 km × 60 km
Averaging time*	: 24 h
Source data	
Pollutant strength	
SO_2	: 2935 g/s

[4] Stern, A C, 1976, Air Pollution, Vol 1, Academic Press, New York.

NO_x	: 614 g/s
SPM	: 115 g/s
CO	: 128 g/s
Stack height	: 275 m
Exit gas temperature	: 419 K
Exit gas velocity	: 30 m/s
Flue diameter (exit point)	: 6 m
Stack location	: centre of simulation area
Receptors: 500 m intervals	
elevation range (w r t stack base)	: 0 - 375 m
Meteorological data	
Hourly wind speed	: HNPCL site
Hourly wind direction	: HNPCL site
Hourly temperature	: HNPCL site
Mixing height (assumed)	: Maximum 1500 m
Stability	
Pasquill's classification, using	: Radiation index
	: On site cloud cover
	: Wind speed
Decay/deposition	: Not opted
Chemical transformation	: Not opted

* Averaging time = 8 h for CO

Uniform (steady state) horizontal wind was assumed for each hour. Straight line transport was assumed to all distances. Separate wind profile exponents applicable for rural cases were used. Vertical wind speed was assumed to be zero.

For both horizontal and vertical dispersion, buoyancy-induced dispersion coefficients were used. Standard Pasquill stability classes were used. Mixing height was accounted for with multiple reflections until the vertical plume standard deviation equalled 1.6 times the mixing height. Uniform vertical mixing was assumed beyond that point. Perfect reflection was assumed at the ground.

Since another thermal power plant of similar capacity, the Simhadri Thermal Power Station, is planned next to the HNPCL site by the National Thermal Power Corporation (NTPC), air quality modelling was carried out taking into consideration the emissions from NTPC's power plant as well. The emission rates of various pollutants from NTPC's stack were assumed to be the same as those from HNPCL's stack. The location of the Simhadri TPS stack was considered at 4.87 km west and 3.89 km north of the HNPCL stack, according to the information provided by APSEB.

Results and Conclusions

The air quality simulation indicated that only SO_2 would be of significance with respect to impact on air quality. For the other parameters - SPM, NO_x, and CO - the maximum increments in the GLCs due to emissions from the HNPCL stack were found to be insignificant (see table below). The existing air quality with respect to these parameters was also found to be excellent. Hence further detailed analysis was limited to SO_2. The isopleths showing increase in concentrations of SPM, SO_2, NO_x and CO considering HNPCL alone are given in Exhibits 4.1 through 4.16.

Parameter	Ground level concentration			Standard (for industrial areas)
	Existing (98th percentile value)	Increment (worst case)	Total	
SPM ($\mu g/m^3$)	127	2	129	500
NO_x ($\mu g/m^3$)	39	10	49	120
CO (mg/m^3)	2.8	0.004	2.804	5.0

SPM and NO_x: 24 h average values, CO: 8-h average values

The values for existing environmental quality in the above table are the maximum 98th percentile values (in any season) out of the six air quality monitoring stations. The figures are based on 52 weeks' monitoring, hence represent the worst-case figures for all practical purposes. Even assuming another 100% incremental addition to the existing concentrations (due to NTPC), the ambient air quality standards will be comfortably met. Hence further analysis was not carried out on these parameters.

As indicated earlier, only SO_2 is expected to affect the air quality significantly. Increments in SO_2 concentrations due to HNPCL alone (H) as well as due to HNPCL + NTPC (H+N) are given in the Table 4.1. It can be observed from the table that the maximum GLCs would be within the limits specified by CPCB even under the worst-case conditions. The actual increments in GLCs of SO_2 are expected to be lower than those predicted by the model. Hence the impact of HNPCL's plant on the air environment would be well within acceptable limits. Even if NTPC's power station is considered, the ambient air quality standards in the area are unlikely to be violated. The isopleths showing increase in SO_2 concentrations considering both HNPCL and NTPC are presented in Appendix G.

The maximum GLCs on hillocks surrounding the HNPCL site would be relatively higher than in the inhabited areas. These hillocks, however, are not inhabited; they harbour mainly thorny bushes with isolated trees. The impact of SO_2 on these hillocks is therefore not expected to be significant.

Coastal Fumigation

Patterns of dispersion at coastal sites differ from those at inland sites primarily because dispersion is affected by differences between temperature and roughness of land and water surface. The temperature difference between land and water can affect dispersion through two mechanisms: (i) it tends to cause a difference in the air pressure above land and water surfaces, leading to the existence of land-sea breeze, and (ii) it tends to produce a different atmospheric stability in the air over water and over land, with an interface between them. Theory indicates that a the pollutant emitted in the stable atmosphere above the thermal internal boundary layer (TIBL) carries more distance to inland with little dispersion, but once the plume strikes the TIBL the entire plume starts to fumigate in the unstable layer below. Hanna's[5] equation is used to estimate the height of TIBL, as follows:

$$\text{Height of TIBL} = 200 + 0.03\,(X - 2000)$$

where X = distance from the coast (m).

Where the height of the boundary layer equals the fanning plume height, plume touches the unstable atmosphere and fumigate downwards and causes high concentration of pollutants locally. These processes, however, will be short-term, and dilution of the plume in the turbulent atmosphere would bring down the concentrations of pollutants further.

The maximum ambient concentration during fumigation can be determined as follows:

$$\chi = \frac{Q}{2.506 \times U \times \sigma_{yf} \times H}$$

$$\text{where } \sigma_{yf} = \sigma_y + H/8$$

Under typical coastline meteorological conditions which favour the formation of an internal boundary layer, the likely concentration of pollutants due to fumigation (considering emissions from HNPCL alone) are calculated. The results are:

- Wind speed: 2 m/s
- Stability: Stable in the upper layer, unstable near surface
- Distance: 10 km from stack

[5]Hanna, S R, 1987, An empirical formula for the height of the coastal internal boundary layer, Boundary Layer Meteorology, **40**, 205-207.

Exhibit 4.2. Predicted maximum (24-hourly average) increase in ground level SO_2 concentrations due to HNPCL's stack emissions during pre-monsoon

Exhibit 4.1. Predicted maximum (24-hourly average) increase in ground level SO_2 concentrations due to HNPCL's stack emissions during winter

Exhibit 4.3. Predicted maximum (24-hourly average) increase in ground level SO_2 concentrations due to HNPCL's stack emissions during monsoon

Exhibit 4.4. Predicted maximum (24-hourly average) increase in ground level SO_2 concentrations due to HNPCL's stack emissions during post-monsoon

Exhibit 4.5. Predicted maximum (24-hourly average) increase in ground level NO_x concentrations due to HNPCL's stack emissions during winter

Exhibit 4.6. Predicted maximum (24-hourly average) increase in ground level NO_x concentrations due to HNPCL's stack emissions during pre-monsoon

Exhibit 4.7. Predicted maximum (24-hourly average) increase in ground level NO_x concentrations due to HNPCL's stack emissions during monsoon

Exhibit 4.8. Predicted maximum (24-hourly average) increase in ground level NO_x concentrations due to HNPCL's stack emissions during post-monsoon

Exhibit 4.9. Predicted maximum (24-hourly average) increase in ground level SPM concentrations due to HNPCL's stack emissions during winter

Exhibit 4.10. Predicted maximum (24-hourly average) increase in ground level SPM concentrations due to HNPCL's stack emissions during pre-monsoon

Exhibit 4.11. Predicted maximum (24-hourly average) increase in ground level SPM concentrations due to HNPCL's stack emissions during monsoon

Exhibit 4.12. Predicted maximum (24-hourly average) increase in ground level SPM concentrations due to HNPCL's stack emissions during post-monsoon

Exhibit 4.13. Predicted maximum (24-hourly average) increase in ground level CO concentrations due to HNPCL's stack emissions during winter

Exhibit 4.14. Predicted maximum (24-hourly average) increase in ground level CO concentrations due to HNPCL's stack emissions during pre-monsoon

Exhibit 4.15. Predicted maximum (24-hourly average) increase in ground level CO concentrations due to HNPCL's stack emissions during monsoon

Exhibit 4.16. Predicted maximum (24-hourly average) increase in ground level CO concentrations due to HNPCL's stack emissions during post-monsoon

Table 4.1. Predicted changes in ambient SO_2 concentrations due to stack emissions from HNPCL and NTPC

Location	Distance from stack (km)	Direction with respect to stack	Season during which maximum GLC (existing + incremental) is likely to occur	Background GLC (24 h) 98th percentile value	Power station	Incremental GLC impact range		Total expected GLC (existing + incremental)	
						Maximum*	Minimum**	Maximum*	Minimum**
Palavalasa	3	NE	Pre-monsoon	25	H	47	31	72	56
					H+N	52	32	77	**57**
Peddapalem	6	N	Winter	27	H	41	22	68	49
					H+N	44	26	**71**	**53**
Chipurapalli	6	WNW	Post-monsoon	19	H	24	15	43	34
					H+N	50	30	**69**	**49**
Thikkavanipalem	3	SW	Post-monsoon	17	H	45	32	62	49
					H+N	48	34	**65**	**51**
Deshapatrunipale	9.5	N	Pre-monsoon	22	H	15	9	37	31
					H+N	48	28	**70**	**50**
Peddagantyada	14	NE	Pre-monsoon	25	H	23	16	48	41
					H+N	28	17	**53**	**42**

Note: Effect of rain was not considered for predicting worst case impacts

H - HNPCL * Maximum - with 0.8% sulphur and no sulphur retention in ash

N - NTPC ** Minimum - with 0.6% sulphur and 20% retention in ash

- Pollutant concentrations
  - SO_2: 656 μg/m³
  - NO_x: 137 μg/m³
  - SPM: 25 μg/m³
  - CO: 28 μg/m³

These concentrations are hourly averages; fumigation will not continue for long periods.

4.2.2 Noise Environment

The principal sources of noise at the HNPCL plant will be turbines, air compressors, fans, mills, pumps, pressure release valves, etc. Besides these, transportation (by rail), crushing, and handling (by conveyor belts) of coal will also have the potential to raise the noise levels.

Apart from the sources inside the plant, the movement of trucks and other vehicles to and from the plant will also contribute to increased noise level inside the plant premises.

If mitigative measures are not taken, these can increase the ambient noise levels inside the factory area and its surroundings. These could have impacts on the workers inside the plant. The US Occupational Safety and Health Administration (OSHA) recommends the following permissible noise levels and exposure duration.

Maximum allowable duration per day (h)	Noise Level (dBA) (Slow Response)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25	115

Thus, to mitigate the impact of HNPCL's power plant on the ambient noise levels, suitable noise abatement measures will be required.

4.2.3 Water Environment

As discussed in Chapter 2, HNPCL will require a large amount (5782560 m^3/d) of water for (once-through) cooling, which would be obtained from the Bay of Bengal. In addition, fresh water would also be required for various purposes. Initially HNPCL had planned to obtain fresh water from the Yeleru canal, but later decided to install a desalination plant and use sea water as the source. Thus, HNPCL's power plant will not exert any additional pressure on the existing water resources of the area.

The water environment in the area around HNPCL can be affected by the wastewater generated in the power plant. In the HNPCL plant, which will use once-through cooling system, cooling water would form the bulk of the wastewater generated. Besides cooling water, the other major effluent streams will be brine resulting from the desalination plant and ash pond effluent. Other sources of wastewater will be boiler blowdown, canteen and sanitary facilities in the plant and domestic wastewater from HNPCL's residential quarters, coal handling, laboratory, mixed bed polisher regeneration, and unit (oily) water. The maximum expected amounts of wastewater from these sources, *without recycling or reuse*, and the typical pollutants from each source are as follows:

Source	Quantity (m^3/d)	Pollutants
Cooling water discharge	5782560	Temperature, residual Cl
Desalination	74357	TDS
Ash slurry	57600	TSS, sulphates, traces of metals, phosphates
Boiler blowdown	1220	TSS, O&G, Cu, Fe
Coal handling	600	TSS
Mixed bed polisher effluent	24	Extreme pH, TDS
Unit (oily) water	30	O&G
Laboratory	10	COD, chemicals
Colony, canteen, and sanitary	500	BOD, COD, nutrients
Total	5916901	

It can be seen from the above table that the largest portion of the wastewater generated at HNPCL would be from cooling and desalination effluent. Of the 5782560 m^3/d of cooling water, 35000 m^3/d will be used for making ash slurry. The rest will be discharged to the Bay of Bengal through an outfall. The impact of each of these sources is given in this section.

a. Cooling Water Disposal

As mentioned above, HNPCL will discharge 5821917 m^3/d of cooling water and desalination effluent into the sea through an outfall. The condenser and other systems at HNPCL's plant will be designed to ensure that the rise in temperature of cooling water is maintained within 5°C of the ambient sea water temperature, as per MoEF's stipulation, to reduce its impact on the Bay of Bengal.

Besides temperature, the other pollutant of concern will be chlorine which will be added to the cooling water to prevent bio-fouling. The chlorine will be added to a final concentration of 1 ppm continuously or 3 ppm as an impact dose from time to time. Free chlorine decays rapidly in water and is converted to chloride ions. Therefore, the residual chlorine in the CW discharge is not expected to exceed 0.5 mg/L. This will be rapidly dispersed and diluted along with the thermal plume. Conversion to chloride ions will reduce the residual chlorine concentration even further.

b. Thermal Plume Modelling

Thermal plume modelling was done to provide improved estimates of the area of impact of the thermal plume resulting from the CW discharge from HNPCL's plant, following on from the initial results reported in the rapid EIA report[6]. The modelling exercise was carried out using the latest version of Cornell Mixing Zone Expert System (CORMIX)[7] version 3.10. The CORMIX modelling gives a fair indication of the area which would be affected by the CW discharge. This improved model allowed a more realistic set of cases to be modelled than was possible with the version used previously. In particular, three additional features were included that had not been modelled during the rapid EIA study.

- The discharge was taken at 45° to the shoreline (towards ESE) as proposed by the design engineers.
- The influence of the detailed shape of the outfall apron was examined in more detail.
- The effect of the increase in salinity (0.2 ppt) due to treated ash water blowdown and desalination effluent was included.

[6]Tata Consultancy Services, 1996, Rapid Environmental Impact Assessment, Environmental Management Plan, Risk Analysis, and Emergency Preparedness Plan for the proposed 2×520 MW Thermal Power Plant near Visakhapatnam.

[7]Jones G R, Nash J D, and Jirka G H, 1996, CORMIX 3: An Expert System for Mixing Zone Analysis and Prediction of Buoyant Surface Discharges, United States Environmental Protection Agency, Washington D C.

To estimate worst-case impacts, a range of ambient conditions were considered for modelling.

Two areas of concern were specifically addressed during this exercise: (i) the area which might be affected by the CW discharge and (ii) the temperature rise likely at the rocky outcrops near Appikonda and Thikkavanipalem. These rocky outcrops were considered important since it was thought possible that they could be within the area affected by the thermal plume, resulting in local heating, which might in turn affect the rich ecosystems observed there.

i. Modelling Approach

The CORMIX model was developed for the analysis, prediction and design of aqueous discharges into diverse water bodies. Major emphasis is on the prediction of plume geometry and dilution characteristics within the receiving water's initial mixing zone, together with prediction of discharge plume behaviour at larger distances. The model represents the effect of the initial discharge momentum and buoyancy, its interaction with the shoreline and sea bed, and the influence of ambient conditions.

The model requires that the receiving water body characteristics be simplified; in particular the depth is assumed constant (although a shallower depth may be used close to the outfall location to simulate near-field boundary interactions) and the flow is assumed uniform, steady, and parallel to the coastline. In selecting the depth value to use, emphasis was given to deriving a depth typical of that likely to be encountered by the plume. It is advisable that depths in the vicinity of the outfall are given priority weighting as these have a strong influence on near-field processes. A base case value of 5 m depth for the receiving water body was used as the mean sea depth to a distance of about 800 m from the shore.

To examine the sensitivity of the thermal plume to the range of currents in the area, three crossflow velocities were considered: 0.1 m/s, 0.25 m/s, and 0.5 m/s. The parameters which were used for this exercise are listed below. Base case parameters given first; alternative values used for sensitivity analysis are shown in parentheses.

- Average water depth :5 m
- Depth near discharge :4 m
- Ambient velocity :0.1 m/s, 0.25 m/s, 0.5 m/s
- Manning's n :0.025
- Ambient density (at 30°C) :1020.08 kg/m^3

(at 30°C and 34 ppt salinity)

- Wind speed :2 m/s
- Discharge angle to crossflow :45°, pointing ESE (approx)
- Bed slope near discharge :1°
- Discharge channel width :20 m - narrow (32 m - wide)
- Discharge channel depth :2 m - narrow (3.5 m - wide)
- CW flow rate :67.75 m^3/s (including all wastewater streams)
- Temperature rise :5 K
- Discharge density (at 35°C and 34.2 ppt salinity) :1017.87 kg/m^3
- Surface heat exchange :0 W/m^2K

ii. Site Details

The HNPCL site lies on the Andhra Pradesh coast between Thikkavanipalem to the west and Appikonda to the east (these two locations are separated by about 6 km, Exhibit 1.1). This part of coastline is relatively straight, and is oriented approximately WSW to ENE. Rocky outcrops exist in the near-shore region to the west of the proposed discharge location, near Thikkavanipalem, and to the east of the discharge near Appikonda.

The bathymetric and hydrographic data used for this study were those contained in the report by Masula Marine Services (MMS), Visakhapatnam[8]. Details of these with regard to local conditions and how they could interact in the CORMIX model are included in Appendix D.

iii. Results

Discharge Plume Features

For the range of conditions modelled, CORMIX predicts that the flow would be dynamically attached to the downstream bank. The penetration into the crossflow would be reduced due to this dynamic attachment. Since the discharge depth would be nearly equal to the depth of the receiving water at the discharge point, the flow would be attached to the bottom in the region close to the outfall. This attachment to the bottom could effectively block off the ambient current and is likely to be the cause of the attachment to the downstream shoreline. Further downstream, the plume would lift off from the bottom as a result of buoyancy.

[8]Masula Marine Services, 1995, Marine Environmental Data off Visakhapatnam (South), Status Report.

CORMIX predicts that during its development, the plume may pass through the following flow regimes:

i. A weakly deflected shoreline attached jet (2-D): The mixing is dominated by the initial momentum, causing relatively constant spreading in the horizontal direction. The deflection by the crossflow is relatively weak. This regime tends to be very short or non-existent in shoreline attached flows.
ii. A strongly deflected shoreline attached jet (2-D): The mixing is dominated by the initial momentum, causing relatively constant spreading in the horizontal direction. The flow is strongly bent over and is dynamically attached to the shoreline. A zone of recirculating effluent exists between the core of the flow and the shoreline. The flow remains attached to the bottom throughout this regime.
iii. A strongly deflected shoreline attached plume: The flow may lift off the bottom as a consequence of buoyancy. The cross-section of the flow becomes distorted due to strong buoyancy-induced lateral spreading.
iv. Far-field buoyant spreading: The plume spreads laterally along the surface while being advected downstream with the ambient current. There is no net change in the centre-line trajectory. The mixing rate is relatively small and the thickness may decrease in this regime. The plume remains attached to the shoreline.
v. Passive ambient diffusion: The ambient turbulence becomes the predominant mixing process in this regime. The plume will grow in both the vertical and horizontal directions at a rate that is dependent on the magnitude of the ambient turbulence. The flow may interact with the bottom in this regime.

In practice, some of these flow regions are found to be of negligible extent under some circumstances. For the cases discussed below, the transition to stage (v), i e, passive ambient diffusion, occurs only in the 0.5 m/s case (occurrence less than 10% of the time).

Plume Profiles and Affected Area

Exhibits 4.17, 4.18, and 4.19 show typical plumes predicted to occur for ambient currents of 0.1 m/s, 0.25 m/s, and 0.5 m/s, respectively, for a mean water depth of 5 m. The plumes formed under SW and NE flow conditions are both indicated on the same figure and are marked with their respective flow directions.

Exhibit 1.1. Map showing HNPCL plant site and access road/rail corridor

Exhibit 4.17. Typical plumes predicted to occur for ambient currents of 0.1 m/s

Exhibit 4.18. Typical plumes predicted to occur for ambient currents of 0.25 m/s

Exhibit 4.19. Typical plumes predicted to occur for ambient currents of 0.5 m/s

The effect of the assumption about the initial flow regime (narrow or wide) is seen to be relatively small for the 0.25 m/s and 0.5 m/s cases. The greatest difference is seen to occur for the crossflow of 0.1 m/s; in this case the narrow outfall produces a discharge which is thrown further offshore initially. The most significant effect of assuming that the near-field flow is dominated by the discharge port length (the "narrow" case) is to produce a higher-momentum discharge, which in turn results in more rapid initial dilution, and a greater offshore penetration of the discharge. In contrast, the assumption of a discharge dominated by the apron width (the "wide" case) produces a lower-momentum discharge which dilutes more slowly and tends to form a more buoyant surface layer.

The effect of discharging the cooling water at a 45° angle towards ESE is to introduce an asymmetry in the resulting plumes. For the months when the flow is to the NE, the plume is relatively narrow, with consequently higher temperatures. For the months when the flow is to the SW, the discharge is directed into the crossflow, and in this case CORMIX predicts increased mixing and lower temperatures (a trend also seen, for example, in the semi-empirical results reviewed in Miller and Brighouse[9]).

The consequence of the above is that the highest plume temperatures occur in the "wide" outfall case when the flow is to the NE.

Exhibit 4.20 shows that the estimated area of influence of the discharge within the 2°C and 1°C temperature rise contours. It is found that in all cases, the initial dilution is rapid, and the area of 2°C rise above the ambient is less than 500 m from the outfall. In this near-field zone, CORMIX predicts that the plume will be attached to the sea bed: near-field temperatures will therefore be strongly influenced by bathymetry, and some caution is required when using these results which are derived with the simplified bathymetry of CORMIX[10].

[9]Miller D S and Brighouse B A, 1984, Thermal Discharges, British Hydrodynamics Research Association.

[10]When comparing these figures with the corresponding figures in the Rapid EIA report, location of the plumes should be moved by 700 m along the shoreline towards the NE as per present engineering design.

Temperature Rise at Rocky Outcrops

The respective increases in temperature at the rocky outcrops to the NE and SW of the discharge location resulting from the CW discharge are tabulated below for the cases modelled.

	Temperature rise (°C)					
	Outcrop near Thikka'palem			Outcrop near Appikonda		
	0.1 m/s	0.25 m/s	0.5 m/s	0.1 m/s	0.25 m/s	0.5 m/s
Wide	<0.3*	<0.4*	0.3	0.7	1.2	0.5
Narrow	<0.4*	0.2	0.3	0.8	0.8	0.5

*For these conditions, the results for a 90° discharge were used, due to the limitation of the model. The rise for angled discharge will be less than this case, as the plume will be directed away from the Thikkavanipalem outcrop.

It may be seen that the influence of the assumed outfall flow pattern (wide or narrow) is not highly significant in influencing the temperature rise at these outcrops. The distance to the NE outcrop from the outfall is about 1900 m, and to the SW outcrop is 4,200 m. The temperature rise at the Appikonda outcrop will therefore be greater than at the Thikkavanipalem outcrop. The absolute rise will, nevertheless, be small (1.2°C at the most).

It should be noted that CORMIX suggests that a buoyant, vertically-stratified plume exists for much of the area of interest. This implies that sea-bed temperatures will remain at or close to ambient temperatures with the warming effect of the discharge being limited typically to the top 2 m to 4 m of the water column.

c. Effluent Disposal

Besides cooling water, 105133 m^3 of effluent are expected to be generated from the plant every day, if there were no recycling or reuse. HNPCL, however, has planned to recycle an average of 20400 m^3/d of decanted water from ash pond into the ash water system. Another 1000 m^3/d of treated effluent will be used as make-up water for bottom ash handling. Thus an average of 81490 m^3/d of effluent will have to be disposed of.

Brine from the desalination plant will be either discharged through the outfall, or can be made available for salt making, if the demand arises. The brine will be only 8% more concentrated than sea water as shown below.

$$\frac{80{,}421\ m^3/d \text{ of sea water}}{74{,}357\ m^3/d \text{ of brine}}$$

$$= 1.082$$

Gorusuvanipalem
Salt pans
Palikeldaddi
Palavalasa
Chepalapalem
Kuru Konda
Nunaparti
Pohtekhapalem
Mud
Gullahipalem
Devi Konda
Visannapeta
Chipurupalle
Pala Konda
Ferry
DISCHARGE
2°C
1°C
ROCKY OUTCROP
Uttarapalem
Korangipalem
Sammangivanipalem
Konda
Venkatapanipalem
Samala Konda
Jalaripeta
10 metres
ROCKY OUTCROP
Tottavanipalem
Dibbapalem
Mutyalammapalem
B A Y O F B E N G
20 metres
0
1km
2km
scale

In the outfall discharge, the resulting increase in the concentration of salts due to this brine and treated ash water blowdown will be less than 0.6%, as shown below:

Stream	Quantity (m^3/h)	Concentration factor
Main CW	239480	1.00
Ash water blowdown	1200	2.00
Brine	3098	1.082

The final concentration factor can be calculated as

$$\frac{(239480\times1.00)+(1200\times2.00)+(3098\times1.082)}{239480+1200+3098}$$

$$= 1.006 \text{ (increase of 0.6\%)}$$

Thus the increase in the salinity of the cooling water discharge from HNPCL due to brine and treated ash water blowdown will be negligible, and is not likely to affect the marine water quality.

HNPCL would use sea water to make ash slurry, which will be dumped in the ash pond. This is not expected to have significant impact on the groundwater in the area, which is already saline. All around the ash pond area there are numerous salt pans which use this saline groundwater for making salt.. Analysis of water collected from a well near the salt pans indicated that the water is saline, and unfit for drinking (Section 3.3.2).

Sea water recirculation without blowdown results in an increase of salt and dissolved solids concentration in the recirculating water. Sea water contains approximately 1300 mg/L $CaSO_4$. The saturation concentration of $CaSO_4.2H_2O$ is approximately 2000 mg/L at 40°C, hence $CaSO_4.2H_2O$ will start precipitating when sea water is concentrated 1.5 times. Furthermore, in contact with ash for extended periods of time, the pH of sea water may increase, which could lead to the precipitation of $CaCO_3$ and $Mg(OH)_2$. Such precipitation may cause plugging in pipelines and may result in fouling of pumps due to build-up of solids on blades and in small gaps. Therefore periodic blowdown of sea water from the ash water recirculation system will be necessary. This blowdown will be discharged into the sea via the cooling water outfall.

The total volume of ash water blowdown will vary depending upon the precipitation and evaporation. During the dry season (March through May), higher evaporation rates are expected, and higher blowdown will be required. During monsoon (October),

rain will dilute ash water and blowdown may not be required. Even during the dry season, the total volume of this blowdown will be very small compared with the cooling water discharge. Therefore the impact of this stream on the marine water quality is expected be negligible.

The effluent from ash pond will contain suspended as well as dissolved solids. If this effluent were discharged untreated into the Bay of Bengal, the water quality would be affected to a limited extent. Nevertheless, HNPCL has planned an appropriate treatment scheme to treat the effluent before discharging directly into the Bay of Bengal through an outfall.

Canteen, sanitary, and colony wastewater is expected to have a BOD of about 250 mg/L. If this wastewater is discharged untreated, it can result in an increase in the BOD of the receiving water, which can deplete the DO in the water body, thereby affecting its beneficial use. Proper treatment of this wastewater is planned by HNPCL to reduce the consequent impacts.

The quantities of wastewater generated from the other sources - coal handling, laboratory, and oily wastewater from floor washing, etc - will be very small. Nevertheless, if these streams are discharged untreated, they can affect the water environment to some extent. Coal handling wastewater will contain suspended solids, which can increase the turbidity of the receiving water body. Oil and grease can result in oily films over receiving water bodies, which can affect the dissolution of oxygen from the atmosphere into the water. Laboratory wastewater may contaminate receiving water(s) with chemicals. Appropriate treatment of these wastewater streams will therefore be necessary before their discharge into the water environment.

d. Possible Impact on Groundwater

According to the soil investigation reported by Black and Veatch International[11], the ash pond area is covered with the clayey soil classified as "CH" or "CL." As per IS-1498, the clayey soil classified as "CH" or "CL" is practically impervious. The coefficient of permeability for the clayey soil in the proposed ash pond area is of the order of 10^{-6} cm/s.

Underneath the ash pond area, a 9 m layer of clayey soil of permeability 7.92×10^{-6} cm/s exists. Below that is an 8 m layer of

[11]Black and Veatch International, 1995, Onshore Subsurface Investigation Interpretive Report.

residual soil of permeability 1.22×10^{-5} cm/s. Below this layer is bedrock, which is impervious (Exhibit 4.21). The composite permeability of the two layers of soil, K', can be calculated by the following formula:

$$K' = (K_1D_1+K_2D_2)/(D_1+D_2)$$

where K_1 is the permeability coefficient of the layer with thickness D_1 and K_2 is the permeability coefficient of the layer with thickness D_2. For the two layers in this case, the composite permeability coefficient is 9.93×10^{-6} cm/s.

The velocity of leachate, V (m/s), can be calculated by multiplying the permeability coefficient (m/s) by the hydraulic gradient, i. The hydraulic gradient for a 25 m hydraulic head and 200 m horizontal distance (approximate distance between the ash pond and the HNPCL boundary) travelled by leachate can be calculated as follows:

i = (hydraulic head)/(horizontal distance travelled by leachate)

= 25 m/200 m

Thus the velocity of groundwater will be

$$(9.93\times10^{-6}\text{ cm/s})\times(10^{-2}\text{ m/cm})\times(25/200) = 12.41\times10^{-9}\text{ m/s}$$

Although the difference of the water table is expected to be about 18 m, a conservative estimate of 25 m pressure head was assumed for worst case impact. Even with this pressure head, the time required for the leachate to traverse the 200 m distance to the plant boundary will be over 500 years. Thus, for all practical purposes, the leachates from the ash pond will be retained in the area and are unlikely to pollute groundwater.

To determine the direction of groundwater flow in the ash pond area, TCS conducted a leach pit test. To assess the impact of ash pond leachates on the groundwater in the area, TCS conducted a test on fly ash collected from the Visakhapatnam Steel Plant (VSP), since VSP also uses the same coal which HNPCL plans to use. In addition, a bench-scale column test was performed in the laboratory for evaluation of adsorption and dispersion coefficients of the clay particles in the proposed ash pond area. Details of these tests are given in Appendix E. The following salient observations were made from these tests:

- The pit tests in the ash pond area indicated that the direction of groundwater flow was towards the centre of the mud flat area rather than towards the villages in N, NE and NW directions.
- Leachate tests indicated that the amounts of heavy metals leaching into recirculation water from the fly ash would be very low.
- The permeability of the clay in the ash pond area is very low (to the order of 10^{-4} to 10^{-5} cm/s). These values were similar to those reported by Black & Veatch International[10].

The report by Black and Veatch International further indicates that the bedrock below the HNPCL site slopes from NE towards SW, i e, towards the Bay of Bengal. Therefore, even if any leachates reach the groundwater, they would flow towards the sea rather than towards the inhabited areas on the land side.

Considering the results of the tests conducted by TCS and the information presented in this section, the impact of HNPCL's wastewater discharges on the groundwater of the area is expected to be insignificant.

4.2.4 Land Environment

In the absence environmental protection measures, the land environment at and surrounding the proposed HNPCL plant could be affected by

- deposition of SPM and other gaseous emissions released from stacks
- dumping of solid wastes and sludge generated from different sources

Major pollutants which may be emitted from the stacks are SO_2 and SPM. Deposition of these on the soil can affect the soil pH and its nutritional status. Wastewater from the plant, if discharged untreated on land, can impair the soil quality by adding a large quantity of organic load (biodegradable and non-biodegradable), alteration of pH, bulk density, permeability, water-holding capacity, and nutrient status.

The major solid waste expected from the HNPCL plant will be ash. The maximum quantities of ash which could be generated based on 36% ash and 670 T/h coal consumption are listed below.

Exhibit 4.21. Profile of ash pond at HNPCL's plant site

Type of ash	Ash production rate (T/h)
Bottom ash	60
Economiser ash	10
Fly ash	171
Total	241

The chemical composition of fly ash depends largely on the geographic and geologic factors of coal. Fly ash primarily contains silicates, aluminium oxide, iron oxide, and calcium oxide (95-99%). The typical composition of fly ash is given below.

Parameter	% Composition	
	Range	Typical value
SiO_2	57.6 - 63.3	60.8
Al_2O_3	27.5 - 32.2	29.4
Fe_2O_3	3.8 - 6.3	4.3
CaO	0.9 - 1.6	0.9
MgO	0.3 - 0.8	0.8
Na_2O	0.3 - 0.5	0.5
K_2O	0.5 - 0.7	0.6
Mn_2O_4	<0.1	<0.1
P_2O_5	0.4 - 0.6	0.6
TiO_2	1.6 - 1.8	1.8
SO_3	<0.1 - 0.7	<0.1

Source: Mahanadi Coalfields Limited

Typical trace metal analysis of VSP fly ash is as follows[12]:

As: 30.5 ppm	Ba: 362 ppm	Bi: 100 ppm	Ce: 82.1 ppm
Co: 12.1 ppm	Cr: 6.1 ppm	Cs: 0.3 ppm	Cu: 96.7 ppm
Dy: 8.1 ppm	Er: 3.0 ppm	Eu: 3.6 ppm	Ga: 47.5 ppm
Gd: 14.6 ppm	Hf: 15.9 ppm	Hg: 0.4 ppm	La: 74.2 ppm
Lu: 0.5 ppm	Nb: 50.8 ppm	Nd: 56.9 ppm	Ni: 12.2 ppm
Pb: 30.6 ppm	Tr: 16.0 ppm	Rb: 57.2 ppm	Rn: 100 ppm
Sc: 20.9 ppm	Sm: 10.9 ppm	Sr: 169 ppm	Ta: 3.9 ppm
Th: 43.1 ppm	U: 8.2 ppm	V: 57.1 ppm	Y: 71.8 ppm
Yb: 4.1 ppm	Zn: 201 ppm	Zr: 2184 ppm	

Disposal of ash will be to the ash pond. A 360 ha (890 acres) area has been earmarked by HNPCL for the ash pond.

[12]Viswanath, K and Bhagavan, G V G K, 1994, A Study on the Characterisation of Fly Ash as Part of Waste Management, in Man and Environment, Allied Publishers, New Delhi.

The other solid wastes expected to be generated at HNPCL plant will be as follows:

Type of waste	Quantity (T/d)
Industrial wastewater treatment sludge	22
Sewage treatment sludge	
(a) Plant area	2.5
(b) Colony	14
Domestic solid waste from plant/colony	1.0

These sludges from the wastewater treatment plant and the sewage treatment plant will have to be thickened and dewatered before final disposal. The domestic waste could be used in green-belt development as manure after proper treatment.

4.2.5 Biological Environment

a. Terrestrial Ecology

Terrestrial plant species could be subjected to the emission from thermal power plant containing oxides of sulphur, nitrogen, CO, HC. Nevertheless, if the prescribed standards for emission through recommended stack height is followed, the emissions are not likely to cause any significant damage.

Among the terrestrial fauna, none except yellow monitor lizard and king cobra in reptiles is listed under Schedules I and II of IWPA (1972, amended till 1991). Nevertheless, these species were found only in the buffer zone, and their numbers were low. Among mammals, jungle cat, jackal, Bengal fox, small Indian civet, and palm civet are enlisted under Part II of Schedule II of IWPA. None of these terrestrial species could be termed rare from the distributional record in India. No specific breeding-population site could be identified in the study area during any of the four season. No wildlife sanctuary is located within the study area and prospect of establishing such a sanctuary is unlikely. The ash pond of TPP is unlikely to have any impact on terrestrial ecology, since it will be located mostly on mud flat area. Since the major habitat for terrestrial fauna fall under the buffer zone rather than the core zone, no significant impact could be foreseen due to the proposed power plant.

Although the impact of HNPCL's project on terrestrial ecology is not expected to be significant, the proposed environmental management plan will have to ensure (i) controlled emissions of air

pollutants (within permissible limits), (ii) adequate stack height (iii) adequate safety while disposing of ash and monitoring of ash pond, (iv) appropriate greenbelt around township and plant area, (v) proper disposal of solid waste and (vi) annual environmental audit.

b. Aquatic Ecology

The survey around the HNPCL plant site indicated that the fish catches off the coast near the site are poor. Most of the fishing activity is northeast of Visakhapatnam.

According to the modelling exercise carried out to estimate the area which will be affected by HNPCL's cooling water discharge, the temperature rise will be 2°C of the ambient at about 0.5 km from the outfall location, and 1°C in about 2.5 km. Thus a very small area will be affected. At the rocky outcrops near Thikkavanipalem and Appikonda, the two habitats of concern near the HNPCL site, the temperature rise will be less than 0.4°C and 1.2°C, respectively. This temperature rise is very low from an ecological point of view, and its impact on the marine flora and fauna will be insignificant.

A number of industries are presently located along the coast. These include Coromandel Fertiliser Factory, Hindustan Petroleum Corporation, Hindustan Ship Building Yard, Hindustan Polymers, Hindustan Zinc, Bharat Heavy Plates and Vessels, Visakhapatnam Steel Plant, etc. Besides these, there is a major port at Visakhapatnam, and a minor one is proposed to come up at Mutyalammapalem. So far, no appreciable changes have been noticed due to these industrial activities in the coastal waters.

HNPCL's proposed plant is unlikely to affect the migratory route of birds in view of large air space used by the migrant species, and their continued use of the same route in spite of extensive industrialisation of the Visakhapatnam area during the past few years.

4.2.6 Socio-economic Environment

a. Power Supply

The main reasons for setting up the power plant near Visakhapatnam are to (i) augment the power generation capacity, hence reduce the deficit between power demand and supply in Andhra Pradesh in the medium term, and (ii) to install thermal capacity

into a grid predominantly served by hydroelectric schemes, as a back-up in case of failure of the monsoon. The thermal/hydro mix currently stands at 40/60, compared to a national average of 60/40.

Acute power shortages have existed in Andhra Pradesh from 1986-87 till date. According to an estimate of the 15th Electric Power Survey Committee (EPSC), the gap between demand and supply was about 915 MW during 1993-94. The cuts in power during 1986-87 to 1994-95 were of the order of 40-60%. The EPSC has predicted the demand and peak availability of power till the year 2001-02. This is shown in the table below.

Year	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
Demand (MW)	4915	5407	5947	6542	7196	7916	8708	9578	10536
Peak available	4000	4200	4210	4878	5280	6474	7748	8325	8707

Source : Report of the High Level Committee, APSEB, April, 1995

From the above table it can be seen that demand in the year 2001-02 would be about 10500 MW. The corresponding installed capacity required to meet the peak and average demand would be about 15000 MW. The additional supply due to the HNPCL plant will partly meet the demand and improve the stability of the APSEB grid system.

b. Impact at Local Level

Skilled as well as unskilled manpower will be required for the operation of the plant. It is estimated that about 1000 persons will be working at the plant during the operational phase. In addition, indirect employment is expected to be generated for many more people. Thus employment opportunities will be created in the region.

Once the HNPCL plant becomes functional, certain service establishments such as repair shops (for scooters, cars, trucks, etc) petrol pumps, typing and photocopying shops, long distance telephone and fax cabins, barber shops, and small restaurants are expected to come up in and around the plant to cater to the needs of the HNPCL employees. This secondary growth will create self-employment opportunities for the local villagers and thus increase their income level.

The secondary growth resulting from the setting up of the HNPCL plant would trigger improvements in the basic amenities, particularly transportation, telecommunication, electricity, educational and medical facilities, etc. This would improve the quality of the life of the local people.

As HNPCL employees would spend more on goods and services available in the area, demand would be created for production of such goods and provision of services. This would give a push to the local enterprises for providing the same which would lead to the creation of more jobs, hence more income. Thus, HNPCL's plant would have a multiplier effect on the local economy.

The lifestyle of the employees of HNPCL is expected to be different from that of the villagers in the surrounding area. This difference in lifestyle can have both positive and negative impacts. A positive impact would be a desire for improvement in their lifestyle, which would prompt them to send their children to schools and insist on higher education which would lead to better employment opportunities for them in the organised sector. The negative impacts could be social tension generated due to inequality of incomes between villagers and HNPCL employees. These negative feelings, however, will start diminishing once the advantages of the establishment of the plant starts being felt.

4.3 Concluding Remarks

The impacts discussed in this chapter are summarised in the impact network diagrams presented in Exhibits 4.22 and 4.23. The impacts of the various activities during the construction phase on the receiving environmental components are shown in Exhibit 4.22, while those during the operational phase are shown in Exhibit 4.23.

The anticipated impacts, as discussed in this chapter, necessitate the formulation and implementation of a comprehensive EMP, so that the environmental quality in the area is not only preserved but enhanced. This detailed EMP, comprising HNPCL's environmental protection strategies and enhancements suggested by TCS, is presented in the following chapter.

Exhibit 4.22. Impact network diagram for construction phase

Exhibit 4.23. Impact network diagram for operational phase

CHAPTER 5

ENVIRONMENTAL MANAGEMENT PLAN

The EMP presented in this chapter covers the environmental management strategies proposed by HNPCL and enhancements suggested by TCS where appropriate. The EMP will reduce the adverse environmental impacts and help HNPCL in complying with the environmental standards and regulations of the CPCB and APPCB. This chapter also outlines specific pollution control measures and technologies for the abatement of air, water, and noise pollution, and solid waste management. A greenbelt development plan, inside and surrounding the plant, is also presented.

The EMP presented in the rapid EIA report was based on HNPCL's compliance proposals to the various conditions laid down by APPCB in their consent to establish. APPCB has since accepted these compliance proposals.

As discussed in Chapter 4, environmental impacts during the construction phase will be mostly temporary and localised. Air quality modelling of impact of construction traffic showed that impact potential during the construction phase would be negligible. Hence no further abatement measures are warranted for controlling air pollution due to vehicular exhaust. Dust control measures, however, will be necessary since dust will rise due to vehicular movement. Water sprays will be used at appropriate locations to mitigate this impact.

The mud flat (proposed ash pond site) is a low-lying area. Stormwater draining into the area during rainy season will be prevented once the bund is constructed for the ash pond. A stormwater drainage channel will therefore be provided around the bund to prevent flooding upstream of the ash pond. Drainage arrangement will be provided for leading this water into the sea.

During construction, HNPCL will provide temporary toilets for the construction workers. Sewage from these toilets will be collected and transported to temporary septic tanks. Effluent from the septic tanks could be used for greenbelt irrigation.

HNPCL has planned to keep the cutting of trees at site to a minimum during the construction phase. The construction of civil structures will result in limited encroachment of cashew and

casuarina plantations on the plant site. This reduction in the green cover, however, will be negligible compared with the greenbelt which HNPCL will develop on the land it acquires. Details of the greenbelt development plan are given later in this chapter.

5.1 Air Pollution Control

5.1.1 Fugitive Emissions

Coal will be transported in bottom-discharge wagons from the mines to the site. Unloading and handling of coal in the storage area and inside the power plant will be carried out in a controlled atmosphere as given below.

Coal will be unloaded into two track hoppers by a merry-go-round system. Water spraying arrangement will be in place at hoppers to suppress dust emission during unloading. Coal will then be transferred to the stockyard by closed conveyor system. Use of high capacity conveyor at low speed rather than low capacity conveyor at high speed will be used to avoid fugitive emission of dust. Use of chute with necessary stone-box or similar arrangement will be provided to prevent straight drop. In the stockyard, the height of the stacker boom would be kept to a minimum above the coal stockpile to minimise the drop height. In addition, the stacker/reclaimer will be fitted with a water spray at the discharge head to the coal stockpile.

The coal stockpile area will be protected by a series of water sprays mounted on masts, arranged in rows alongside the stockpile. The stockpile surface will be wetted in rotation to prevent escape of air-blown dust. At the tripper house, each of the trippers will have an insertable filter type (dust filter) dust control unit, to be fitted into the discharge chute to prevent escape of dust.

At each transfer tower, a conveyor discharge hood will be provided with dust filter to catch dust emission; the collected dust will be returned to the hopper below. All conveyors will be covered to prevent the escape of dust during transfer.

Coal crusher building will be provided with a dust extraction system to eliminate fugitive coal dust emissions.

5.1.2 Stack Emissions

The major pollutants from the stacks of HNPCL's TPP will be SO_2 and SPM, besides relatively smaller amounts NO_x and CO (Chapter 4). As stipulated by MoEF, HNPCL will build a 275 m tall stack for effective dilution and dispersion of pollutants and will use washed, low-sulphur Indian coal (0.6-0.8% S) for its TPP. Two electrostatic precipitators (ESPs), one for each unit, will be installed for the removal of particulates from the steam generator flue gas to achieve a guaranteed outlet emission of 90 mg/Nm^3 over the full range of design coal and 115 mg/Nm^3 (at 12% CO_2, dry) with one field out of service. This would satisfy the standard stipulated by APPCB. Design basis of the ESPs is given below.

Parameter	Unit	Design basis
Gas volume (for one boiler)	Nm^3/h	1988.8×10^3 (wet) 1795.1×10^3 (dry)
Gas temperature (inlet)	°C	146
Inlet dust concentration	g/Nm^3	50.8 (wet) 56.3 (dry)
Outlet dust concentration	mg/Nm^3	90 (dry) 115 (dry), in case one field is out of service

Air quality modelling indicated that ambient concentrations of all pollutants (SPM, SO_2, NO_x, CO) would remain well within limits for industrial areas as per CPCB and APPCB standards, even under the worst case scenario. Hence, no additional abatement measures other than those already proposed are warranted.

Apart from the boiler stack emissions, pollutants will also be emitted, albeit occasionally, from the auxiliary boiler stack and the DG set stack. The height of the auxiliary boiler stack will be raised according to the following formula (given by CPCB/ APPCB):

$$H = 14 \times Q^{0.3}$$

where

H = height of stack (m)
Q = flow rate of SO_2 (kg/h)

The auxiliary boiler will use LFO as the fuel at a maximum rate of 2.7 T/h. Since LFO may contain a maximum of 1.8% sulphur, the maximum SO_2 discharge can be

$$2.7\ T/h \times 1000\ kg/T \times 1.8\ kgS/100\ kgLFO \times 64\ kgSO_2/32\ kgS$$

$$= 97.2\ kgSO_2/h$$

$$\therefore H = 14 \times 97.2^{0.3} = 55.3\ m$$

DG set stack will be raised according to the following formula (given by CPCB/APPCB):

$$H = h + 0.2 \times (kVA)^{0.5}$$

where

H	=	total height of stack (m)
h	=	height (up to roof top) of building (m) where DG set is installed
kVA	=	total generator capacity (kVA)

The generator capacity will be 776 kVA. Therefore the height to which the stack will have to be raised above the roof of the building housing the DG set will be at least 5.6 m, as follows:

$$H = 0.2 \times (776)^{0.5} = 5.6\ m$$

5.2 Noise Pollution Control

Some sections inside the HNPCL plant will have noisy operations; therefore HNPCL will mitigate the exposure of workers to relatively high noise levels with appropriate measures. Noise from major equipment at the plant will not exceed 85 dBA at 1 m from the equipment at a height of 1.2 m. Noise and its consequent adverse impacts will be reduced by:

- Stopping leaks from steam lines, compressed air lines, and high pressure equipment
- Providing acoustic lagging and silencers at various locations to reduce rattling and vibration
- Providing noise-proof cabins (control rooms) for operators wherever remote control of noisy equipment is possible
- Providing ear plugs or ear muffs to workers in high noise areas
- Encasing noise-generating equipment wherever possible

With the above noise abatement measures, it is expected that the noise level inside the HNPCL plant area will be maintained as per OSHA standards given in Chapter 4. HNPCL, however, has assessed that the noise level emitted by the power station at any time in continuous mode of operation, would not exceed the following limits:

Location	Noise level
At the site boundary	75 dB(A) during day time 65 dB(A) during night time
At the nearest residence (inside HNPCL plant boundary)	55 dB(A) during day time 45 dB(A) during night time

Thus, HNPCL will comply with the limit stipulated by MoEF for ambient noise levels in industrial areas.

5.3 Water Pollution Control

Different sources of wastewater and their major pollutants have already been discussed in Chapter 4. This section details the wastewater management plan of HNPCL.

5.3.1 Cooling Water

As stated earlier, HNPCL proposes to use once-through cooling system using sea water from the Bay of Bengal. Apart from small a amount (35000 m^3/d) of cooling water (CW) which would be used to make ash slurry, the rest (5747560 m^3/d) will be discharged into the Bay of Bengal through an outfall.

In addition to CW, other wastewater streams will also be discharged through the outfall. The hourly flow rates of all streams (per each 520 MW unit) and their respective temperature differences (with respect to the ambient sea temperature) are given in the following table:

Source	Flow rate (m^3/h)	Temperature difference (°C)
Condenser	116140	5
Heat exchanger	3600	3.84
Desalination brine	1549	7
Ash water discharge	600	0
Wastewater	6	0

The resultant temperature of these streams at the outfall discharge will be

$$\frac{116140\times5 + 3600\times3.84 + 1549\times7 + 600\times0 + 6\times0}{116140+3600+1549+600+6}$$

$$= 4.966 \text{ (less than 5°C)}$$

It will be ensured that the temperature rise in cooling water will be maintained within 5°C of the ambient sea water temperature under all normal operational conditions.

The outfall discharge point will be located below the low tide level; thus it will always be completely submerged. The outfall will be via submarine pipe construction. Final outfall design will be decided during the detailed design stage, after detailed bathymetric survey and hydraulic modelling.

The intake is expected to be located approximately 500-600 m offshore from the coastline. The intake and outfall locations will be planned in such a way that recirculation of outfall water into the intake will be avoided. The final intake and outfall locations will be reconfirmed after detailed mathematical modelling and bathymetry survey.

Cooling water will meet the minimum national standards (MINAS) for discharge into the sea, as given below.

Parameter	Maximum limiting concentration
pH	6.5-8.5
Temperature	Not more than 5°C higher than the intake water temperature
Free available chlorine	Less than 0.5 mg/L

All of the above parameters will be regularly monitored to ensure their limits in the cooling water discharge.

5.3.2 Ash Water

Ash water recirculation (when sea water is used) without blowdown results in an increase of salt and dissolved solids concentration in the recirculating water. Therefore periodic blowdown of sea water from the ash water recirculation system will be necessary.

The conductivity (which is directly proportional to salt concentration) of the ash water will be checked continuously. The conductivity of normal sea water is approximately 53,200 μSiemens/cm. If the conductivity reaches 79,800 μSiemens/cm, water recirculation will be stopped and the water will be led to an effluent treatment plant. Sea water would then be drawn into the recirculation system from the condenser discharge for make up.

The effluent treatment plant is being designed to treat a maximum of 50% blowdown (28,800 m^3/d) which may be required in the worst case. The plant will have the following components:

- Ash water recirculating sump
- Ash water recirculating pump
- pH adjustment basin with mixer
- Sedimentaion basin (clarifier) with sludge scrapers
- Coagulant aid feed equipment

Effluent from the ash pond will be pumped to the pH adjustment basin, where effluent pH will be adjusted to 6.5-8.5. Caustic soda (45% NaOH) and hydrochloric acid (35% HCl) will be used for pH adjustment. Effluent from the pH adjustment basin will be pumped to the flocculation/sedimentation basin where coagulant (polymer) will be added for precipitating the total suspended solids (TSS) from the effluent. Necessary dosing equipment (for coagulant) will be provided with the system to bring TSS concentration in the clarified water down to 30 mg/L. The treatment system will achieve quality better than the relevant CPCB standards, as follows:

Parameter	HNPCL design target	CPCB standard
pH	6.5-8.5	6.5-8.5
Total suspended solids	30	100
Oil and grease	10	20

A schematic of the treatment system is shown in Exhibit 5.1.

The sludge from the treatment plant will be recycled to the ash pond.

5.3.3 Desalination Unit Wastewater

Wastewater from the desalination unit will be discharged into the Bay of Bengal via the cooling water outfall. Provision will

also be made for offering the brine to the local salt farmers if there is interest.

5.3.4 Industrial Effluent

Industrial effluent will comprise unit (oily) wastewater, boiler blowdown and cleaning wastewater, laboratory wastewater, and demineralisation (DM) plant wastewater.

Oily wastewater from plant drains, transformers, and oil tank areas will be collected and directed to the oil-water separation systems. Water from the oil-water separation systems will be led to wastewater collecting pond/storage basin. The oil thus collected will be incinerated in the boiler. It is expected that oil to be used in transformers will be free of poly-chlorinated biphenyls (PCBs). Nevertheless, as prescribed by APPCB, any oil containing PCBs will be collected separately, stored at site, and disposed of in a secured landfill.

Boiler blowdown and cleaning wastewater, DM plant effluent, and laboratory wastewater will also be directed to the wastewater collecting pond/storage basin and channelled to the industrial effluent treatment system.

The wastewater storage basin will be divided into three compartments. Regular wastewaters will be collected in one component (1000 m^3 volume) while irregular wastewater will be collected in two separate compartments (4000 m^3 total volume). Each compartment of the wastewater storage basin will be equipped with air blowers and diffusers for agitation and aeration.

The industrial effluent treatment system will consist of pH adjustment (neutralisation) tank, aeration tank, and clarifier. The pH adjustment tank will be designed for a retention time of 5 min. The tank will be equipped with a corrosion-resistant liner or coating, mechanical mixer, and a dosing tank for pH regulation. NaOH (45%) and HCl (35%) will be used for pH adjustment. The aeration tank will be equipped with a corrosion-resistant liner or coating, blower, and diffuser. The clarifier will be a slurry-recirculation type, equipped with a scraper. The retention time in the clarifier will be 1.5-2.5 h. Ferric sulphate (11%) and polymer will be used as coagulant/flocculant in the clarifier. The dosing systems for coagulant and other chemicals will include two solution tanks (about 2 m^3 each) with mixers and two dosing pumps each. Treated water from the clarifier will be channelled to a unit discharge pond, equipped with an air or mechanical agitator. The unit discharge pond will be designed for a 1-2 h maximum dis-

Exhibit 5.1. Ash water management at HNPCL's plant

charge flow rate. The majority of this discharge (1000 m^3/d) from the pond will be utilised for bottom ash handling; the rest (282 m^3/d) will be pumped to the sea via the CW outfall.

A schematic diagram of the industrial effluent treatment system is given in Exhibit 5.2.

The industrial effluent treatment plant will be designed for continuous treatment of regular wastewater and treatment of irregular wastewater within 15 days. The wastewater treatment system will be designed for 24 hourly operation. The capacity of the treatment system will be about 70 m^3/h.

Treated water, before being discharged to the cooling water outfall, will have the following characteristics:

Parameter	Quality* of HNPCL's treated effluent	CPCB Standard (land discharge for irrigation)
pH (pH units)	6-9	5.5-9.0
COD	<100	-
BOD	<30	100
TSS	<70	200
Oil and Grease	<10	10

*Design target
(All units are in mg/L unless otherwise specified)

The effluent quality will meet standards for land application for irrigation. It is therefore recommended that this water be used for irrigation of the greenbelt at HNPCL.

Sludge from the clarifier will be thickened and dewatered before final disposal to the ash pond. The clarifier underflow will be pumped directly to the thickener without the use of the sludge pump. All sludge piping will be equipped with flushing capability. A sludge conveyor will be located under the sludge dehydrator.

The piping used in the industrial wastewater treatment system will be as follows:

System	Piping material
Chemical wastewater system	Polypropylene-lined carbon steel and FRP
Sludge waste	Carbon steel
Reuse water	Carbon steel
Oily wastewater	Carbon steel
Coagulant and hypochlorite	Polypropylene-lined carbon steel
Compressed air	Carbon steel
Coagulant aid	Stainless steel

Effluent treatment plant tanks will be made of steel or concrete which are impervious. Areas where effluent could possibly spill from the effluent treatment systems such as chemical tanks and pumps will be paved by concrete to prevent groundwater pollution.

5.3.5 Domestic Wastewater

As per Indian standards, in unsewered areas, every house should have arrangements for treating its sewage in septic tank(s), effluent from which should be given secondary treatment either in a biological filter, upflow anaerobic filter, on land, or in a sub-surface disposal system. Considering the sub-soil conditions at the HNPCL site, groundwater level, and maintenance cost, HNPCL will have a septic tank and upflow anaerobic filter system.

The amount of domestic wastewater (from plant area as well as colony) will be about 500 m^3/d, and will have a BOD of about 250 mg/L. After treatment through a septic tank and upflow anaerobic filter, the BOD will reduce by about 70%. Thus the BOD of the treated effluent will be about 75 mg/L, i e, below the 100 mg/L limit for land application. This treated effluent will be used for irrigating the greenbelt, coal stock cooling, dust suppression, etc. The sludge from this system will also be used for greenbelt development, as a soil conditioner/manure. A schematic of the domestic wastewater treatment system is given in Exhibit 5.3.

5.3.6 Stormwater

Stormwater runoff from the coal yard will be collected by gravity flow through concrete open ditch to a sedimentation tank. Clarified water will be reused for dust suppression. The sedimentation tank will be cleaned when needed, at least once in a year by wheel loader after the monsoon season. Sludge from the sedimentation tank will be transported by dump truck and disposed of into the ash pond.

Stormwater from power plant area will be led to a stormwater reservoir by gravity flow through concrete pipes with manholes and reused for coal handling, ash handling, and greenbelt irrigation.

A schematic diagram of stormwater management from the coal yard and the plant area is given in Exhibit 5.4.

At the ash disposal area, stormwater will be led to an ash sedimentation pit and will be reused for making ash slurry.

Exhibit 5.2. Industrial effluent treatment at HNPCL's plant

Exhibit 5.3. Domestic wastewater treatment at HNPCL's plant

Exhibit 5.4. Stormwater management at HNPCL's plant

Stormwater in the area which currently drains into the mud flat will be prevented once the ash bund is built. Therefore, a channel will be provided around the ash pond for the water to drain into the Bay of Bengal.

5.4 Solid Waste Management

Apart from ash, three other categories of solid wastes are expected to be generated from the proposed project: (i) ETP sludge, (ii) sludge from sewage treatment plant, and (iii) solid wastes from plant and colony. The management plan for the first two have been discussed earlier. The domestic waste will have to be disposed of in a suitable landfill. Waste oil (only PCB-free oil) from the oil-water separator will be burnt in boiler. Sludge from boiler cleaning will be mixed with coal and burnt in the boilers. The following section discusses the collection, handling and disposal of bottom ash, economiser ash, and fly ash.

5.4.1 Ash Management Plan

The ash handling system will consist of the following major units:

- Bottom ash system
- Fly ash system
- Ash slurry system and
- Ash water system

Details of all four systems are given in this section. A schematic diagram showing ash management at HNPCL's plant is given in Exhibit 5.5 (Drawing No 54126-1104 of MHI).

a. Bottom Ash System

Bottom ash (BA) system would collect, quench, crush and transport the bottom ash from the furnace hoppers to the ash slurry sump for subsequent pumping to the ash pond. The system will have the following major units for continuous removal rate of 44 T/h :

- BA hopper with submerged chain conveyor, one per unit
- BA crushers (clinker grinders), one per unit
- BA conveyors
- BA dewatering bin, one per unit

The BA will be removed from the furnace hopper by means of a submerged chain conveyor (SCC). The discharge from the SCC will be taken to the BA conveyors via a clinker grinder. The BA conveyors will transfer the BA to a 1000 m^3 dewatering bin from which the BA will be discharged to lorry for sales or to ash slurry sump. In case of failure of the SCC system, the complete trough assembly could be removed, with the unit still on load, and a stand by hopper put in place. The standby hopper, which will be common to both units, will be designed to contain the ash produced with the worst coals during the time taken to repair the SCC (nominally 8 hours).

b. Fly Ash System

The fly ash system will collect fly ash in a dry form from ESP hoppers and transfer those to the fly ash storage silo via a pressured pneumatic conveyor (details given in Sub-section "f" later in this Section). At the silo discharge point, facilities for loading the ash into open trucks or closed trucks without causing any dust nuisance will provided. This ash will be provided to downstream users (details given later in this chapter). The fly ash remaining after fulfilling ash users' requirements will be mixed with water to form a wet slurry which will be fed to the ash slurry sump by gravity.

The ash from the economiser hoppers, the air heater hopper and the flue gas duct hopper will be transferred to the cinder ash silo (12 h storage capacity) via a pressurised pneumatic conveyor. The fly ash during start-up, i e, when oil is also used along with coal, will also be led to the cinder silo since it is not appropriate for downstream ash users. The discharge from the cinder ash silo will be mixed with water and discharge will be mixed with water and dumped to the ash slurry sump by gravity.

The fly ash system will have the following major components[1] :

- Transfer air blowers — 3 × 50% per unit
- Transfer air dryers — 3 × 50% per unit
- Transfer air receiver — 1 × 100% per unit
- Fly Ash Storage Silos — 2 × 750 m^3 per unit
- Cinder Ash Silos — 1 × 500 m^3 per unit
- Silo bag filters — 150 m^2 per silo
- Fluidising air blowers — 3 × 30 m^3/min per unit
- Fluidising air heaters — 3 × 30 m^3/min @>120°C per unit

[1] The specifications may undergo minor changes during detailed engineering, but these changes will not affect the total capacity of ash to be handled nor increse pollution potential in any way.

Exhibit 5.5. Ash management at HNPCL's plant

- Dry fly ash loading points — 2 × 150 T/h per unit
- Fly ash conditioners — 2 × 100 T/h per unit
- Slurrifiers — 3 × 75 T/h per unit (1 per silo)
- Dust transfer pipework — Carbon steel, lined at wear points
- Slurry pipework to Sump — Carbon steel, basalt-lined at wear points

The fly ash collected in each of the hoppers (precipitator, economiser, air heater or ductwork) will be transferred to storage silos by an automatic system as described below:

The system will put air into the hopper outlet and the dust intake valve will be opened to allow dust into the air stream by gravity. The dust will then be blown to the storage silos via a wear-resistant dust pipeline. Once the hopper is emptied, the system will shut the dust intake valve and put air into the next hopper in the cycle. If the dust transfer pipeline back pressure exceeds a set level, the dust intake valve will be closed to allow the cleaning of the pipe; once the back pressure is below another (lower) set level the hopper emptying process will recommence.

Fly ash drawn from the hoppers will be blown through the transfer pipes to the fly ash storage silos. The pipe network will be equipped with diverter valves to enable the entire fly ash of a unit to be diverted to either of the fly ash storage silos for that unit or distributed between the two. If fly ash quality is low, the fly ash can alternately be blown into the cinder ash silo. Both the fly ash and cinder ash storage silos will be designed for 12 h storage capacity for each unit and will be equipped with reverse jet bag filters to enable transfer of maximum air volume and fluidising air pads around the two outlets per silo.

Each of the four fly ash storage silos will have a fully air fluidised base with the provision of 150 T/h of dry dust unloading point in addition to a dust conditioner and a slurrifier. The conditioners will be capable of discharging conditioned dust, of moisture content up to 20% (w/w), into trucks at a rate of up to 100 T/h. The slurrifiers will be connect to the ash slurry sump and will be designed to empty the fly ash silo within a 12 h period. The outlet of the dry dust unloading system will be equipped with a dry fly ash road tanker loading facility along with telescopic loading spout and full dust control measures. A truck weigh bridge will be provided for each unit.

c. Ash Slurry System

The ash slurry system will provide temporary storage of ash slurry and transport the ash slurry from the ash slurry pit to the ash

disposal area. The ash slurry system will have the following major components:

- Ash slurry sump : 1 per unit
- Ash slurry pump sets : 2 per unit
- Ash disposal pipework : Basalt-lined carbon steel

The ash slurry system will collect the slurries from the bottom ash system, fly ash system and the cinder ash system and will pump the slurry from the ash slurry pit to the ash disposal area. The ash slurry pumps (4 × 50%) will be designed to discharge the total daily ash generation via the ash slurry pipework to the ash lagoon within a 12 h period.

d. Ash Water System

The ash water system will recycle partially filtered neutralised water from the ash ponds back to the ash handling system. The ash water system will have the following major components :

- Ash water treatment plant
- Ash water return pumps — 2 × 100% for the station
- Ash handling water storage tank
- Ash system booster pumps for the station, stainless steel — 3 × 50% HP, 3 × 50% LP
- Dust conditioner pumps — 2 × 100% per unit
- Sealing water pumps — 2 × 100%
- Ash water make-up pumps — 2 × 100%
- Ash water pipework — Epoxy coated carbon steel

The ash water return system will collect part of the decanted water from the ash pond settling chamber and recycle this to the ash slurry pit, the fly ash conditioners and the furnace hoppers. Recirculation of ash pond water will be done as long as concentration of salts and dissolved solids in it remains within the allowable range to avoid precipitation. When the concentration exceeds the limit, makeup/blow down of sea water will be done.

Ash water booster pumps, 3 × 50% LP and 3 × 50% HP, will recycle water from the ash water settling chamber to the BA hopper/ash slurry sump and ash silo slurrifier, respectively. Dust conditioner pumps (2 × 100% per unit) will recycle the decanted water to the dust conditioner. Ash water booster pumps (2 × 100%) will recycle water to the BA hopper system. The sealing water pumps will provide seal water from the potable water system to all pumps handling slurry.

e. Ash Pond

The on-site ash disposal pond will be constructed in phases over a 30 year period. The first phase will be completed with the power station construction period and will accommodate 10 years of ash generation. The ash pond will be made impervious to avoid groundwater contamination. Escape of dust from the ash pond will be minimised by (a) maintaining a water level of 15 cm above the ash stored in the ash pond and (b) greenbelt surrounding the pond. The total area of the entire ash pond will be about 360 ha (about 890 acres).

According to the soil investigation reported by Black and Veatch International[2], the ash pond area is covered with the clayey soil which is practically impervious. The coefficient of permeability for the clayey soil in the proposed ash pond area is of the order of 10^{-6} cm/s. HNPCL proposes to build the dyke of the ash pond from clayey soil in the first phase to meet the requirement of the first 10 years of operation. The bottom of the ash pond with coefficient of permeability less than 10^{-5} cm/s will be left as it is. A clay blanket with a minimum thickness of 500 mm and permeability of the order of 10^{-8} cm/s will be provided where the coefficient of permeability is more than 10^{-5} cm/s. Further, HNPCL plans to leave 200 m between the ash pond and the property boundary. These measures will ensure that the leachates from the ash pond will be retained in the area and will not pollute groundwater.

f. Dry Ash Collection

Provisions will be made for dry disposal of ash as discussed below.

Dry dust outlets (150 T/h) of the fly ash storage silos will be equipped with a dry fly ash road tanker loading facility, with telescopic loading chute, dust conditioner, and dust control system. The dust control system will consist of the following:

- Paddle wheel mixer conditioner
- Telescopic unloading spout for dry fly ash

The paddle wheel unloader minimises sensitivity of paddle wheel mixer conditioner to consistent feed and ash properties. The inlet feeder (rotary vane) would be fitted with a variable speed drive to provide capability for fine-tuning.

[2] Black and Veatch International, 1995, Onshore Subsurface Investigation Interpretive Report.

Enclosed spouts will be used to accomplish dry unloading to avoid escape of dust. Telescopic unloading spout would take the form of pipe (through which the ash is discharged) enclosed in a flexible tube through which the dust would be vented. This pipe would minimise free fall of dust since it is lowered to within few inches of the bottom of the vehicle, and then raised in increments as per requirement. The flexible outer tube will terminate in a hood that would make a tight closure over the hatch of the closed vehicle. Displaced dust-laden air would be vented off between the pipe and the sleeve and returned to the top of the silo.

5.4.2 Ash Utilisation Plan

Indian fly ash possesses pozzolonic properties. A pozzolonic material possesses little or no cementitious value, but in finely divided form and in presence of moisture chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. Due to these properties, fly ash can be used in several useful ways. Bottom ash, on the other hand, has not been successfully commercialised for useful products. It can be used only as a landfill material.

HNPCL will have provision for collecting both fly ash (in dry form) and bottom ash (after dewatering) and loading on to trucks for transport and further use.

a. Uses of Fly Ash

Fly ash can be used in:

- Building materials
- Cement manufacturing
- Landfill, road construction, railway track construction, etc.
- Extraction of minerals
- Manufacture of special-grade materials such as ceramics
- Soil conditioning

Of the above, the latter three uses are still in their infancy and limited to laboratry- or pilot-scale. Hence the discussion here is limited to the first three uses which can be presently considered for HNPCL. HNPCL is also in contact with various agencies - such as Central Power Research Institute (CPRI), Bangalore, National Metallurgical Laboratory (NML), Jamshedpur, Ceramic Research Institute (CRI), Bangalore - to suggest to HNPCL any potential enterpreneurs who could use ash in bulk.

i. Building Materials

Because of the inherent qualities of fly ash such as strength and reactivity with lime, use of fly ash in building materials is wide-spread and growing. Numerous building materials using fly ash have been successfully experimented; these are:

- Fly ash bricks
- Autoclaved aerated concrete
- Hollow blocks using high volume fly ash
- Fal-G building materials
- Aerocon Sandwich Panels
- Access Flooring
- Cement

Fly Ash Bricks

The use of fly ash in the manufacture of bricks is very promising and if these bricks are used in place of conventional clay bricks, a substantial portion of fly ash production can be used for this purpose.

Fly ash for manufacturing bricks should preferably satisfy the following requirements:

- Available silica : Not less than 35 %
- Available alumina : Not less than 15 %
- Available MgO : Not more than 5 %
- Loss on ignition : Not more than 12 %

As given in Chapter 4, the fly ash which will be produced in HNPCL's proposed TPP will meet the above requirement.

Machine-pressed fly ash bricks offer a number of advantages over clay bricks[3]. Compressive strength of machine pressed fly ash bricks is around 10-17.5 N/mm^2 compared with 10 N/mm^2 for clay bricks. Water absorption for machine-pressed fly ash bricks varies from 13-17%, which is less than that for clay bricks (20%). Fly ash bricks are lighter (1550-1650 kg/m^3) than clay bricks (1700 kg/m^3). Shrinkage of fly ash bricks is negligible.

[3] Source: National Council for Cement and Building Materials

Autoclaved Aerated Concrete

Autoclaved aerated concrete (AAC) is concrete in its basic chemical nature. It is cellular in structure, light, strong, easy-to-handle, fast-to-construct-with, and has excellent thermal insulation properties. Because of these properties, the product has become increasingly popular for construction of buildings.

AAC building elements consist of the following:

- AAC blocks: These are as much as 16 times the size of a conventional brick. These machine-cut blocks are used to construct external walls, both load-bearing and non-load-bearing, and internal partition walls.
- AAC floor/roof slabs: Though one third the weight of conventional RCC, these panels can be designed to carry the required loads.

The following advantages are offered by AAC building elements:

- Light-weight construction
- Significant savings on materials
- Smaller size of foundations
- Smaller size of structural members such as columns and beams
- Low seismic-induced forces
- Fast construction
- Higher thermal- and sound insulation
- Easy working for concealed conduiting and piping, etc
- Enhanced fire resistance
- Facility to construct on poor ground conditions
- Addition of floors under working conditions

AAC blocks are very popular in Europe; however, use in India is still not very common as clay bricks are more economical and widely available. The advantages of AAC are still not appreciated by various agencies. A rise in demand is expected as general trend is towards constructing more and more multi-storied buildings.

Hollow Blocks

Concrete blocks are being used as an alternative to burnt clay bricks, but are not widely accepted because of relatively higher material cost. Fly ash hollow blocks are found to be a cheaper alternative to concrete blocks. About 20-30% of cement can be replaced by fly ash in the concrete blocks. It has been observed that

the strength and workability of fly ash concrete is better. Hardness of the block depends on the type and properties of fly ash and the mix proportion used.

A block of size 390 mm × 190 mm × 190 mm can replace more than 8 conventional bricks. Thus, if only the cost of blocks per unit volume is compared, the blocks are slightly more expensive. Nevertheless, the mortar requirement and the labour requirement for block masonry are lesser, hence cheaper, than for brick masonry, as blocks are much larger than bricks. The other advantages of fly ash concrete blocks are their lighter weight, higher design strength, and the space saving which is possible due to reduced thickness of wall.

Fal-G Building Materials

Fal-G brick substitutes the clay brick and hollow bricks made out of cement on one side, and cement on the other, with attractive cost-effectiveness. Fal-G has emerged as a better alternative to traditional cement, with such advantages as low price and conservation of energy and minerals. Fal-G can be used for making bricks, as a block, as mortar, and in concrete.

Fal-G is ground blend of fly-ash (60-75%), lime, and calcined gypsum (25-40%). It yields high hydraulic strengths, to the order of 350-450 kg/cm^2, by rendering a hard mass which is totally impervious to water. These characteristics of Fal-G help to develop mortar and concrete grades parallel to those of ordinary Portland cement (OPC), with due modification in mix design, with cost savings of about 50%.

Fal-G brick is 20-30% less dense and 3-7 times stronger (80-160 kg/cm^2) than clay brick, depending on the manufacturing conditions. The price is comparable to clay brick. Fal-G bricks can be cast in larger sizes than conventional bricks.

The Institute of Solid Waste Research and Ecological Balance (INSWAREB) at Visakhapatnam, a pioneer institution in developing the Fal-G technology and its commercialisation, has about 55-60 entrepreneurs have registered with it to set-up Fal-G brick/block units. It is understood that all the enterprenuers have not set up the plants since sufficient dry fly ash is not available at Visakhapatnam. Nevertheless, twelve Fal-G brick/block plants including two Andhra Pradesh State Housing Corporation (APSHC) plants are operating successfully at Visakhapatnam.

HNPCL has already initialled a memorandum of understanding (MoU) with INSWAREB for making available dry fly ash for setting up a cluster of brick plants.

Aerocon Sandwich Panels

This is a product/process developed and patended by Hyderabad Industries Limited (HIL), Hyderabad. Aerocon panel is made of two fibre-reinforced cement sheets, on either side of a light-weight concerete core composed of Portland cement, binder (fly ash), and silacious and micaseous material aggregate. HIL has already set up a plant at Hyderabad to manufacture such panels. These panels can be used as load-bearing walls for buildings up to two storeys high and for non-load-bearing walls in multi-storied buildings. The main advantages of these panels are:

- Fire resistance
- Good accosutic properties
- Thermal insulation

Access Floor Tiles

Thes tiles are made of two fibre-reinforced cement sheets on either side of a light-weight concerete core composed of Portland cement, fly ash, and silaceous and micaseous material aggregrate. The tiles are fully cured. The typical size is 2'×2' with a thickness of 33 mm or more. This process/product has been patented by Hyderabad Industries Limited, Hyderabd.

Access floor tiles are ideal for offices; their layout can be changed quickly as they are designed for efficient repair and rearrangement.

Other Building Materials

Apart from the building materials described above, fly-ash-sand-lime bricks, and fly-ash-stone-dust-cement bricks can also be manufactured using fly ash.

Demand for Building Materials

HNPCL's power plant will be located in Visakhapatnam district. Considering the existing transportation facilities in the region, surrounding districts, will form a part of market segment. In addition to the rural markets, urban agglomerations could also provide possible markets for building materials (bricks, panels, tiles, etc) produced from fly ash generated at HNPCL's plant.

ii. Cement Manufacturing

Fly ash is being used as an additive to cement in several countries. France leads all other countries in the use of fly ash in cement manufacture; it utilises more than 50% of its fly ash in cement manufacture and one third of the entire cement produced in the country contains fly ash. The technology to manufacture cement from fly ash is becoming more and more common. Pozzolona cement is being manufactured by various cement plants all over India. Cement manufacturers prefer to use fly ash from the later ESP hoppers as this ash is fine and its carbon content is less.

Indian fly ash is a suitable raw material for manufacturing Portland Pozzolona cement (PPC). Nevertheless, apart from suitability of fly ash, some other considerations - such as the chemical composition and fineness of clinkers, the amount of fly ash to be mixed with cement, and the method of blending fly ash and Portland cement - are also important. PPC has several advantages over OPC: low heat of hydration, reduction in alkali silica reaction for the production of more chemically-resistant concrete, etc.

Two technologies are used for manufacture of fly ash cement: (i) cement is blended with fly ash or (ii) fly ash cement is made by intergrinding Portland cement with clinker. Both these technologies are relatively cost-effective and operationally simple.

Demand for Cement

Indian cement industry now ranks fifth amongst the cement producing countries after China, Russia, Japan, and USA. Present production capacity of cement in India is close to 83 million tonnes per year. Most of this cement is produced in large cement plants. In Andhra Pradesh, 18 large-scale and 20 small-scale cement plants are located.

The installed capacity for cement production in the country is likely to expand at a rate of about 9% per annum up to 2000 A D. As of June 1995, there were 55 cement projects on hand. Of these, 25 projects were under implementation and the rest in either proposal or announcement stages. Together, these 55 projects are expected to add nearly 50 million tonnes of additional capacity by 2000 A D. The 25 projects under implementation are expected to be set up by 1997 and will have a capacity of 20.23 million tonnes.

Since the investments in infrastructure by the public and private sectors are expected to increase in the coming years, the demand for cement is expected to rise. Recent initiatives to involve

the private sectors in building roads, developing ports and setting up hydro-power generating plants are expected to provide a significant boost to the demand for cement.

b. HNPCL's Proposed Fly Ash Utilisation Strategy

Considering the potential uses of fly ash and its demand for downstream uses, HNPCL's fly ash utilisation plan was prepared. The salient features this plan are as follows:

- Hardware will be provided as a part of the project for:
  - collecting 100% fly ash from ESP hoppers in dry form in silos
  - loading dry fly ash onto open (through use of paddle mixers) and closed truck (through use of telescoping chutes) under the silos without causing dust nuisance
  - segregating dry ash based on fineness and offering ash from any ESP hopper to a user for appropriate use
  - loading dewatered bottom ash in a truck, for ash to be used for landfilling
- Area will be provided in the plant layout for setting up ash users plants.
- Fly ash will be offered free of cost to any user for 10 years from the start of power plant operation.

HNPCL has been continuously interacting with various potential ash users and has concluded MoUs for possible utilisation of ash from the plant. Only those companies which showed keen interest and have the technology and the resources to set up these plants were chosen for the MoUs; these are listed in Table 5.1.

As the project nears financial close, HNPCL will advertise in leading regional newspapers about the hardware provided in the plant and that fly ash and bottom ash would be made available free of cost for the first 10 years after the start of the operational phase. It is anticipated that the need for bottom ash and fly ash will pick up as more and more awareness is created in the region through the above endeavour, especially for constructing roads and landfilling. Demand is likely to increase further in future when the availability of clay - for landfilling, embankments for roads and railways, and brick-making - becomes scarce, which would make ash products more competitive. Legislative support from the government promoting the use of products based on ash is also likely to help in use of ash in future.

Table 5.1. Potential users of ash from HNPCL's plant

Agency	Date of signing of MoU	Ash proposed to be used (T/d)	Product/Remarks
Nagarjuna Construction Company Ltd (NCCL)	Jun 1996	100+400	Bricks+Cement (Large construction company, already has a cement plant)
INSWAREB	Jul 1996	100 (initially)	Bricks, FAL-G (Recognised institute, already has brick plants based on in-house technology)
Geo Mine Tekniks	Oct 1996	75+200	75 for bricks + 200 for proposed cement plant (Existing mining and construction company)
DCL Exim Private Limited	Dec 1996	400	Cement (DCL Exim is already operating cement plants in AP)
Hyderabad Lite Crete Company	Under discussion	500	AAC blocks
Associated Cement Companies	Under discussion	Under discussion	Pozzolona cement (Reputed cement manufacturer, already has a number of cement plants in operation all over India)
Hyderabad Industries Limited	Under discussion	Under discussion	Aerocon Wall panels, Asccess Floor Tiles, AAC blocks (Reputed company of the Birla Group, already using dry ash from Vijaywada TPS. Holds patent for aerocon panels and access floor tiles. Company planning expansion project)

Scouting of ash users has been pursued vigorously by HNPCL and will be actively pursued in future as well. It is expected that the ash users' interest will also grow further, when activity starts at the site. This is expected to generate further potential for ash use.

HNPCL will utilise a part of the fly ash generated at the plant for increasing the height of the bund around the ash pond. The initial bund (about 7-8 m high) will be made with clay and will be sufficient for the first 10 years of operation. To cater for the life of the plant (30 years), a bund with a height of about 18 m with side slopes of 1:2 to 1:3 would be required[4]. The fly ash would need to be compacted to a density of 1.4 T/m^3. While developing this proposal, adequate care will have to be taken to avoid dust nuisance. Approximately 4 years' production of ash could be utilised for increasing height of the ash bund. After the 30-year period of the operation of the plant (design plant life), if the plant is to be scrapped, the ash pond would be reclaimed by planting appropriate species of trees.

The basic concept of raising the height of the ash bund using fly ash is depicted below. It must be noted that the land has been provided for the worst-case scenario, i e, no ash is utilised. In case sales of ash pick up, the final height of the ash bund will be less than 18 m.

The height of the dyke will be raised depending on ash usage. It is anticipated that ash sales will pick up and actual height may be less than the above. The area not used for the dyke (depending on ash usage) would be converted to greenbelt or given to ash users.

National Power (NP), HNPCL's Joint Venture partner, has extensive experience of beneficially utilising coal ash. Approxi-

[4] Exact slope can be determined during the detailed engineering phase, only after detailed soil investigation and studying the properties of the material available for constructing the dyke. Space will be provided in the layout for 1:3 slope.

mately 6 million tonnes of coal ash are produced by NP's coal-fired power stations in the UK; over half of this ash is put to beneficial use, making NP the largest ash selling company in UK. In the UK, coal ash utilisation has been established since the 1960. Since then NP has developed a large skill base devoted to the beneficial utilisation of ash. This experience and skill base will be available to HNPCL during the operational phase of the project.

5.5 Greenbelt Development

Development of a greenbelt in and around an industry is an effective way to check pollutants and their dispersion into the surrounding areas. The degree of pollution attenuation by a greenbelt depends on its height and width, foliage surface area density, dry deposition velocity of the pollutants and the average wind speed through the greenbelt.

The main objectives of greenbelt development in and around the proposed HNPCL plant will be:

- mitigation of impact due to fugitive emissions
- attenuation of noise levels
- creation of an aesthetic environment
- Reuse of plant effluent

The greenbelt in and around the HNPCL plant will be developed in harmony with the environmental conditions of the area. The environmental quality of the area including meteorology, groundwater quality, and soil quality have already been discussed in Chapter 3. The general climate at Palavalasa is subtropical with moderate temperatures, high humidity, and low wind velocity except during cyclones. Rainfall in the area is seasonal and controlled mostly by SW monsoon.

The soil at and surrounding the HNPCL plant site was found to vary in texture. Predominant textural class was found to be silty-clay except the locations near coast, where soil was found to be sandy. Soil at the plant site near the cashew plantation was sandy, whereas the soil from the mud flat (proposed ash pond) was silty-clayey. Infiltration rate at most locations was found to be low (5-12.5 cm/h) except at Thikkavanipalem (23.4 cm/h) and plant site (22 cm/h) where the soil was predominantly sandy. The pH was found to be in the neutral range. The soil was moderate in nutritional status with fairly high amounts of organic matter, moderate NPK content, and adequate quantities of the micronutrients B, Mn,

Cu, and Zn. The soil was non-saline with low electrical conductivity and had relatively low concentrations of NaCl and Na_2CO_3.

Depth of the groundwater table was found to be low with the average depth ranging from 1.5 m to 3 m. Groundwater quality at the site and near the salt pans was found to be saline with relatively high concentrations of sodium and chlorides. This type of soil can be made suitable for agricultural purposes with proper agro-management practices. These practices can help build a healthy soil environment for the saplings to enable them to be established initially. The preparation for the greenbelt plantation, such as soil conditioning, landscaping, etc, will be carried out before the advent of the rainy season. The major greenbelt plantation will be taken up during the rainy season, when minimal irrigation support will be required. Thereafter, sufficient irrigation support will be provided till the greenbelt is established in the local agroclimatic conditions. The irrigation support could be provided by laying pipelines (to be determined during detailed engineering design phase) and further by hoses, and/or portable equipment. Treated domestic sewage and industrial effluent can be used for irrigation of the greenbelt. A full-time horticulturist will be employed by HNPCL to maintain its greenbelt. As per MoEF's clearance condition, endorsement of the District Forest Officer will be obtained at an appropriate time for the greenbelt development.

Preparation for the greenbelt plantation will commence at the same time as construction of the main plant, with the exception of the areas for access roads and main plant where major earth works are required. Plantation of casuarina and cashew trees already exists in HNPCL site. The existing plantation will be maintained to the extent possible to avoid disturbance to the natural ecosystem and habitats.

HNPCL has proposed to maintain a greenbelt in an area of about 650 acres (over 260 ha), which is larger than four times the built-up area, as required by APPCB. A 500 m wide greenbelt will be developed from the high tide line (HTL) on the southern boundary of the plant. A greenbelt of around 150-200 m will be developed around the ash pond where it is adjacent to other properties, and around 100 m on the other sides. Apart from this, greenbelt will be developed in the appropriate open spaces surrounding the coal unloading point and stockyard, boiler house, DG sets room, and ETP. Exhibit 5.6 shows the proposed greenbelt area of HNPCL. Plantation of trees alongside the roads inside the plant and HNPCL's access road from NH5 to the plant site is recommended.

Two principal factors have been considered in the selection of plant species for the proposed greenbelt.

- Plant species should be able to thrive under local agro-climatic conditions.
- Plant species would need minimum level of maintenance including fertilisation and other soil amelioration.

The trees and plants that have been recommended are native and can grow in the coastal climate of Visakhapatnam plant site. In addition, due consideration has been given to the ability of the plant species to tolerate pollution. The trees and plants chosen show "moderate" to "high" levels of tolerance to SO_2, fly ash, and SPM, the major pollutants expected from the proposed TPP. In addition, plant species like *Acacia arabica*, *Gardenia florida*, *Mangifera indica*, and *Helianthus annus* have also been suggested. These are reportedly "sensitive" to pollutants and can thus act as "biomonitors" to indicate the level of air pollution. Nevertheless, the primary criteria of selection of plants in both the cases was the adaptability of the plants to grow in the existing agro-climatic conditions at and around the site.

In developing the greenbelt surrounding the battery limit of the proposed plant, the relative height of the plants will be taken into account so that trees of lower height like *Gardenia*, *Nerium*, *Bauhinia*, etc, will be grown at the front, followed by trees of medium height like *Acacia*, *Anacardium*, *Annona*, etc; taller trees like *Casuarina*, *Ficus benghalensis*, *Azadirachta*, etc, will be grown at the outermost periphery of the greenbelt to create a good visual impact.

In addition to developing the greenbelt around the boundary of the industrial complex, trees will be planted alongside the roads within the plant premises and inside the colony with a view to provide:

- shade
- protection of roads from erosion
- wind breaks
- mitigation of noise
- mitigation of fugitive emissions

An indicative list of plants that may be considered for greenbelt development is given below:

- *Acacia arabica* : Shrub
- *Acacia nilotica* : Tree

Exhibit 5.6. Proposed greenbelt area of HNPCL

- *Aegle marmelos* : Tree
- *Albizzia lebbeck* : Tree
- *Anacardium occidentale* : Tree
- *Annona squamosa* : Tree
- *Azadirachta indica* : Tree
- *Bauhinia purpurea* : Tree
- *Bougainvillea* spp : Shrub
- *Cassia siamea* : Tree
- *Casuarina equisetifolia* : Tree
- *Cassia siamea* : Tree
- *Delonix regia* : Tree
- *Ficus religiosa* : Tree
- *Gardenia florida* : Shrub
- *Helianthus annus* : Herb
- *Mangifera indica* : Tree
- *Nereum odorum* : Shrub
- *Prosopis juliflora* : Tree
- *Syzygium cumini* : Tree

In the vacant space between the trees, plants like *Acalypha indica*, *Mimosa pudica*, *Catharansus roseus*, and *Cynodon dactylon* (grass) can be grown as ground cover. This will check the loss of soil moisture through evapotranspiration.

Suggested trees for avenue plantation are listed below:

- *Acacia nilotica*
- *Azadirachta indica*
- *Bauhinia purpurea*
- *Cassia siamea*
- *Casuarina equisetifolia*
- *Delonix regia*
- *Ficus reliogiosa*

5.6 Community Development Plan

HNPCL has planned to involve the local community during the entire project development. For this purpose, HNPCL/contractors will recruit local work force to the extent possible during both construction and operational phases. HNPCL will encourage training for the local people to develop skilled manpower required to carry out technical work in the proposed plant during operational phase.

HNPCL will organise a community advisory group that would help HNPCL in finding ways to participate with its neighbours in addressing socio-economic concerns. With the advice of its community advisory panel, local officials, and other key individuals and groups, HNPCL will sponsor appropriate programs and projects to benefit its neighbours and the community as a whole. HNPCL plans to reinforce one of the existing approach roads from NH5 to the site, which would be used during the construction period till its own road is built. Some other community development programmes that could be considered by HNPCL are suggested here:

- encouragement to residents in the nearby localities for self-employment ventures, such as by assisting them in arranging finances for starting transport services, plumbing services, setting up shops, etc.
- periodic training programmes on health and sanitary education, women and child development, and income generation schemes
- participation in improving the existing medical and educational facilities of the area - for this purpose, it is suggested that HNPCL provide funds to the local hospital and school
- development of a park and a traffic island to build a green and clean environment in the surrounding area

5.7 Post-Project Monitoring Plan

To monitor the extent of environmental impact of the proposed project, it is advisable to periodically check the pollutant loads generated from the plant. This section describes the post-project environmental quality monitoring plan and the organisational set-up necessary to implement the EMP.

5.7.1 Meteorology

The nearest meteorological station of the India Meteorological Department from Palavalasa is located at the Visakhapatnam Airport, around 20 km away from the HNPCL plant site. To monitor the alteration of meteorological conditions in the area around HNPCL, a weather station for monitoring wind speed and direction, temperature, rainfall, and relative humidity will be installed within the plant premises.

5.7.2 Air quality

Air quality monitoring includes stack emission monitoring and ambient air quality monitoring. HNPCL plans to install an automated analyser at the stack for continuous monitoring of SO_2, NO_x, CO, SPM, and oxygen. Results of this monitoring will be submitted to the APPCB regularly. Details of the monitoring equipment are given in the following table.

Item	SPM	SO_2	O_2	CO	NO_x
Location	Stack inlet	Stack inlet	Economiser outlet	Stack inlet	Stack inlet
Principle	Opacity	Pulse fluorescence	Zirconia	NDIR	NDUV
Range	0-100%	0-1500 ppm	0-10%	0-500 ppm	0-1000 ppm

NDIR = Non-dispersive infra-red absorption
NDUV = Non-dispersive ultra-violet absorption

On-line flow monitoring of flue gas will be as per the following specifications:

- Technology : Correlation technique
- Detector : Infra-red type
- Range : 0-30 m/s

Prior to the commissioning of the plant, four ambient air quality monitoring stations will be established around the plant site depending on the predominant wind directions to assess the effectiveness of the pollution abatement measures. The exact locations of these monitoring locations will be decided in consultation with APPCB.

5.7.3 Noise

Noise levels will be monitored at various locations inside the plant where noisy operations are conducted and also at the security gate and canteen. Noise levels will also be monitored in the nearby villages such as Palavalasa, Devada, Islampeta, Peddapalem, and Dalaipalem. Noise monitoring will be done once a month, using portable noise meters.

5.7.4 Water Quality

Monitoring of effluent streams after treatment will be carried out to ensure that treated effluent meets the standards prescribed by the APPCB and CPCB. The following parameters will be monitored once a week:

Wastewater source	Type of sample	Parameters to be monitored
Condenser cooling water	grab	pH, temperature, free available chlorine
Boiler blowdown	composite	SS, O&G, Cu, Fe
Ash pond effluent	composite	pH, TSS, COD, O&G, Cr, Zn, Fe, Mn, Ni, Pb
Oil water separator	grab	O&G
Industrial effluent treatment plant	composite	pH, TSS, COD, O&G
Domestic sewage treatment plant	composite	pH, TSS, BOD, COD, O&G

Parameters such as oil and grease, TSS, COD, BOD will be measured manually as per Standard Methods, whereas pH, residual chlorine, and temperature will be monitored with appropriate meters. The results of the monitoring will be sent to APPCB regularly.

Groundwater monitoring will be carried out at four locations on the periphery of the ash pond, to assess the impact of the ash pond on the groundwater quality. Boreholes will be made by HNPCL for the purpose. pH, conductivity, and trace metals will be the parameters of concern, and will be monitored once a season.

5.7.5 Soil Quality and Solid Wastes

Quality of soil inside the plant premises, where the greenbelt will be located, will be monitored to examine alteration of physico-chemical properties of the soil, if any. This would help in taking corrective measures at the appropriate time. The frequency of sampling may be once in every season. The following parameters will be analysed:

- Textural class
- pH
- Bulk density
- Organic matter
- Alkalinity
- NaCl
- Na_2CO_3
- Grain size distribution
- Sand (%)
- Silt (%)
- Gravel (%)
- Clay (%)
- Available phosphorus (%)
- Available potassium (%)
- Available nitrogen (%)
- Available copper (%)

5.7.6 Laboratory and Equipment

One analytical laboratory will be set up to carry out the monitoring and analysis as mentioned above. In addition to the instruments required for collection of samples, the laboratory will be equipped with the following:

- Single pan balance
- pH meter
- Conductivity meter
- Dissolved oxygen meter
- Incubator
- Flame photometer
- UV/Visible spectrophotometer
- Atomic absorption spectrophotometer

5.7.7 Consumption of Power and Chemicals

Separate power connection with energy meter will be provided for the following pollution control equipment:

- electrostatic precipitators
- wastewater treatment plant
- chlorination plant

Consumption of chemicals will be recorded on a regular basis at all chemical dosing pumps.

5.7.8 Environmental Management Cell

An environmental management cell (EMC) will be set up to look after all the environment-related activities in the plant. This cell will be responsible for regular environmental quality monitoring, proper operation of pollution control equipment and the ETP, and liaison with regulatory bodies like APPCB and CPCB.

a. Functions of EMC

The EMC will be responsible for the following:

- to implement the environmental policy principles of HNPCL; these principles are:
  - to integrate environmental factors into business decisions
  - to monitor compliance with environmental regulations and to perform better than they require, where appropriate
  - to improve environmental performance continuously
  - to review regularly, at Board level, the company's performance
  - to establish a reputation for effective environmental management

- to implement an environmental management system to the standard of BS 7750 or equivalent
- to ensure that ETPs function properly and meet effluent discharge standards
- to conduct environmental quality monitoring and to maintain the analytical laboratory
- to ensure systematic and routine house-keeping to reduce generation of pollutants inside the plant
- to maintain the greenbelt
- to bring awareness about the pollution hazards among all personnel of the plant
- to keep up with the regulatory requirements and arrange for the necessary certificates or consents (air consent, water consent and consent for hazardous material)
- to conduct yearly environmental audit and submit environmental statement to the APPCB

b. Personnel

The EMC will be headed by a Manager (Environment). (S)he will be a chemical or environmental engineer/scientist with adequate knowledge and experience in the processes involved in a TPP. (S)he will have an overall knowledge of pollution control equipment (like ESP), ETPs and their maintenance, and environment-related laws and standards. (S)he will be supported by a senior chemist who will be responsible for all matters related to the environmental monitoring and analysis and will be capable of preparing the reports and data sheets. (S)he will have sufficient knowledge in sampling and analysis of environmental parameters. Under the senior chemist two junior chemists will work who will be responsible for field work. A horticulturist will be appointed for supervising greenbelt plantation and its subsequent maintenance.

5.8 Cost of EMP and PPMP

HNPCL has made adequate budgetary provisions for the monitoring and control of pollution. The estimated capital cost for the above purpose is Rs 2500 million. Recurring annual O&M expenditure has been estimated to be Rs 50 million. This will include maintenance of the ETP and other pollution abatement measures, monitoring costs, maintenance of greenbelt, consultancy charges, etc.

EVALUATION OF IMPACTS

The environmental impact of a project depends both on the project activities and on the background environmental setting. The impact potential of HNPCL's proposed TPP has already been discussed in the Chapter 4. This chapter evaluates these impacts under various scenarios.

The environmental impact assessment process involves four basic steps:

- Identification
- Evaluation
- Interpretation
- Communication

A number of techniques are available for the assessment of impacts. Each of these techniques has its own advantages and disadvantages. The selection of any of these techniques for any particular project depends largely upon the choice of judgment of the analyst. The technique chosen should be comprehensive, easy to understand, systematic, and flexible. Considering these criteria, for this project, the matrix method was used, with an impact scale of -4 to +4.

6.1 Matrix Method

The matrix used for EIA consists of project activities on the x-axis and the environmental components likely to be affected by these activities on the y-axis. Each cell of the matrix represents a subjective evaluation of the impact of a particular activity on a particular component, in terms of magnitude and importance. A blank cell indicates no impact of the activity on the component. The magnitude (*m*) is represented by a number from 1 to 4 where

1 = minimal	2 = appreciable
3 = significant	4 = severe

Positive sign (or no sign) indicates beneficial impact and negative sign indicates adverse impact. The importance (*w*) of the impact is given on a scale of 1 to 4 in each cell. This number indi-

cates the relative importance of the impact of the activity on the concerned component *for this (HNPCL's TPP) project.* The magnitude and importance are multiplied to get a score for each cell ($m_{ij}w_{ij}$). The scores of individual cells in each row are added to determine the total impact of all project activities on each component. Similarly, the scores in individual cells in each column are added to determine the total impact of each activity on all the environmental components likely to be affected. The grand total of all cells indicates the total project impact. This can be represented by the following equation:

$$\text{Total project impact} = \sum_i \sum_j m_{ij} w_{ij}$$

where

m_{ij} = (positive or negative) magnitude of the jth activity on the ith environmental component, and

w_{ij} = importance of the jth activity on the ith environmental component

Since both m and w vary from 1 to 4, the total score in each cell can theoretically vary between -16 and +16. Therefore the total project impact can vary between (-16 × total number of cells in the matrix) and (16 × total number of cells in the matrix). To compare scores from matrices containing different number of cells, the total project score can be normalised to a scale of 100 as follows:

$$\text{Total project impact}_{\text{scale of 100}} = \frac{\text{Total project impact}_{\text{computed by matrix}}}{16 \times \text{Total number of cells in matrix}} \times 100$$

On this scale, the overall impact can be classified as follows:

Total project impact (scale of 100)	Magnitude of Impact
-100 to -75	Severely adverse
-75 to -50	Significantly adverse
-50 to -25	Appreciably adverse
-25 to 0	Minimally adverse
0 to 25	Minimally beneficial
25 to 50	Appreciably beneficial
50 to 75	Significantly beneficial
75 to100	Very highly beneficial

6.1.1 Limitations of Matrix Method

While assessing impact by the matrix method, the following limitations should be borne in mind:

- Guidelines for the use of this approach are minimal; this may lead to ambiguities.
- Evaluation of impacts is based on subjective judgment, which can vary from individual to individual.
- Component to component interaction cannot be represented, hence inter-relationships between impacts cannot be shown.
- Primary, secondary, and tertiary impacts cannot be clearly distinguished.

6.1.2 Justification for Matrix Method

In spite of the limitations listed above, the matrix method is useful for the purpose of this project. It identifies the impact of each project activity on each environmental component. Evaluation and interpretation of impacts, albeit subjective, do convey a holistic view of the environmental impacts of the project. In addition, the matrix is an easy-to-understand way of communicating the results of the EIA exercise.

6.2 Alternative Scenarios

Impact score for the project was calculated for three scenarios using the matrix method described above. Matrices were prepared to represent each of these scenarios.

- Scenario 1: No project, i e, the site near Palavalasa, where the TPP of HNPCL is proposed to be located, remains as it is and the proposed project development does not take place.
- Scenario 2: EIA without EMP, i e, proposed development takes place without any environmental management measures.
- Scenario 3: EIA with EMP, i e, proposed development takes place with the environmental management measures suggested in Chapter 5.

In addition to the three matrices corresponding with the above scenarios, another matrix was prepared to represent the impacts during the construction phase.

The main reason for preparing the matrices for different scenarios was to evaluate the impacts of each of the project activity on individual environmental component. Matrices for all scenarios are discussed in the following subsections.

6.2.1 Scenario 1: No project

Even if HNPCL's project is not implemented, there are about 32 large and medium scale industries in a 30 km radius of the proposed project site. These include engineering, chemical and allied, electrical and electronics, mineral and ceramic, and miscellaneous industries. This industrial activity surrounding the proposed project site along with non-industrial activities of the villagers (agriculture, salt making, aquaculture, lime making from shells, brick preparation, etc) were considered in this scenario for assessing the impacts on individual environmental components.

The total project impact score for this scenario was found to be -5, as can be seen from Table 6.1. On a scale of ±100, the score was calculated to be -0.25. Thus the impact of the existing activities in the region on the environment will be minimally adverse even without the proposed project.

6.2.2 Scenario 2: EIA without EMP

This scenario was based upon the assumption that the proposed development would go ahead without any environmental management options proposed by HNPCL or suggested by TCS in Chapter 5. The total project impact for this scenario, as can be seen from Table 6.2, was found to be -128. On a scale of ±100, the score was -7.1, or minimally adverse. This means that if the project goes ahead without an EMP, the adverse impact on the existing environment would be several times that of the impact without the project. Thus the environmental management plan described in Chapter 5 will have to be fully implemented to minimise the potential negative impact of the proposed project.

6.2.3 Scenario 3: EIA with EMP

If the environmental management strategies discussed in Chapter 5 of this report are fully implemented, the adverse impact of the project would be nullified, and there will be an overall improvement in the physical, chemical, biological, and socio-economic environment of the region. This is reflected in the total project impact score, +17, as shown in Table 6.3, for this scenario. This is an improvement over both scenarios considered earlier. The score on a scale of ±100 for this scenario was found to be +0.84, which is on the beneficial side. Therefore, the proposed thermal power project will be beneficial for the environment of the area, provided the EMP is in place.

Table 6.1. Impact assessment matrix for Scenario 1 (No Project)

Environmental component likely to be affected		Activity likely to affect environmental components									Total impact on component
		Transportation of raw materials/products to/from plant	Storage and handling of material	Manufacturing of products	Agriculture	Salt making	Fishing	Aquaculture	Lime making from shells and brick making	Power generation by alternate means	
Air Quality	Magnitude	-1	-1	-2	-1	-1	-1	-1	-1	-1	
	Importance	1	1	1	1	1	1	1	1	1	-10
Noise and Vibration	Magnitude	-1	-1	-1	-1	-1	-1	-1		-1	
	Importance	2	1	1	1	2	2	2		1	-12
Surface water quality	Magnitude		-1	-1	-1			-2			
	Importance		1	1	1			2			-7
Groundwater Quality	Magnitude			-1	-1	-1		-1			
	Importance			1	1	2		1			-5
Soil Quality	Magnitude	-1	-1	-1	-1	-2			-1		
	Importance	1	1	1	1	2			1		-9
Flora and fauna	Magnitude	-1		-1	-1	-1	-1	-1	-1	-1	
	Importance	1		1	1	2	1	1	1	1	-9
Aesthetics	Magnitude	-1	-1	-1	-1	-1			-1		
	Importance	1	1	1	1	1			1		-6
Land and property value	Magnitude	1	1	2	2	1		1			
	Importance	1	1	2	2	2		1			13
Landuse pattern	Magnitude	-1	-1	-2	1	-1		-1			
	Importance	1	1	2	1	2		2			-9
Recreation	Magnitude	-1		-1	1	-1			-1		
	Importance	1		1	1	1			1		-3
Human health	Magnitude	-1	-1	-1					-1	-1	
	Importance	1	1	1					1	1	-5
Employment	Magnitude	1	1	1	2	1	2	1	1	1	
	Importance	1	1	2	2	2	2	2	1	1	18
Trade and commerce	Magnitude	1		2	2	1	2	1	1	1	
	Importance	1		2	2	2	2	2	1	1	19
Economy and income level	Magnitude	1	1	1	2	2	2	1	1	1	
	Importance	1	1	2	2	2	2	2	1	1	20
Total action impact		-5	-4	-2	11	-5	8	-4	-3	-1	-5

Impact Scale: 1 = Minimal, 2 = Appreciable, 3 = Significant, 4 = Severe

Positive sign indicates beneficial impact

Negative sign indicates adverse impact

Blank space indicates no impact

Table 6.2. Impact assessment matrix for Scenario 2 (EIA without EMP)

Environmental component likely to be affected		Project activity likely to affect environmental components								Total impact on component
		Transport of raw materials to plant (coal/oil)	Storage/handling of raw materials (coal/oil)	Desalination of sea water	Steam generation	Power generation and transmission	Cooling water discharge	Ash disposal	Disposal of other wastewater(s)	
Air Quality	Magnitude	-1	-2		-3	-1		-1		
	Importance	2	2		3	1		2		-18
Noise and Vibration	Magnitude	-1	-1	-1	-2	-2	-1	-1		
	Importance	2	2	1	2	2	2	2		-17
Surface water quality	Magnitude		-1	-1	-1		-2	-2	-2	
	Importance		2	1	2		3	2	2	-19
Groundwater Quality	Magnitude		-1		-1			-2	-1	
	Importance		1		2			2	2	-9
Soil Quality	Magnitude	-1	-1		-2			-2	-2	
	Importance	1	2		3			3	2	-19
Flora and fauna	Magnitude	-1	-1	-1	-2	-1	-2	-2	-2	
	Importance	1	1	1	3	1	3	2	2	-24
Aesthetics	Magnitude	-1	-1		-2	-2	-1	-2	-1	
	Importance	2	2		2	2	1	2	1	-18
Land and property value	Magnitude	1			2	2		-1	-1	
	Importance	2			2	2		1	1	8
Landuse pattern	Magnitude	-1	-1		-2	-2		-2	-1	
	Importance	2	1		3	2		2	1	-18
Recreation	Magnitude	-1	-1	-1	-2	-1	-1	-2	-1	
	Importance	1	1	1	2	2	1	2	2	-16
Human health	Magnitude	-1	-1		-2	-1	-1	-2	-1	
	Importance	2	2		2	2	2	2	2	-18
Employment	Magnitude	2	1	1	2	2	1	1		
	Importance	2	1	1	2	2	1	1		16
Trade and commerce	Magnitude	2	1	1	2	2	-1			
	Importance	2	1	1	2	2	1			13
Economy and income level	Magnitude	1	1	1	2	2	-1	1		
	Importance	1	1	1	2	2	1	1		11
Total action impact		-2	-15	-1	-31	-2	-19	-37	-21	-128

Impact Scale: 1 = Minimal, 2 = Appreciable, 3 = Significant, 4 = Severe

Positive sign indicates beneficial impact

Negative sign indicates adverse impact

Blank space indicates no impact

Table 6.3. Impact assessment matrix for Scenario 3 (EIA with EMP)

Environmental component likely to be affected		Project activity likely to affect environmental components									Total impact on component
		Transport of raw materials (coal/oil) to plant	Storage/handling of raw materials (coal/oil)	Desalination of sea water	Steam generation	Power generation and transmission	Cooling water discharge	Ash disposal	Disposal of other wastewater(s)	Greenbelt development	
Air Quality	Magnitude	-1	-1		-1	-1		-1		1	
	Importance	1	1		2	1		1		2	-4
Noise and Vibration	Magnitude	-1	-1		-1	-1	-1	-1		1	
	Importance	1	1		1	1	1	1		2	-4
Surface water quality	Magnitude				-1		-1	-1	-1	1	
	Importance				1		1	1	1	1	-3
Groundwater Quality	Magnitude				-1			-1	-1	1	
	Importance				1			1	1	1	-2
Soil Quality	Magnitude	-1	-1		-1			-1	-1	1	
	Importance	1	1		1			1	1	2	-3
Flora and fauna	Magnitude	-1			-1		-1	-1	-1	1	
	Importance	1			2		1	1	1	2	-4
Aesthetics	Magnitude	-1	-1		-1	-1	-1	-1		1	
	Importance	1	1		1	1	1	1		2	-4
Land and property value	Magnitude	1		1	2	2		-2	-1	1	
	Importance	2		1	2	2		2	1	1	7
Landuse pattern	Magnitude	-1	-1		-2	-2		-1		1	
	Importance	2	1		2	2		1		1	-11
Recreation	Magnitude	-1	-1		-1	-1	-1	-1	1	1	
	Importance	1	1		1	1	1	1	1	2	-3
Human health	Magnitude	-1	-1		-1	-1		-1		1	
	Importance	1	1		1	1		1		2	-3
Employment	Magnitude	1	1	1	2	1	1	2	1	1	
	Importance	2	1	2	2	2	1	3	1	1	20
Trade and commerce	Magnitude	1	1	1	2	1		2		1	
	Importance	2	1	1	2	2		3		1	17
Economy and income level	Magnitude	1	1	1	2	1		2		1	
	Importance	1	1	1	2	2		2		1	14
Total action impact		-2	-4	5	1	1	-4	2	-3	21	17

Impact Scale: 1 = Minimal, 2 = Appreciable, 3 = Significant, 4 = Severe

Positive sign indicates beneficial impact

Negative sign indicates adverse impact

Blank space indicates no impact

6.2.4 Environmental Impact of Construction

Construction activities will be temporary and will not adversely affect the environment on a long-term basis. Nevertheless, an impact matrix was prepared for the construction phase and is shown in Table 6.4. The total impact of this phase was found to be -53 on a scale of ±1120 and -4.73 on a scale of ± 100. Thus the impact of construction would also be minimally adverse.

6.3 Concluding Remarks

It is clear from the above discussion that the proposed thermal power project of HNPCL would have some negative impacts without any environmental management strategies. If the EMP, as discussed in Chapter 5, is strictly adopted and implemented, the adverse impact would be nullified and the overall environmental quality of the area would improve. The project would result in the following advantages:

- The power generation capacity would improve, hence the deficit between power demand and supply in Andhra Pradesh will be reduced in the medium term.

- Acute power shortages have existed in Andhra Pradesh from 1986-87 till date. The demand for power in the year 2001-02 would be about 10500 MW. The corresponding installed capacity required would be about 15000 MW. The additional supply due to the HNPCL plant will partly meet the demand and improve the stability of the APSEB grid system.

- Skilled as well as unskilled manpower will be required for the operation of the plant. It is estimated that about 1000 persons will be working at the plant during the operational phase. In addition, indirect employment is expected to be generated for many more people. Thus employment opportunities will be created in the region.

- Once the HNPCL plant becomes functional, service establishments are expected to come up in and around the plant to cater to the needs of the HNPCL employees. This secondary growth will create self-employment opportunities for the local villagers and thus increase their income level.

- The secondary growth resulting from the setting up of the HNPCL plant would trigger improvements in the basic amenities, particularly transportation, telecommunication, electricity, educational and medical facilities, etc. This would improve the quality of the life of the local people.

- As HNPCL employees would spend more on goods and services available in the area, demand would be created for production of such goods and provision of services. This would give a push to the local enterprises for providing the same which would lead to the creation of more jobs, hence more income. Thus, HNPCL's plant would have a multiplier effect on the local economy.

Thus, having evaluated both positive and negative environmental impacts of HNPCL's proposed power plant, it can be concluded that the project (with the proposed EMP in place) will be a welcome development.

Table 6.4. Impact assessment matrix for construction phase

Environmental component likely to be affected		Project activity likely to affect environmental components					
		Excavation and refilling	Raw material preparation for construction	Construction of roads/buildings/civil structures	Transportation of men/material/wastes	Disposal of liquid/solid wastes	Total impact on component
Air Quality	Magnitude	-1	-1	-1	-1		
	Importance	2	1	2	1		-6
Noise and Vibration	Magnitude	-2	-1	-2	-2	-1	
	Importance	2	2	2	2	1	-15
Surface water quality	Magnitude	-1	-1	-1	-1	-2	
	Importance	2	1	1	1	2	-9
Groundwater Quality	Magnitude	-1		-1		-2	
	Importance	1		1		2	-6
Soil Quality	Magnitude	-2	-1	-2	-1	-2	
	Importance	2	1	2	1	2	-14
Flora and fauna	Magnitude	-2	-1	-2	-1	-1	
	Importance	2	1	2	1	1	-11
Aesthetics	Magnitude	-2	-1	-2	-1	-1	
	Importance	2	1	2	1	1	-11
Land and property value	Magnitude	2	1	2	1		
	Importance	2	1	2	1		10
Recreation	Magnitude	-1	-1	-2	-1		
	Importance	1	1	2	1		-7
Human health	Magnitude	-1	-1	-1	-1	-1	
	Importance	1	1	1	1	2	-6
Employment	Magnitude	2	1	2	1		
	Importance	2	1	2	2		11
Trade and commerce	Magnitude	1	1	2	1		
	Importance	1	1	2	1		7
Economy and income level	Magnitude	1	1	2	1		
	Importance	1	1	2	1		7
Socio-cultural values	Magnitude	-1	-1	-1	1		
	Importance	1	1	2	1		-3
Total action impact		-14	-6	-11	-5	-17	-53

Impact Scale: 1 = Minimal, 2 = Appreciable, 3 = Significant, 4 = Severe

Positive sign indicates beneficial impact

Negative sign indicates adverse impact

Blank space indicates no impact

RISK ANALYSIS

The objectives of the industrial risk analysis presented in this chapter were as follows:

i. Identifying potential physical hazards which could trigger loss-causing events in both process operations and storage areas

ii. Assessing the adequacy of the safety features incorporated in the plant design, and other protection measures in the processes and storage areas

iii. Evaluating the hazard ranking for vulnerable areas based on the safety features provided

iv. Identifying maximum credible accident (MCA) scenarios and assessing the consequences of the identified scenarios in terms of fire, thermal radiation, toxicity effects etc and estimating overall damage potential to both personnel and property

v. Estimating the probability of occurrence of major hazardous events

vi. Studying the overall layout of the plant and suggesting risk reduction measures for minimising hazards of worst accident possibilities identified during the above steps

7.1 Hazard Identification

Hazards were identified using two criteria:

- Manufacture, Storage and Import of Hazardous Chemicals Rules, Ministry of Environment and Forests (MoEF), 1989
- Fire-Explosion and Toxicity Index (FETI), a relative ranking technique based on toxic, flammable, and explosive properties of chemicals.

7.1.1 MoEF Criteria

MoEF rules specify chemicals and their respective threshold quantities beyond which these chemicals considered hazardous. Fuels to be used by HNPCL are LFO and HFO, which are less in quantities than specified, are not considered as hazardous.

7.1.2 FETI Approach

Fire and Explosion Index analysis (F&EI) is a systematic evaluation of the realistic fire, explosion, and reactivity potential of processes, equipment, and its contents. The F&EI is a number which indicates damage potential due to the fire and explosion of a particular unit. The index is calculated by evaluating the loss potential of all the units in the storage area and process area. It is a product of three attributes, material factor, general process hazards, and special process hazards.

The material factor (MF) is a measure of intrinsic rate of potential energy released from fire or explosion produced by combustion or other chemical reaction. It is obtained from a Flammability factor and Reactivity factor, i e, N_f and N_r, respectively, are given for various chemicals by the National Fire Protection Association (NFPA). The MF is considered for the most hazardous material or mixture of materials present in the unit in sufficient quantity to actually present the hazard.

Process hazards that contribute to the magnitude of losses are quantified as penalties. To compute F&EI, general process hazards (GPH) and special process hazards (SPH) are taken into account as penalties. GPH include exothermic and endothermic reaction, handling and transfer of materials, enclosed or indoor process units, accessibility of equipment and facilities with respect to drainage or spill control. Whereas SPH include process temperature, operating pressure, operation in or near flammable range, quantity of flammable or toxic material, corrosion and erosion, leakage, joints and packing.

Thus, $F\&EI = MF \times (1 + GPH)(1 + SPH)$

Based on F & EI, the degree of hazard is classified as follows:

F & EI RANGE	DEGREE OF HAZARD
0 - 60	Light
61 - 96	Moderate
97 - 127	Intermediate
128 - 158	Heavy
>159	Severe

In addition to F&EI, a toxicity index (TI) is included for the purpose of evaluating the process exposure level for toxicity hazards. TI is defined as :

$$TI = \{T_h/100\} \times \{GPH+SPH\}$$

where, T_h is the factor obtained from NFPA health factor N_h for the most hazardous material in the process.

Based on TI, the degree of hazard is identified as follows:

TI RANGE	DEGREE OF HAZARD
0 - 5	Light
5 - 10	Moderate
>10	Severe

The F&EI and TI calculated should not be considered as an accurate reflection of the absolute risk posed in process area, but should be considered as an estimate, to compare the relative risks of the area analysed. Additionally, it also helps to identify the specific area of the facility which should be subjected to a detailed study.

Based on the FETI approach, the HNPCL plant will have the following hazards:

S No	Unit	Qty	Material Factor				Penalties		FEI		TI	
	storage	(m^3)	N_h	N_f	N_r	MF	GPH	SPH	Index	Cat	Index	Cat
1	HFO	1400	0	2	0	10	1.4	1.2	52.8	light	-	-
2	LFO	500	0	2	0	10	1.4	1.1	50.4	light	-	-

As can be seen from the above table, there is light hazard involved in the HNPCL plant.

7.2 Maximum Credible Accident Analysis

A Maximum Credible Accident (MCA) can be characterized, as an accident with a maximum damage potential, which is still believed to be probable.

MCA analysis does not include quantification of the probability of occurrence of an accident. Moreover, since it is not possible to exactly indicate a credible level of probability, the selection of MCA is somewhat arbitrary. In practice, accident scenarios representative for an MCA analysis are selected on the basis of engineering judgment and expertise in the field of risk analysis studies, especially accident analysis.

As an initial step in MCA, the storage units and activities believed to represent the highest level of risk for the surroundings in terms of damage distances are identified, based on:

- type of compound, viz. flammable or toxic
- quantity of material present in a unit or involved in an activity
- storage conditions such as temperature, pressure, flow, mixing and presence of incompatible materials.

In addition to the above factors the location of a unit or activity with respect to adjacent activities is also taken into consideration to account for the potential escalation of the consequences of an accident, i e, the Domino effect.

The following steps are involved in the visualisation of MCA scenarios :

1. Chemical inventory analysis
2. Identification of hazardous storage units
3. Analysis of past accidents of similar nature to establish credibility to identified scenarios
4. Shortlisting of MCA Scenarios

7.2.1 Identification of Hazardous Storage Units

Heavier hydrocarbon liquids (e g, HFO, LFO, LSHS) have a boiling point above ambient temperature and thus they are stored in atmospheric tanks at ambient temperature and pressure. Any spillage or loss of containment would give rise to a highly flammable pool of liquid. There would not be any flashing of liquid and consequent vapour cloud. The vapour generated would be due

to evaporation, however this would be very small and restricted to the area immediately over the pool.

Off-site hazards from the heavier hydrocarbons liquids would be due to thermal radiation from a bund fire and liquid on fire running down a storm drain.

7.2.2 Analysis of Past Accidents

There are various potential sources of leakage which may release hydrocarbon into atmosphere. This could be in the form of small gasket failure in a flanged joint or a bleeder valve left open inadvertently, or a guillotine failure of a pipeline, or any other sources of leakage. Past accident data reveal a number of these sources and their modes of failure.

In general, failures take place in the following ways :

1. Storage oil tank on fire	Tank fire
2. Storage oil dyke on fire	Pool fire
3. Mechanical seal failure of storage feed pumps	Seal failure

Catastrophic rupture of atmospheric vessel occurs rarely. On the otherhand, failure of small bore pipeline is relatively more frequent. The frequency of occurrence of failure varies widely. Risk that issues from each of the failure cases is a combinations of frequency and consequences.

7.2.3 Shortlisting of MCA Scenarios

Based on the hazard identification and comparing the nature and occurrence of hazards with that from past accident information analysis, the scenarios identified for carrying out consequence analysis are:

- Pool fire due to leakage of fuels and accumulations
- Pool fire due to rupture

7.3 Consequence Analysis

Despite the universal acceptance of excellent codes of practice for design and operation of plant and storages, there have been a number of occurrences of losses due to major accidents of varying

degree of severity. In many cases, these accidents could be attributed to failure of adherence to the codes of practice.

As each calculation involves many steps, the consistent use of assumptions at each stage would cause an error in the final result which should be given due importance whilst interpreting the values. It should be borne in mind that the results of this study should be regarded as indicative rather than definitive.

7.3.1 Model used for Consequence Analysis

The heat load on objects outside a burning pool of liquid can be calculated with a heat radiation model. This model uses an average radiation intensity which is dependent on the liquid. Account is also taken of the diameter-to-height ratio of the fire, which depends on the burning liquid. In addition, the heat load is also influenced by the following factors :

- distance from the fire
- the relative humidity of the air (water vapour has a relatively high heat-absorbing capacity)
- the orientation i.e. horizontal/vertical of the object irradiated with respect to the fire.

Computation of various effects for all cases of identified MCA scenarios have been made based on the aforementioned discussion along with appropriate assumptions wherever sufficient data is not available. EFFECTS software developed by The Netherlands Organisation (TNO), Netherlands has been used for these computations. In addition to referring to the manual or Yellow Book of TNO, certain improvements have also been made to the models based on the derivations given in Lees (1980). Damages due to heat radiation intensity are given in Table 7.1.

a. Assumptions for Various Scenarios

The following are the assumptions made for calculating the damage distances for pool fires:

1. Steady state burning is assumed.
2. The flame is cylindrical in shape.
3. A constant and uniform surface heat flux is maintained by the flames.
4. No account is made for the pulsation effects known to occur within large fires.

Table 7.1. Damage due to incident radiation intensity

Incident Radiation Intensity (kw/m^2)	Type of Damage
37.5	Sufficient to cause damage to process equipments unless the equipment is fully thermally fire protected (insulation, fire proofing, sprinkler protection etc.). Lethality to human beings will be 100%.
25	Minimum energy required to ignite wood at infinitely long exposure (non-piloted) and would damage thermally unprotected tanks, equipment, etc. Lethality to human beings will be 50%.
12.5	Minimum energy required for piloted ignition of wood, melting plastic tubing, etc. Lethality to human beings will be 1%.
4.5	Sufficient to cause pain to personnel if unable to reach cover within 20 seconds, blistering of skin (1st degree burns) is likely.
1.6	Will cause no discomfort to long exposure.

The heights of dykes surrounding LFO and HFO storage tanks have been assumed to be equal to 1m for evaluating the pool fire scenarios.

Pool fire scenario was modelled using the EFFECT model. This indicated that the result for the heat radiation effect and various damage distance for HFO (storage capacity 2 × 1400 m^3) would represent the worst case as the LFO storage (capacity 2 × 500 m^3) would be only 35 % of the HFO capacity. The radiation effects and various damage distances for storage units of HFO are given in Tables 7.2 and 7.3.

7.3.2 Results and Discussion

The results shown in Tables 7.2 and 7.3 indicate the extent of damage effect or hazard distance in case of failure of tank and subsequent pool fire. The maximum permissible radiation intensity on adjoining tanks (thermally protected) is 37.5 kW/m^2 and 8 kW/m^2 for thermally unprotected adjoining tanks as per relevant IP code. If this limit is exceeded in case of an adjoining tank on fire, it is important that cooling of adjoining tanks is restored promptly. It is also necessary to cool the tank on fire, so that tank shell does not give way.

The safe distance for exposure of HFO tank fire is 140 m in case of a circular pool fire. The heat radiation intensity of the pool is 70.6 kW/m^2. The 100%, 50% and 1% lethality distances are 2 m, 7 m, and 25 m, respectively. The quantity of HFO considered for the pool fire scenario is 1400 m^3. The first degree burn damage distances are 24 m only, whereas the safe distance for exposure is 54 m. Damage distances for heat radiation effects from HFO storage tank are depicted in Exhibit 7.1.

a. Secondary or Domino Effects

A fire or explosion in one installation may lead to hazards in the surrounding installations. The effects of this nature are called Domino effects. In the present study, it has been identified that domino effects can be ignored as 37.5 kW/m^2 heat radiation effects for both the installations are falling within the dyke area.

7.4 Recommendations

To reduce the risk at HNPCL, the following measures are recommended:

1. Small leaks could occur frequently in routine operations, pump seal failure, sample point valve or drain valve left open, flange leak, etc. Drip trays should be provided at all such locations where routine operational leaks are expected.

2. All non-routine work such as gasket replacing, welding, etc. should be carried out under a permit system. No welding/gas cutting work should be carried out within 25 m of fuel oil storage tanks without obtaining a proper safety permit.

3. In case of any fuel storage tank catches fire, the cooling of adjoining tank should be resorted to promptly. It is also necessary to cool the tank on fire so that tank shell is protected. In view of the simultaneous cooling of three tanks at a time, the fire water system should be designed accordingly.

4. The function of sprinkler operating valves needs to be checked periodically. Also, shields can be provided for operating sprinkler valves and the proximity suits should be used by fire fighting personnel during fighting these fires.

5. The wind direction plays a major role in case of hydrocarbon releases. Hence an adequate number of wind socks should be provided at strategic locations so that people can notice and take appropriate action in case of emergency.

6. Adequate number of gas detectors should be provided at vulnerable points to give alarm sufficiently in advance in case of leakage. Adequate numbers of fire detectors should also be provided in fire prone areas.

7. The damage distance due to any failure could be reduced by reducing the time required to stop the leak, which in turn would reduce the quantity of spillage. The response time could be reduced by installing/ maintaining instruments, effective communication system, etc. HNPCL is planning to install various types of safety and relief valves for their storage tanks and planning to automate their control. Hence, it will be possible to reduce the spillage and thereby damage extent.

8. Appropriate colour coding and labeling of the pipelines should be provided for easy identification of products proposed to be handled through them.

Table 7.2. MCA Scenario 1: Pool fire due to rupture and outflow of HFO

Service	HFO
Number of Tanks	2
Quantity (m^3) (Each Tank)	1400
Scenario	Circular pool
Diameter of the Pool (m)	41
A. Intensity of Radiation at the Centre of Cloud (KW/m^2)	70.6
B. Damage Distances for the Heat Radiation (m) :	
a. 100% Lethality ($37.5\ KW/m^2$)	2
b. 50% Lethality ($25\ KW/m^2$)	7
c. 1% Lethality or severe burns ($12.5\ KW/m^2$)	25
d. First degree burns ($4.5\ KW/m^2$)	60
e. No discomfort ($1.6\ KW/m^2$)	140

Table 7.3. MCA Scenario 2: Pool fire due to leakage of HFO

Service	HFO
Quantity (MT)	230
Scenario	Circular pool
Diameter of the Pool (m)	17
A. Intensity of Radiation at the Centre of Cloud (KW/m^2)	70.6
B. Damage Distances for the Heat Radiation (m) :	
a. 100% Lethality ($37.5\ KW/m^2$)	1.2
b. 50% Lethality ($25\ KW/m^2$)	4
c. 1% Lethality or severe burns ($12.5\ KW/m^2$)	14
d. First degree burns ($4.5\ KW/m^2$)	32
e. No discomfort ($1.6\ KW/m^2$)	70

LEGEND

C - 1% LETHALITY

D - FIRST DEGREE BURNS

E - NO DISCOMFORT

Exhibit 7.1 Damage distances for heat radiation effects from HFO storage tank

9. Rubber mats should be provided in front of every electric panel boards of the plant with a view to prevent employees from receiving electric shocks.

10. Personnel not directly concerned with operations and maintenance activities should be located away from plant area. They include administration and accounts staff.

11. Unauthorised population growth around this complex should be watched closely. With the help of appropriate authorities, unauthorised growth of shanty colonies, huts etc. around the plant boundary can be avoided. Existing population around the plant should be made aware of the safety precautions to be taken in the event of any mishap within the plant. This can be effectively done by holding safety presentation demonstrations.

12. This risk analysis is based on assumptions that the storages are designed, constructed, and operated in accordance with the safe engineering practices and standards. Strict adherence to the standards and accepted practices will be followed not only during the installation of the plant but also throughout the life of the plant.

13. Maintenance plays a vital role in proper upkeep of the plant. One important function is monitoring of health of equipment, pipelines and machines. Regular thickness survey checks(including supports), records of maintenance of history, and preventive maintenance practices will be maintained to ensure plant performance and safety.

7.5 Storage Practices for Coal

The power station will utilise 4.8 million tonnes of coal annually. As Talcher coal is subject to spontaneous combustion, it may catch the fire at any moment. This fire hazard is greatly influenced by the amount of air flow through the mass of coal. Thus, storage of coal should be designed in such a way that the air content of the coal pile is minimised. Dimension of the stack, particularly the height, is a very important parameter for making safe storage of coal.

7.5.1 Uncompacted Coal Storage

Normally coal is stored in an uncompacted form [801-881 kg/m^3 (50-55 pcf)] where the air occupies approximately 35% of the volume of the pile. Thus, it is relatively easy for air movement through the pile. Coal is at this density when it is handled on conveyors, in bunkers or silos or in any other form of live pile.

As coal is susceptible to spontaneous oxidation due to high air content in the coal pile, certain precautions need to be incorporated while designing an uncompacted coal storage. These are listed below:

- There should be no dead or unmoving portion in the storage system so that while the coal is still subject to slow oxidation, it will move through the system before any appreciable heating can take hold. Thus, the bunkers, silos and bins should be designed for mass flow of coal.

- Where mass flow of coal is not possible, sealing of the bottom of the storage system can minimise the air flow through the coal pile. The space above the coal in the storage system, however, should not be sealed, to prevent the accumulation of gas that may get liberated from the coal. Preferably the area above the coal pile should be well ventilated to have an air sweep across the top surface to vent away any accumulation of gases.

- The coal storage systems should be designed to prevent formation of hazardous mixture of gases and coal dust with air.

- Static deposits of coal should be removed to reduce the heating in the coal pile. The use of water for cooling the static deposit is best achieved by a fine mist of water.

- the height of an uncompacted pile should be approximately 5 m as Talcher coal has high heating tendencies.

7.5.2 Compacted Coal Storage

HNPCL proposes to adopt compacted coal storage practices given in Fire Protection Hand book(17th edition,NFPA) for storing its coal. Compacted coal storage density is about 1121-1201 kg/m^3 (70-75 pcf) and air occupies approximately 12% of the volume of the pile. Coal is distributed by grab buckets or any other

means in a uniform layer not over 1m deep. The layer is then levelled by rolling. Distributing the coal evenly avoids breakage and segregation of fine coal. The sides as well as the top are thoroughly compacted. Compacted coal storage, with regular temperature checks greatly reduces the chances of oxidation, thus reducing the risk of fire.

The following precautions need to be taken while designing a compacted coal storage:

- Coal should be of a definite specification to secure characteristics least likely to support spontaneous combustion while providing a satisfactory fuel.
- Storage of coal in contact with any sourçe of external heat and over iron or steel fire service water mains should be avoided.
- Air movement through the coal pile should be reduced.
- Regular temperature checks should be maintained.
- Low grade coal should be piled not higher than 3m. and best grade coal not higher than 5m. If the coal is piled by roll packing, then the height of the pile should be nominally around 8 m.

7.5.3 Special Storage Precautions

It is beneficial to handle coal in a manner that prevents segregation of coarse from the fines. Segregation occurs when coal is placed in a conical pile; the coarse coal runs to the edges and outside of the pile and the fines collect in the centre. Air can then move readily through the course coal to the fines having the large specific surface area and heating is greatly encouraged.

Placing coal in storage near a vertical wall presents special problems, because coal tends to be less compacted when it is placed near these vertical surfaces unless special precautions are taken. Preferably, coal should not be stored around supporting beams or similar members. Less dense coal provides a natural flue for air ventilation. When vertical walls or surfaces of any kind cannot be avoided, it is desirable to move the coal into storage along the wall or parallel to the wall as opposed to pushing the coal up to the vertical surface.

a. Checking Temperatures

Steam (white vapours) rising from a coal pile or the odour of burning coal is an indication of spontaneous heating, but an earlier and more reliable indication can be obtained by checking the temperature. This can be done by driving 1 inch (25 mm) capped piping to within 0.3 m to 0.6 m of the bottom of the pile at points about 3 m apart on centres. A two-hole stopper is fitted in an ordinary test tube, and a thermometer inserted in one of the holes. The test tube is filled nearly full with water, and lowered into the pipe by a string. It is allowed to remain until it has assumed the temperature of the coal. The water prevents a rapid change in thermometer reading when the tube is withdrawn.

b. Heating in Railway Wagons

Incidence of fire is reduced if:

- the top surface of the coal dump in the wagon is levelled,
- the trap doors of the wagon are kept properly plugged, and
- care is taken not to feed the wagon with already hot coal.

c. Heating in Bunkers

Usually, fine coals have a tendency to cling to the sharp bends in the bunker, which on accumulation become the source of initiation of the spontaneous heating. These spots need to be cleaned from time to time and the accumulation or sticking of coals at the edges should not be allowed.

7.5.4 Handling Coal Fires

a. Stack Fires

The usual methods of dealing with fires in stacks are to dig out the hot mass, or to isolate it by cutting a trench, if the fire is at an edge. The exposed surface is then cooled with water and the loose material is consolidated to prevent further heating. But, it is difficult to follow above procedure in practice, since once disturbed the whole stack becomes vulnerable and the fire may spread faster. Hence, success in dealing with stack fires depends on the speed of the operation and optimisation of the above steps.

b. Conveyor Belts

Coal conveyor belt system presents two principal fire hazards, (i) those due to rubber belts, and (ii) those due to coal. The belts are combustible and likelihood of damage due to tearing is possible besides the danger of spreading fire from one area to another.

Friction between the conveyor belt and roller is a common cause of fire, hence conveyers need to be inspected regularly to detect belt slippage or defective rollers. All moving parts should be lubricated regularly.

Careless cutting or welding on the conveyer or its housing is another leading cause of fire. Hot globules or metal sparks could ignite combustibles on the belt. If cutting or welding is needed, accumulated combustibles should be removed, belt should be covered with a flame resistant tarpaulin, or a water tray should be provided to collect the hot globules of molten metals. Besides, a fireman equipped with an extinguisher or a fire hose should be posted.

Electrical short circuits and spontaneous ignition are other causes of conveyer fires. Fire occurring at the electrical motors which provide motive power to the belt is another possibility. The motor may be overloaded by excessive friction within itself, obstruction in the driven belt, overloading the belt beyond the safe limits, etc. If any of these conditions cause overloading of the motor, self heating will occur, resulting in breakdown of insulation, melting of soldered connections, or the bearing being damaged. To safeguard the motor and to prevent fires, it is recommended that overload relay opening the circuit to the motor should be frequently checked and maintained in good working conditions.

Wooden planks on MS grating constituting a pathway for the operator to walk should be maintained and broken planks replaced regularly.

A safety wire cable should be provided along each section of the conveyor belt which the operator can pull to stop that section of the conveyor. This safety measure should be incorporated for all conveyors having walkways.

The belt conveyors should be of a material designed to resist ignition. The system must be provided with a device arranged to automatically shut-off driving power in the event the belt slows down. The hydraulic system for belt alignment, if provided,

should be of fire resistant hydraulic fluids. Means should also be provided to remove tramp metal and other foreign objects to the extent possible, to prevent damage to the belt.

The transfer points of the belt conveyors or loading points should be adequately hooded and dust collectors with suction hoods having sufficient capacity should be installed at these points.

Detection Systems for Coal Conveyors

In conjunction with fixed fire protection systems, fire detection systems are usually necessary because they sense fire more rapidly and operate usually more quickly than the fixed systems. Detectors should be sensitive to heat, smoke, products of combustion, or light (radiation) produced by fire.

Detection systems commonly used and recommended are:

a. fixed temperature devices, both pneumatic and electrical
b. combustion or ionization type detectors
c. smoke or light obscurity detectors, sometimes known as optical smoke detectors
d. radiation type detectors, both ultraviolet and infra red
e. combination of the above-mentioned detectors

7.5.5 Fire Protection Arrangement

An effective fire loss control program aims at the prevention of loss of life, injuries to personnel, loss of property, and business interruption. Its primary purpose is to prevent the inception of fire. Nevertheless, evidence that inspite of adopting the best measures for fire prevention, the possibility of eruption of a fire on account of some failure or inadvertence, cannot be ruled out. To control such situations, it is of paramount importance to have adequate arrangements for:

- Fire detection systems
- Fire communication systems
- Fire protection systems

HNPCL has designed the fire protection system as per NFPA/TAC guidelines. Major components of the fire protection system proposed by HNPCL are:

- Fixed water systems to automatically detect and suppress fires in protected areas
- Independent smoke detection systems to automatically detect fires and provide alarms in protected area
- Instrumentation and control equipment for alarm, indication of system status and actuation of fire protection equipment
- Portable fire extinguishers
- Stand pipes and fire hose houses
- Fire hydrants and accessories, including hoses
- Underground yard piping, aboveground piping and valves
- Piping and valves between fire water source and the various fire protection systems

a. Fire Detection Systems

The HNPCL plant will be manned round the clock in three shifts. Therefore, the detection of fires is not likely to be delayed as all the areas would be normally occupied. As a safety precaution measure, HNPCL proposes to install fire detectors at all important places, i e, control room, battery room, administration building, turbine building, boiler floor, storage tanks, laboratory, yard control building, EP control house etc.

The control room will be housing sophisticated instrumentation, cables, fixtures, etc. Therefore, HNPCL is planning to provide ionisation type smoke detectors. When smoke particles enter the ionisation area, they decrease the conductance of the air by attaching themselves to the ions, causing a reduction in mobility. When the conductance is less than a predetermined level, the detector responds. Since the control room will be provided with smooth false ceiling, the spacing between two detectors in the control room may be not more than 9.1 m (30'). Manufacturer's recommendation, however, should be complied with. A minimum of two detectors should be provided in the control room even if its size is small to ensure that fires are detected automatically even if one of the detectors fails during fire.

Similarly, such smoke detectors may be installed in the administrative office to detect fires, especially during non-occupancy hours.

The detectors installed in the plant will be connected to annunciator panels. Local annunciator panels may be installed at the same location where detectors are provided, while the central an-

nunciator panel will be installed in the plant control room and/or the security office at the gate.

Isolation of any detection system will not be resorted to. In case of false alarms, due to some faults, etc., the system will be rectified and be made operational at once.

Regular inspection and testing of detectors will be carried out in accordance with manufacturers guidelines, company policy and national standards.

Emergency power supply will always be available for the fire detection system.

b. Fire Communication System

HNPCL has proposed to provide break glass type, manual fire call points at several locations to facilitate communication regarding fire to all employees. In the event of a fire, an employee can break the glass of the alarm, to actuate an alarm/siren to warn all the personnel in the plant.

To provide proper distribution and protection in the plant, a fire alarm box should be visible from a distance and the travel distance to reach the fire alarm box should not be more than 61 m (200'). These may preferably be installed along the escape route of various areas in the plant. These fire alarms may be connected either to a separate siren/ hooter or to the annunciator panels connected to the detectors. In addition to the fire alarms, internal telephones/ pagers/walkie-talkies will be provided which will also facilitate communication in the event of a fire.

c. Fire Protection System

Portable Fire Extinguishers

HNPCL proposes to provide foam, carbon dioxide, dry chemical powder (DCP) and other types of portable extinguishers at various locations depending on their compatibility and as per the rules laid down by Tariff Advisory Committee (TAC).

Fires have been classified into four categories, A,B,C and D by NFPA. Suitable type of extinguishers for each class of fire are listed in the following table:

Class	Description	Suitable type of extinguishers
A	Fires in ordinary combustible materials such as wood, cloth, paper, rubber, and many plastics	Water
B	Fires in flammable liquids, oils, greases, tars, oil-based paints, lacquers, and flammable gases	Foam, carbon dioxide, and dry chemical powder
C	Fires that involve energised electrical equipment where the electrical non-conductivity of the extinguishing media is of importance (When electrical equipment is de-energised, extinguishers for class A or B fires may be used safely)	Carbon dioxide and dry chemical powder
D	Fires in combustible metals, such as magnesium, titanium, zirconium, sodium, lithium and potassium.	Special type of Dry powder

Portable fire extinguishers are generally used for extinguishing fires in their initial stages immediately after their detection. These extinguishers are designed for this purpose but their effective use depends on the correct selection of extinguisher, proper location and availability of a person who is well-trained to make an effective use of the extinguisher.

In accordance with the above table and anticipated class of fire, suitable type of extinguishers will be provided at various locations in the plant. The distribution of extinguishers will be in compliance with Indian Standards IS:2190-1992 "Code of practice for selection, installation and maintenance of portable first air fire extinguishers."

Portable extinguishers may be provided at convenient locations in order to ensure ready access. The maximum running distance to locate an extinguisher may not exceed 15 meters. The effective use of these extinguishers in controlling the fires would largely depend on their easy accessibility and availability of a person who is well trained in operating the extinguishers and is also aware of their compatibility depending on the class of fire. The extinguishers may be mounted at a height with a red rectangle or band

painted above them. This would enable the employees to locate the extinguishers from a distance.

Fire Hydrant System

HNPCL will install a 10,800 m^3 water storage tank exclusively for fire-fighting. The fire hydrant system normally requires an exclusive static water storage capacity of not less than 3 hours' aggregate pumping capacity which comes to 900 m^3. Therefore, HNPCL's plan for fire-fighting water storage will be adequate.

Electrical motor as well as diesel engine driven fire pumps will be installed to ensure uninterrupted water supply in case of emergency. Pumps will have a capacity of 273 m^3/h and a discharge pressure of 7/8.8 $kg/cm^2.g$.

The hydrant system will be pressurised at all times by a jockey pump. The capacity of the jockey pump should be between 3% (with a minimum of 180 LPM) and 10% of the installed pumping capacity.

The fire water pressure system may be designed for a minimum residual pressure of 3.5 $kg/cm^2.g$ at the hydraulically remotest point of application in the plant.

At least two fixed water monitors will be installed in coal storage and tankfarm yard for fighting fires from a distance.

The number of hydrants may be determined by maintaining a separation distance of not more than 45 m. may be considered for coal storage yard.

7.6 Ash Pond Dyke Failure

The ash pond dyke will be designed, constructed, and operated according to the best international standards/practices. National Power PLC, UK, one of HNPCL's promoters already operate plants generating over 20,000 MW worldwide. They have built and are operating plants with individual plant capacities and ash ponds larger than that proposed at Visakhapatnam.

The designs submitted by the EPC contractor will include the usual provision of toe drain, impervious core, etc. The designs would be reviewed by HNPCL's engineering consultants and in-

house specialists before start of construction. The construction would also be appropriately supervised.

As detailed in earlier sections of this document, the ash pond effluent is proposed to be re-circulated and also provides for a 50% blowdown to sea (after treatment) via the outfall. The ash pond design will include adequate provision of seasonal as well as anticipated unseasonlal rain during cyclones. During operation, water levels will be monitored and managed within acceptable safe limits to eliminate any risk of overspill.

CHAPTER 8

EMERGENCY PREPAREDNESS PLAN

Emergency is a general term implying hazardous situation both inside and outside the factory premises. Thus the emergencies are termed "On-site" when it confines itself within the factory even though it may require external help and "Off-site" when emergency extends beyond its premises. If an emergency occurs inside the plant and can not be controlled, it may lead to an off-site emergency.

The type of emergency primarily considered here is one which has the potential to cause serious danger to persons and/or damage to property and which tends to cause disruption inside and/or outside the site and may require the use of outside resources.

Emergency preparedness plan is a comprehensive plan to (i) respond to a number of foreseeable emergencies anticipated in the works, (ii) minimise the loss of human life and property, and (iii) provide speedy and effective remedial measures. An important prerequisite for emergency planning is to foresee an accident scenario which leads to a major fire, explosion, release of toxic material/fumes, their spread or extent and their damage potential. This information is used in conjunction with layout of the units in the plant, and adjacent communities in preparation of the EPP.

The objectives of emergency planning are as follows:

1. Identification of the disaster potential scenarios and advance planning for each case to combat the disaster and minimise damage to life and property
2. Disaster phase, i e, warning, protective actions such as evacuation of personnel, etc
3. Containment of disaster by isolating, fire fighting, etc
4. Rescue, relief assistance to the people affected in the works/community effectively and efficiently based on the actual needs and on the information collected locally, both in before and earliest possible after the disaster occurs
5. Restoration of normal conditions after the disaster is contained

To effectively achieve the objectives of emergency planning, the following factors are critical:

- reliable and early detection of an emergency and careful planning
- command, co-ordination, and response organisation structure along with efficient trained personnel
- availability of resources for handling emergencies
- appropriate emergency response actions
- effective notification and communication facilities
- regular review and updating of the EPP
- appropriate training of the concerned personnel

The format and contents of the EPP have been developed taking into consideration the regulatory guidelines, other applicable documents and accepted industry good practice principles formulated as a result of lessons learned in actual emergencies requiring extensive emergency response.

It is recognised that an EPP will work smoothly and effectively only if the instructions are correctly and promptly followed and action taken at various levels is well co-ordinated.

8.1 Responsibility

Responsibility for establishing and maintaining a state of emergency preparedness lies with the Station Manager. (S)he is responsible for maintaining distribution control of the plan, and for ensuring that the plan and the applicable implementing procedures are reviewed and revised periodically. The Safety Manager is responsible for the training of personnel to ensure that adequate emergency response capabilities are maintained in accordance with the plan. (S)he is also responsible for ensuring the adequacy of the conduct of drills, as outlined in the EPP. All employees of various departments are responsible for carrying out their responsibilities, as given in this EPP.

8.2 Scope and Applicability

This EPP describes the organisational structure, facilities, equipment, services, infrastructure, etc necessary to respond to emergency situations which could have on-site and off-site implications. The plan also applies to participating government agencies that are responsible for emergency response within the immediate area surrounding the plant and to those agencies, organisations, contractors, and facilities which provide assistance to the facility during an emergency.

The plant may also call upon or render assistance to other facilities or agencies as requested and to the extent possible under the Mutual Aid Scheme. It is necessary to maintain liaison with government agencies to ensure an understanding of and proper interfaces for notifications, responsibilities of personnel, and the resources of state and local agencies.

8.2.1 Organisational Structure

For handling an emergency effectively, an organisation chart for the specific purpose is proposed. This organisation chart given in Exhibit 8.1 could be modified to suit HNPCL's requirements.

8.3 Concept of Operations

Concept of operations deals with the possible steps associated with an emergency response assuming the most severe emergency scenario (although this may not, and most likely, will not always be the case). This includes :

- Accident initiation and raising alarm
- Accident evaluation and classification of on-site emergency declaration
- Off-site and external agency notification
- Implementation of on-site response actions
- Implementation of protective actions and evacuation
- Co-ordination of response actions with external agencies
- Management of emergency resources
- Recovery and plant re-entry procedures

Thus, should an emergency occur, the initial indication would be by raising the alarm in the Main Control Centre or by the person who first notices a problem. The Station Manager is to be immediately notified and would assesses the severity of the condition, classifies it appropriately and directs the response actions of the plant personnel to mitigate the condition. Upon classifying the situation as an On-Site (Site Emergency) or Off-Site (General Emergency) emergency situation, the Operations Manager will assume the responsibility of the Main Controller and activate the EPP, pending the arrival of the Main Controller.

After classification of the emergency as a Site or General Emergency, the Main Controller would provide for the immediate notification of the appropriate off-site governmental agencies, provide recommendations for protective actions, if necessary, and

activate the full Emergency Response Organisation. This organisation, operating out of the Main Control Centre, functioning as Emergency Control Centre (ECC), provides overall assessment, damage control, notifications and communications, and employee and public protective actions during emergency.

Upon termination of the emergency, the Main Controller in conjunction with plant management, will establish a Recovery Organisation to manage those activities necessary to return activities to normal.

8.3.1 Raising of Alarm

Raising the alarm is the first step in the implementation of EPP. Any employee noticing an unusual event will be responsible for raising the alarm or at least alerting someone who can then raise the alarm. This procedure has the advantage of permitting the earliest possible warning of any potential abnormal situation. All employees will be trained in the procedures for raising the alarm and will know that initial steps to take (e g, activating the fire alarm). It will also be the responsibility of any staff member noticing an emergency situation to inform the Operations Manager/ Plant Engineer/ Shift Engineer, etc.

- Public address system
- Horns, sirens, etc.
- Telephone messages, fax messages, pagers, hot lines
- Sending message through a messenger
- Rushing personally to the cabin

While giving the message, the person should :

1. Identify himself/herself
2. State briefly the type of emergency, i e, whether fire, explosion, etc.
3. Give the location of the incident
4. Estimate the severity of the incident and return to a safe area nearest to the incident and await instructions from the Operations Manager
5. Check wind direction and move upwind or crosswind of the incident site
6. Conduct a preliminary check and try to identify the cause, type and location of the accident
7. Stand by to render all possible assistance.

Exhibit 8.1. Proposed organisational structure for handling emergency

The following alarm system or similar system will be used to identify the various levels of emergency.

1. First level warning - for an accident within the plant and at the site of the incident.

   Hooter - Short, intermittent

2. Second level warning - when the Main Controller perceives the affected area to be the entire plant but which can be confined within such limits.

   Siren - wailing, short, intermittent siren

3. Third level warning - when the Main Controller considers that the accident would assume off-site implications.

   Siren - wailing, long and short, intermittent siren

4. All clear - to declare the end of emergency

   Siren - long, continuous siren lasting one minute

8.3.2 Emergency Functions

Command and control of an emergency comprises the key management functions necessary to ensure the health and safety of employees, as well as the public living in the vicinity. In addition, the implementation of the EPP rely on a number of response functions which deal with different aspects of emergency, with the most important emergency functions being:

- Communications, Co-ordination, and Liaison
- Fire and Rescue
- Special Hazard (Leakage and Vapour Release Control)
- Process/Utilities
- Engineering/Technical Services
- Environmental and Field Survey
- Medical Services
- Security
- Safety
- Logistics
- Administration

The personnel in charge of each of these functions will respond to the Main Controller or Incident Controller. Each function will

be staffed with a team, the size and composition of which will depend on the task to be carried out during the emergency and the size of the plant. These teams will operate according to the instructions provided by the Main Controller and utilise guidelines to accomplish their task. Some of these teams will mainly operate in the ECC (e g, the co-ordination/liaison team) and others would operate in the field (e g, the fire and rescue teams) or in other parts of the plant.

8.4 Action Plan - Duties of Personnel

It is important that the EPP creates a response organisation structure capable of being deployed in the shortest time possible during an emergency. Appropriate initial response actions can significantly reduce the consequences of an accident before it escalates in magnitude.

Accidents may happen during any time of the day or night. Consequently, the emergency response organisation will be available to be deployed even during those periods when the plant may be operating in shifts with reduced personnel. Thus, the responsibility of coordinating the emergency response actions will be assigned to the Shift Supervisor until (s)he is relieved by higher-ranking personnel, such as the Operations Manager. Initially, the Shift Supervisor would temporarily assume the function of Main Controller and, as such, assess the level of severity of the accident, declare the emergency using the emergency alarm levels described earlier, notify the appropriate personnel, departments, and agencies, and begin the response actions. Similarly, additional plant personnel will be assigned the task of covering other important key functions in the EPP until other personnel arrive at the scene of the accident to relieve them.

Effective command and control to accomplish these functions necessitates training of personnel in the EPP along with adequate facilities and equipment to carry out their duties and functions. Such training and facilities will be provided.

8.4.1 Main Controller

It is essential that only one person be in-charge of the overall emergency response organisation at the plant. This person is the Main Controller with the main responsibility of overall guidance of emergency management. Co-ordination may be carried out by the Incident Controller. The other tasks include the overall supervi-

sion of all protective actions aimed at protecting the public, employees, environment, the site plant and the support and accident control actions to bring the emergency under control.

The Main Controller's function will be assumed by the Station Manager because of the responsibilities associated with it. The designated deputies to the position of Main Controller could be the Operations Manager until relieved by the next higher-ranked designated official, ensuring round-the-clock coverage of the command post.

In most instances, the Main Controller would co-ordinate the response action from the control room with the support of the control room staff. Nevertheless, should the emergency escalate, the emergency management centre should be moved to a alternate designated ECC from where the entire response organisation would operate. The Main Controller would operate from this location together with his/her staff, except for such personnel, as the Field Operations Co-ordinator, who may be directly involved at the scene of the accident.

The Main Controller should :

1. relieve the Incident Controller of responsibility of the Main Controller
2. analyse the emergency and decide on the emergency level warning
3. direct, co-ordinate and supervise the emergency response activities
4. direct the shutting down, evacuation, and other operations at the plant, and if required, take any other appropriate action that may be necessary for the emergency response
5. ensure on-site and off-site personnel protection, safety and accountability
6. ensure that the casualties, if any, are given medical attention and that the relatives are informed, if necessary
7. arrange for relief of personnel when emergency is prolonged
8. liaise with off-site emergency response personnel, departments and organisations such as fire and police officials and other statutory bodies and advise them of all likely effects of the incident outside the plant premises (if any)
9. regulate traffic movement within the plant
10. issue authorised statement to the news media
11. ensure preservation of evidence for inquiries to be conducted by statutory authorities

12. authorise the termination of emergency situation by sounding of the "All Clear" siren

8.4.2 Incident Controller

The Incident Controller will operate from the ECC, and be responsible for supervising and coordinating the activities of those functions involved in mitigating the consequences of the accident. (S)he will keep the Main Controller informed of the situation from time to time. (S)he shall immediately proceed to the scene of emergency and assess the situation. The Incident Controller should be equipped with a distinctive fluorescent jacket for easy identification (which should be provided in the ECC).

Operations Manager would assume the role of Incident Controller and take charge of the situation. Typically the person fulfilling this function should be fully familiar with the operation of the plant and its response organisation. When deemed appropriate, the Incident Controller position may coincide with the Main Controller function and both positions assigned to just one person. This may also be the case during the initial phases of the emergency, when the full response organisation has not yet been deployed.

The Incident Controller should:

1. help the Main Controller organise and direct the emergency response activities keeping in mind the safety of personnel and minimising loss and damage to property
2. formulate strategies and advise the Main Controller of the actions to be taken to mitigate the consequences of the accident
3. maintain direct communications with the on-site Field Operations Co-ordinator
4. co-ordinate the activities aimed at organising, requesting, and obtaining additional resources (both as equipment and personnel) to support the field operations
5. co-ordinate with the Security In-charge, Safety Co-ordinator, Fire Controller, etc
6. check for casualties
7. arrange for rescue of trapped workers and those in a state of shock
8. get all non-essential workers safely evacuated after stopping all those jobs which are not required during an emergency
9. set up a communication system with the ECC through telephone, wireless and/or messenger system

10. pending arrival of the Main Controller, direct the shutting down and evacuation from the plant and call outside emergency service, if necessary
11. allot jobs to the emergency squad
12. report all developments to the Main Controller
13. preserve all evidence for subsequent use in case of an inquiry

8.4.3 Field Operations Function

The Field Operations Controller is the highest-ranking Emergency Response Organisation officer at the scene of the accident with headquarters at a safe location as closest to the emergency from where the emergency field operations are carried out.

The Field Operations Controller should have good technical expertise and must be fully familiar with the plant. This position will be assigned to a Senior Engineer. The main responsibilities associated with this position are:

1. Direction and co-ordination of all field operations at the scene of the accident
2. On-scene accident assessment
3. Implementation of on-site response actions to protect plant personnel and the public (protective actions)
4. Implementation of on-site response actions to bring the emergency under control (support and emergency control actions)
5. Co-ordination of these actions with the Incident Controller at the ECC

8.4.4 Administration Function

This function should provide the necessary administrative and clerical support to relieve the technical personnel from such responsibilities. The Administration Manager would perform the administration functions.

The Administration Manager should :

1. immediately proceed to the ECC
2. work as a liaison officer during the emergency
3. under the direction of the Main Controller, handle police, press and other enquiries, receive reports of roll call from emergency assembly areas and pass on the absenteeism information to the Incident Controller

4. ensure that casualties receive adequate and immediate medical attention
5. inform the nearby hospitals and call for ambulance, if required
6. control traffic in and out of the plant and ensure that alternate transport is available when required for casualties
7. maintain prior agreed inventory of emergency equipment at the ECC and make up for shortages
8. keep chronological records of what is happening during the emergency, and prepare reports for the Main Controller and his/her staff, including:
   - recording any change in the emergency action level status
   - keeping track of all external agencies notified
   - keeping track of emergency personnel intervening
   - keeping track of emergency personnel notified and arriving at the scene
   - maintaining a record of the changes in the emergency organisation structure as higher officials arrive to relieve lower-ranked personnel
   - keeping a record of all events affecting the emergency
   - keeping a record of the decisions made and emergency actions taken during the emergency operations
   - updating maps and wall charts displaying the spreading of the emergency (e g, units affected by fire, areas affected by evacuation orders), and maintaining a record of them
   - updating the charts mentioned above showing the position of the emergency squads or fire companies, and keeping a record of them
   - recording the arrival of special emergency materials or equipment (this may be especially important for subsequent financial accountability)
   - recording any other fact of relevance occurring during the emergency

The chronological log is extremely valuable both during and after the emergency. The greatest advantage of such a system is to maintain an update of the situation. This information can then be used by the emergency co-ordination staff to assess the situation and make appropriate decisions. In addition, such a log can be used after the emergency is over to assess responsibilities and proper conduct of the emergency operations, and for determining the financial liabilities of bringing the emergency under control. Records can also be extremely useful in planning for future emergencies, and for training.

8.4.5 Fire and Rescue Function

This function can be handled by the Fire Officer/Chief Security Officer/Inspectors. This function will be composed of personnel from the different plant units or departments, such as works, maintenance, technical services, safety and security. The team will have basic training in the handling of various types of emergencies. As fire is the most common hazard, the team members will be trained in recognising different types of fires and the appropriate extinguishing agents for fighting these fires. They will also be trained to handle the available fire-fighting equipment including hoses, nozzles, portable extinguishes and fixed fire-fighting units.

The fire and rescue team leader will report directly to the Field Operations Controller and make important decision regarding the response to the particular emergency.

The duties of the fire and rescue team leader will be as follows:

1. to be the overall in-charge of the fire fighting operations
2. to inform the Main Controller if external fire tender/fire fighting equipment/materials/mutual aid is required
3. to liaise with the utilities and arrange for external water supply/diesel for hydrant pump/ D G sets, etc
4. To maintain adequate supplies for fire-fighting equipment and facilities.

8.4.6 Medical Function

The Medical Function will be handled by the Medical Officer on duty. The primary responsibility of the Medical Officer during an emergency will be to provide first-aid to victims of the accident, and to ensure their prompt transportation to a treatment installation, such as a hospital, if required. In this regard, the Medical Officer will work closely with the Commercial Manager responsible for logistics function to organise such an emergency transportation system. In addition, the Medical Officer will be responsible for maintaining a first-aid station for the immediate treatment of possible victims, which should be appropriately equipped with medical supplies, oxygen, resuscitators, and other supplies. The Medical Officer must ensure that the emergency response personnel are familiar with first aid administration.

The medical officer will provide information on the nature and properties of substances, be responsible for possible injuries, and

for ensuring most appropriate emergency treatment of injured or exposed personnel.

The Medical Officer should :

1. establish contact and cooperate with local hospitals and ensure that the most likely injuries (e g burns) can be adequately treated at these facilities
2. advise the Main Controller and his/her staff on industrial hygiene matters, and make sure that the plant personnel are not exposed to unacceptable levels of toxic compounds during emergency operations
3. make arrangements for treating and transporting the injured to the hospitals where arrangements are made to handle such emergencies
4. inform the above hospitals of the situation in case of a toxic release and apprise them of the antidotes that would be necessary for treatment
5. maintain a list of blood groups of employees with special reference to rare blood groups

8.4.7 Logistics Function (Commercial Manager)

This function involves (i) making the necessary supplies available to response teams during an emergency, (ii) organising and maintaining the staging area and providing temporary storage for emergency supplies and equipment for rapid deployment, and (iii) coordinating, hiring, controlling, and operating all emergency vehicles such as ambulances, trucks for transportation of emergency materials and supplies and other emergency transportation vehicles.

The person responsible for this function, the Logistics Coordinator, in this case the Commercial Manager, should report to the Incident Controller and keep him/her updated on available supplies and equipment needed for an emergency. A list of emergency materials and equipment is as follows:

- Fire extinguishers and fire-fighting agents
- Fire hoses and nozzles
- Personal protective equipment, including full protective clothing, self-contained breathing apparatus, and respirators
- Emergency lights and power generators
- Spill control agents for the decontamination of toxic spills of different classes of chemicals
- Earth-moving machinery

- Fuel and gasoline for the operation of emergency vehicles and machinery

8.4.8 Security Function

During the initial phase of an emergency, the security personnel may be in charge of communications within the plant as well as with outside agencies, before being relieved by the appropriate coordinator. The position of the Security Controller could be handled by Security Officer and assisted by inspectors and guards. The main responsibility, however, of the Security Controller, will be to ensure that plant security is maintained. The Security Controller should:

1. raise alarm by sounding the siren
2. inform the Operations Manager/Shift Supervisors
3. close the gate(s) and ensure that unauthorised persons/vehicles do not enter the premises
4. instruct the security guards to occupy pre-determined posts for controlling the security of the plant
5. control the entry of authorised personnel, such as officials of outside agencies and other personnel that may be at the plant
6. control the escorting of outside official agency representatives and other appropriate personnel to the corresponding plant liaison personnel, as per instructions; also ensure that media representatives are not directly admitted to the ECC (in order to minimise any unnecessary interference during emergency operations).
7. be in charge of personnel accountability during the emergency; should some plant employees be unaccounted for, and presumed to be still in the area affected by the emergency, alert the Incident Controller, who will then initiate a search and rescue operation (if feasible)
8. direct the exit of plant personnel in case of evacuation, and cooperate with external police force(s) to organise and direct evacuation operations for the public, if necessary
9. arrange for proper transport for required personnel in the plant during an emergency
10. ensure that the affected area is not crowded by non-essential persons.
11. provide assistance in fire-fighting and rescue operations

8.4.9 Safety and Environment Function

The Safety and Environment Function involves advising the emergency co-ordination staff on safety of members before implementing any of the response actions. The position could be assumed by the Safety and Environmental Engineer. (S)he should (i) deal with all aspects of safety during emergency operations, (ii) be responsible for minimising the impact of an accident on the environment by implementing methodologies to control hazardous spills and co-operate with the emergency response squads to conduct the actual clean-up work during and after the emergency, (iii) contain the run-off of fire water and other water from the damaged unit in case of fire, and especially if the fire involves toxic/ flammable materials, (iv) determine the level of contamination of the site as a result of an accident.

8.4.10 Engineering/Technical Services Function

This function involves providing technical support during the emergency and act as the main technical advisory team during the emergency. The individual responsible for this function would report directly to the Incident Controller. The Engineering Coordinator should work closely with the Utilities/Engineering function which is responsible for implementing the recommended actions.

The Engineering Coordinator should:

1. elaborate plans for providing continuity of emergency supplies and services such as fire water, electric power, emergency lighting, and other required utilities
2. remain alert on duty for any electrical isolation of equipment during an emergency
3. suggest optimal strategies for conducting emergency isolation operations of damaged process equipment, the emergency transfer of materials and all other process-related emergency operations.
4. assess damages and provide technical assistance to determine the operability of damaged units
5. carry out or assist the accident investigation.

8.4.11 Process/Utilities/Maintenance Function

The function is responsible for controlling the plant's process during the emergency and ensure that the plant units are shut down, if required. This function will be staffed with Production and Maintenance personnel and will operate under a Co-ordinator

(Engineering & Maintenance Manager) responding to the Incident Controller in the ECC in conjunction with the Fire and Rescue teams.

The duties of the co-ordinator of this function will include:

1. recommending the appropriate procedures to isolate damaged units without introducing new hazards and providing resources, both in terms of personnel and equipment
2. making available the necessary utilities during the emergency, isolating or recommending emergency isolation procedures to prevent utility distribution to damaged parts of the plant, if required, and activating backup emergency utility generators
3. assisting in extricating trapped personnel by cutting structures, wires, etc

8.4.12 Emergency Squad Function

This function involves bringing any emergency associated with toxic or hazardous materials under control. Emergency squads will be equipped with appropriate protective devices (e g, respirator, self-contained breathing apparatus, full protective clothing) and be able to handle special hazards. The emergency squad may work in conjunction with the fire and rescue teams for handling an emergency.

The emergency squad shall comprise members drawn from various departments of the factory, particularly production, security and service (utilities), a minimum of 6 or 7 persons should be available in each shift. The members of the emergency squad will respond to the alarm and report directly to the On-site Field Operations Controller. Their duties would be to:

1. act as fire-fighters and assist the Field Operations Controller in controlling the emergency
2. act as runners and messengers
3. act as first-aiders and rescuers and handle casualties / persons overcome by fire / toxic release
4. provide details of casualties
5. provide lighting in the area
6. isolate equipment
7. evacuate non-essential personnel and visitors
8. maintain record of evacuated personnel
9. carry out any other job assigned by the Field Operations Controller

8.4.13Transport Function

The person in-charge of this function will be responsible for keeping vehicles and drivers in readiness and maintain constant contact with the Main Controller/Medical Officer-in-charge and despatch the vehicles as per their needs. All drivers on duty at the plant will on sounding of the alarm rush back to their departments and await instructions. A minimum of two cars should be kept standby at the plant for the emergency use and for transporting critically injured to hospital.

8.4.14Telephone Function

The responsibility the person in-charge of this function (the Telephone Operator or designated stand-in for evening and night shifts) would be to:

1. notify the location of emergency to the Security Department, Emergency Squad members, Main Controller, Safety Officer, Administrative Officer etc
2. on receipt of instructions from the Main Controller or his/her designate, notify the fire brigade, police, hospitals, District Collector, Factory Inspector, etc
3. keep the telephone board open for emergency calls and transmit the same to the concerned personnel effectively
4. refrain from exchanging any information pertaining to the emergency and refer any queries from authorised persons to the Main Controller

8.4.15Personnel in Emergency Affected Area

The personnel in the emergency affected area(s) should:

1. continue to handle the emergency as per the procedures laid down and as guided by the Incident Controller
2. avoid crowding of the affected area by unwanted personnel
3. stop all non-essential work/unwanted operations
4. remove unwanted persons from the area to a "safe assembly area" (to be clearly marked on the site plan).

8.4.16Personnel in Non-affected Areas

The personnel in non-affected areas/departments shall:

1. promptly relieve the Emergency squad members and direct them to rush to the scene of incident

2. immediately rush back to the department/plant, on hearing the alarm, in case they are in the canteen or toilet or any other place
3. act as per the instructions of the Incident Controller
4. confine themselves to the place of work and wait for further instructions
5. take adequate steps to safeguard important documents if the area is likely to be affected
6. stop their work and report at the assembly areas, if they are employees of contractors

8.4.17 On Sundays, Holidays, and After Working Hours

During off hours, the security guards shall take up the initial responsibility of addressing an emergency. They will:

1. try to extinguish the fire with extinguisher, in case of fire, if possible
2. inform the Operations Manager/Administration Manager on phone and summon help from external agencies in accordance with their advice

The Operations Manager/Administration Manager after receiving information shall ensure that outside emergency services are summoned (depending on the severity of the incident) and direct the shutting down and evacuation of plant and areas likely to be threatened by the emergency.

8.5 Emergency Actions

8.5.1 Initial Response Organisation

Accidents may happen during any time of the day or night. Consequently, the emergency response organisation must be deployed even during those periods when the plant may be operating in shifts with reduced personnel. It is often the case that appropriate initial response actions may significantly reduce the consequences of an accident before it escalates in magnitude.

Especially under these conditions, it is essential that only one person be designated as being in-charge of the initial response to the accident. It is appropriate to assign the responsibility of coordinating the emergency response actions to the Operations Manager until relieved by a higher-ranking person. Initially, (s)he will

temporarily assume the function of Main Controller and as such, will assess the level of severity of the accident using the emergency alarm levels described earlier, notify the appropriate personnel, departments, and agencies, and begin the response actions. Similarly, additional plant personnel will be assigned the task of covering other important key functions in the initial emergency response organisation until other personnel arrive at the scene of the accident to relieve them.

8.6 Emergency Capabilities

To respond to an emergency effectively, an inventory of certain facilities must be maintained and sufficient supplies of equipment must be available with help from mutual aid industries, where agreements should be developed in advance. This includes facilities, equipment and supplies.

8.6.1 Emergency Control Centre

Upon classification of an emergency condition, the Main Control Centre is designated as the ECC. Manned for round-the-clock operations, this plant will house instrumentation, controls, and alarms for the continuous monitoring of operations.

During an emergency, the ECC will be manned by the emergency management staff, including the highest-ranking personnel in-charge of the entire operation. Therefore, the ECC will be adequately equipped with telephones, dedicated telephones, radios, and other equipment, to allow unhampered communication with the teams involved in bringing the accident under control, and with the external response organisations and other nearby industries.

The ECC will be designed to provide shelter to its occupants against the most common accidents, and especially against the ingress of smoke/vapours from accidental releases. In addition, the ECC's communication systems will be protected as much as possible against shutdown. The ECC will have its own back-up power generator for lighting and electrical communication system operations.

Only a limited number of designated people will be admitted to the ECC when in use which would eliminate unnecessary interference and reduce confusion. Security will be put in-charge of limiting access to the ECC.

The plant will also be provided with an alternate ECC to be used in case the main ECC is directly affected by the accident or too risky to operate. The location of this alternate site will be chosen carefully to minimise the possibility that both the ECCs become inoperative simultaneously.

It is likely that the site security office will be designated as alternate ECC.

The ECCs should be equipped with the following facilities/information :

- Master plan of the plant and 5 km surrounding area
- Layout of plant, equipment and storages
- Details of hazardous substances along with the material safety data sheets (MSDSs)
- Fire water system and other sources of water supply
- Availability and location of fire-fighting equipment and material
- Layout of fire extinguishers indicating their types and numbers
- First aid boxes
- Availability and location of personal protective equipment
- Self-contained breathing apparatus sets and spare cylinders
- External telephone with direct dialling and STD facilities
- Internal telephones
- List of important telephone numbers, both internal and external, displayed on the wall
- Transport plan
- Location of the plant vis-à-vis neighbouring villages, and other important facilities
- Maps highlighting assembly points along with escape routes
- Extra copies of the plant layout to be used for spot-marking of affected areas, movement of vehicles, problem areas, evacuated areas, etc
- Details of hazardous substances along with the MSDSs
- Telephone directory both local as well as of the surrounding district
- General stationery such as paper, pencil, etc
- Nominal roll and addresses of all permanent employees
- List of employees, specifically with those with rare blood groups
- Details of all contractors and their employees
- List of first aiders and emergency squad members
- Public address system

- Details on meteorological information during different seasons such as wind speed and direction, temperature, humidity, etc
- Copy of off-site plan for the district

8.6.2 Fire-fighting Facilities, Equipment, and Supplies

The plant will comprise a fire station equipped with two fire pumps, hydrants, hoses, nozzles, etc. In addition to water as the most common supply in fire fighting operations, a number of other extinguishing agents are used. Foam is one of the most important of them. Other hand-held fire extinguishers such as CO_2, DCP, pressurised water type, etc should also be provided and would be used after ensuring compatibility with the type of fire. Additional equipment and material required for fire-fighting operations to protect the fire fighters include:

- Full protective gear (fire suits) and other personal protective equipment
- Stretchers
- First aid kit
- Safety harness/life lines
- Resuscitators
- Ropes
- Cutting torches
- Wrenches and tools
- Bolt cutter
- Power saw
- Cutting tools
- SCBA
- Oxygen cylinders
- Safety helmets
- Gumboots

8.6.3 Spill and Vapour Release Control Equipment and Supplies

Many techniques and equipment are available for stopping and containing a liquid spill. A spill can be contained by dykes, curbs, and entrenchment. Plastic linings and floating booms can be used to limit the leaching of the spilled material into the ground and to nearby water streams. Spill containment equipment and supplies will be stored at the plant in sufficient quantities to cope with any possible spill.

8.6.4 Communications Equipment and Alarm Systems

Communications equipment and alarm systems are vital for notifying external agencies of an accident, making the emergency known both inside and outside of the plant, and coordinating the response actions among the various groups involved in response operations. This includes :

a. Horns, Sirens, and Public Address Systems

These are audible alarm systems commonly used in facilities. Horns and sirens rely on tones of different types and lengths to convey pre-identified messages. An alarm should do more than just warn. It should also instruct people to carry out specific assignments, such as reach an assembly point for further instructions and actions, or carry out protective measures, such as take shelter in the case of release of toxic materials. This can be achieved only if the people are familiar with the alarm system and are trained to respond to it. Training in recognition of alarms will be provided to all staff.

As horns and sirens can convey only very few and simple messages, Public address (PA) system is advantageous as it can convey a verbal message. PA systems may not always be as effective as expected because of the poor quality of the audible reception and the presence of external noise. A combination of siren/horn and PA system is more effective.

b. Telephones/ Pagers/ Walkie-Talkies

Telephones/pagers/walkie-talkies are likely to be the most commonly used communications systems to report an emergency. This equipment will link the different units of the plant during normal and abnormal operations.

c. Fax Machines

This equipment can be used during an emergency to quickly receive and transmit schemes, diagrams, maps, drawings, and other information with a high visual content.

8.6.5 Emergency Power and Lighting

The plant will be equipped with a diesel generator set (DG Set) which automatically starts on the loss of power to the premises.

The DG Set will provide emergency lighting throughout the plant, and feeds key emergency equipment, video displays in the ECC all key instrumentation, and plant alarms.

8.6.6 Medical Facilities, Equipment and Supplies

The plant will be equipped to deal with the most likely medical emergencies (like burns) at the plant and be provided with first-aid equipment. The rescue team at the plant will be trained in cardio-pulmonary resuscitation. Serious injuries, however, should be treated at the local hospital and not at the plant. For transporting the injured to the local hospital, an ambulance, or suitable vehicle that can be adapted, should be kept available.

8.6.7 Transportation Systems

During an emergency, supplies and equipment have to be transported to the scene of the accident. Some of this material is transported on emergency vehicles. Additional equipment is transported using trucks, vans, and other vehicles typically used during normal plant operation. It is important, however, that, upon the declaration of an emergency, these vehicles be made available for emergency operations, and their use co-ordinated by the personnel in charge of the emergency response organisation.

8.6.8 Meteorological Data

Meteorological conditions greatly affect the outcome of fire emergencies, especially if the magnitude of the release may have off-site implications and the public may be affected.

Wind direction and speed are the most important meteorological parameters. The plant will be provided with a meteorological station where this key information can be obtained. The monitoring stations will be located in such a way so as to provide meaningful data on the real wind direction and wind speed at ground level.

8.6.9 Security and Access Control Equipment

In case of an emergency, an important task of the security personnel is to direct the flow of incoming response teams and resources in the affected area. Moreover, the traffic flow in the plant has to be directed based on wind direction, specially in the case of flammable releases where entry to the affected areas should be restricted to response personnel. This requires the availability of equipment such as emergency lighting, road barriers, reflective

vests, reflective tape to mark restricted areas, traffic control areas, etc.

8.7 Protective Actions

Protective actions are aimed at protecting the life and health of plant personnel and the public during an emergency. These actions typically include :

- Search and rescue operations
- Personnel accountability
- Plant evacuation
- Sheltering
- Control of access to contaminated areas

There are two distinctly different areas for the protection of personnel: the "on-site" and "off-site" areas. Planning differs for these two areas, due to the nature of the population affected.

8.7.1 Plant Site

Plant instrumentation, direct observation, and verbal reports provide a base for initiating protective actions. In addition to normal operating functions, the plant instrumentation and control systems provide the means to cope with abnormal operating conditions.

Support and management personnel can be notified by telephone, or PA system. The time required for this notification should not be more than a few minutes for personnel within the plant area.

Based on the extent of emergency, the Main Controller should notify ECC staff of the need to evacuate who would then direct the evacuation in accordance with the established emergency response procedures.

For personnel accountability, attendance will be noted at the designated assembly areas. The list of unaccounted-for personnel should be reported to the Main Controller, who shall then take the necessary steps to initiate a search and rescue operation.

Evacuees will be examined for injuries and/or exposure to hazardous chemicals and dismissed or put on standby to aid in the emergency, at the discretion of the Main Controller.

Search and rescue operations should be initiated when an individual is definitely known to be trapped or injured, or when an individual is definitely known to be missing and all other attempts to contact him/her have failed.

A re-entry operation will be necessary to redefine the nature and extent of the hazard that remains following abatement of an emergency condition, to support the operations personnel on shift, and establish the means by which recovery operations can begin to bring the plant back to normal.

8.7.2 Off-site Areas

In the event of a significant release of hazardous material or other emergency condition potentially affecting off-site populations, immediate notifications to off-site authorities should be made in accordance with the emergency response procedures. Prompt on-site and off-site notification is essential for mitigating the emergency condition and minimisation of any impact on personnel on-site and off-site.

8.8 Support Actions

Support actions are those activities that take place while the emergency response plan is implemented, and which are required to support the main accident response actions and protective actions. Such activities include the medical treatment of injured persons, establishment of a staging area to organise the external incoming resources, co-ordination of action with the mutual aid teams from neighbouring industries and local response agencies, provision of social services for evacuees, law enforcement, and the recovery, plant re-entry, and restoration of services at the end of the emergency.

Emergency medical treatment and medical support will be provided to any injured personnel by the designated members of the response team. For maximum effectiveness, emergency medical treatment activities should be as prompt as possible considering rapidity of intervention and the co-ordination of intervention. Therefore emergency response personnel will be trained in basic first-aid techniques.

The staging area is an area dedicated to the operations associated with the logistics of the emergency response activities, such as:

- Receiving, temporarily storing, and despatching logistic materials to the emergency response teams
- Assembling the off-site response teams before deployment
- Parking all transportation vehicles, ambulances, fire engines, and other vehicles coming to the site
- Setting up a decontamination site (if applicable / necessary)

The staging area will be at a safe location as close to the actual scene of the accident as possible. The area will have parking facilities and provide for the possibility of movement of emergency vehicles. The availability of lighting, power, water and its security will be considered when choosing the staging area.

Law enforcement at the plant site during an emergency is an important task and is the responsibility of the security function and the local police. Their main task is to prevent non-essential personnel and onlookers from entering the plant or the scene of accident, to direct the flow of traffic in order to protect the public, and speed up emergency operations. Plant security will also be in charge of controlling access to the ECC and protecting vital plant areas, such as storage areas, emergency supply storerooms, and sensitive areas where important records and trade secrets are kept.

8.9 Notification and Communication

The Notification and Communication element of emergency planning deals with the equipment, methods, and procedures required for effective communication during the emergency. Communication is essential for the effective co-ordination of the response actions among the different response teams and functions during an emergency. In addition, if certain quantities of toxic materials are released into the environment, communication must also be established with external agencies to notify them of the release or of the possibility of a release, as mandated by law. Finally, communication is vital for implementing protective measures, such as evacuation, that may affect the general public.

In particular, communication and notification procedures are necessary for:

- raising alarm
- making the emergency known within the plant
- notifying external agencies, where required

- establishing and maintaining communication among the different functions within the response organisation at the plant, including the ECC(s)
- establishing and maintaining communication between the on-site emergency response organisation and external agencies and other response organisations
- making the emergency known outside the plant, if the general public may be affected.
- informing the media

The initial communication procedures are especially important since they determine how soon the emergency plan can be activated and also the mobilisation of outside resources, where necessary.

Communications equipment must be available to each function within the response organisation, to avoid communication breakdowns which could severely cripple the effectiveness of the EPP. Detailed communication procedure should also be in place not only to co-ordinate emergency actions to bring the accident under control, but also to alert the plant personnel and the public, should this become necessary.

8.9.1 On-site

Upon the discovery of an emergency by the plant personnel, operations personnel, or security, notification is made to the shift superintendent via the radio system or, alternatively, by internal telephone. The shift superintendent classifies the emergency, assumes the role of Main Controller, ensures that off-site notifications and plant management notifications are completed, and activates the emergency response organisation. Non-essential plant personnel, visitors, and contractors' employees are also advised about the protective actions to be taken (e g, moving to safe assembly points, taking shelter, or evacuating in the plant).

8.9.2 Off-site

Depending on the type and severity of emergency, the Main Controller at the plant should notify the appropriate external agencies. The major emergencies should be notified to:

- law enforcement departments
- fire departments and other response teams
- hospital and emergency medical services
- ambulance services

- local government officials
- local environmental agencies
- utility companies, such as water, sewer, public works, telephone, and electricity
- contractors for heavy and special machinery
- suppliers of emergency equipment
- neighbouring companies which can provide additional emergency response personnel and material
- media

The notice shall include the following information:

- Name and address of the site where the emergency has occurred
- Name, position, and telephone number of the caller
- Chemical name of the material released(in case of accidental release or spill), and whether or not the material is classified as hazardous material
- Location of the point of the release; description of the source, cause, and type of release; quantity and concentration of the material released; and whether the release is continuous
- Any known or anticipated acute or chronic health risks associated with the emergency and, where appropriate, advice regarding medical attention necessary for exposed individuals
- Proper precautions to be taken as a result of the release, including evacuation
- The name(s) and telephone number(s) of the person(s) to be contacted for further information
- Weather conditions, including wind direction and speed, and expected off-site effects, if any
- Emergency classification

Neighbouring industries can often be a source of additional resources, in terms of expertise, personnel, material and equipment. In case of other local external agencies, such possible co-operation can be more effective only if predetermined plans for intervention have been established. Mutual aid associations can be developed for this purpose. The member companies would then know in advance what kind of co-operation can be provided and by whom. During an actual emergency, the co-ordination of these outside interventions should be assigned to the designated plant function.

8.9.3 Making Emergency Known to General Public

In a situation where the general public can be affected by the accident, two possible courses of action can be taken: (1) evacuation or (2) sheltering inside buildings and houses. Whichever action is decided upon, the public must be informed of it. This can be a challenging task if an effective communication procedure is not already in place. Siren can only be effective if the public is already aware of what actions to take if the siren is sounded. The content of the messages should be as brief and clear as possible, and provide information on the action to be taken. In addition, the public should be asked to refrain from using the telephone (to minimise the potential for line overload), and to notify neighbours of the emergency (again, without using the phone). Should evacuation be recommended, the messages should inform the public of where the designated relocation areas are, and which evacuation routes to follow.

The authority to enforce these actions to protect the public is, in general, lies with local or state officials. Nevertheless, the emergency response team should be prepared for such a course of action, and :

- be ready to advise local officials
- have developed guidelines (based on the hazard analysis) on when to recommend public evacuation versus sheltering
- be knowledgeable about anticipated acute or chronic health risks associated with the emergency and, where appropriate, advice regarding medical attention necessary for exposed individuals
- take proper precautions, including evacuation, as a result of the release
- have name(s) and telephone number(s) of the person(s) to be contacted for further information
- monitor weather conditions, including wind direction and speed, and expected off-site effects, if any
- classify the emergency

8.9.4 Press Release and Accident Reports

News of the emergency and any resulting injuries would be released to the press only by the authorised officials listed in the EPP, i e, the Main Controller.

The person responsible for this function will be responsible for holding periodic press conferences, and providing accurate infor-

mation to the media. When information is not available, the person in this function should make it clear to the press.

A chronological log of events during the entire period of emergency will be maintained at the ECC by the administration function. Amongst other things, the following important data will be recorded during an emergency:

- Description of the accident
- Personnel injuries
- Equipment damages
- Response time of various service groups such as medical, transport, security, fire, safety, etc.

8.10 Maintaining Emergency Response Capabilities

To ensure prompt and professional emergency response capability, plant personnel are required to be knowledgeable of the possibility of various emergencies and emergency actions. General safety training will be provided to all employees and contractors to familiarise them with alarms, evacuation routes, sheltering areas, etc. In addition, personnel who are a part of the Emergency Response Organisation are required to have additional safety training and first-aid training and will participate in periodic drills and exercises.

8.10.1 Training and Education

Regular training will be provided to all personnel who have a role in planning and operational response to an emergency. The main goal of training for emergencies is to enable the participants to understand their respective roles in the response organisation, the tasks associated with each position and the procedures for maintaining effective communications with other response functions and individuals.

The training objectives are :

1. to familiarise personnel with the contents and manner of implementation of the EPP and its procedures
2. to train personnel in the performance of the specific duties assigned to them in the EPP and in the applicable implementing procedures

3. to keep personnel informed of any changes in the EPP and the implementing procedures
4. to maintain a high degree of preparedness at all levels of the emergency response organisation
5. to train new personnel who may have moved within the plant organisation
6. to test the validity, effectiveness, timing, and content of EPP
7. to update and modify the plan on the basis of experience acquired through exercises and drills

8.10.2 Drills and Exercises

Emergency drills and exercises constitute another important component of emergency preparedness. They refer to the enactment, under the assumption of a mock scenario, of the implementation of response actions to be taken during an emergency.

Emergency drills and integrated exercises have the following objectives:

1. to test the efficacy, timing, and content of the EPP and implementing procedures
2. to ensure by demonstration that the emergency organisation personnel are familiar with their duties and responsibilities
3. to provide hands-on experience with the procedures to be implemented during an emergency
4. to maintain emergency preparedness

The frequency of the drills would vary depending on the severity of the hazard. Nevertheless, drills will be conducted at least once per year. Scenarios may be developed in such a manner as to accomplish more than one event objective.

Drills and exercises will be conducted as realistically as possible. Planning for drills and exercises will include:

- basic objectives
- dates, times and places
- participating organisations
- events to be simulated
- approximate schedule of events
- arrangements for qualified observers
- appropriate critique of drills/exercises with participants

Evaluation of drills and exercises will be carried out and include comments from the participants and observers. Discrepancies noted by the drill observers during the drill will be pointed out during the drill. A written evaluation of the drill or exercise will be prepared by the individual responsible for conducting the drill or exercise. The evaluation will include assessments and recommendations on:

- areas that require immediate correction
- areas where additional training is needed
- suggested modifications to the EPP or procedures
- correcting deficiencies in equipment, training, and facilities

The evaluation of a drill or exercise shall be submitted to the Operations Manager for review and acceptance who should then determine the corrective actions to be taken and assign the responsibility to appropriate personnel.

The Safety Manager should track all approved drill and exercise corrective actions as a means of assuring that corrections are made in a reasonable period of time, and should advise the Station Manager/Operations Manager of the status of implementation of corrective actions.

Records of drills, exercises, evaluations, and corrective actions will be duly maintained.

8.10.3 Emergency Preparedness Plan Review

The EPP and associated implementing procedures should be reviewed to ensure compliance with relevant regulations and applicable state and local emergency plans.

The review will be the responsibility of the Station Manager/Operations Manager. The review encompass the plan, response procedures, equipment, training, drills and interfaces with local emergency management agencies. The need for changes will be based upon the following aspects:

- Written evaluations of drills and exercises which identify deficiencies or more desirable methods, procedures, or organisations
- Changes in key personnel involved in the organisation
- Changes in the plant organisation structure
- Changes in state regulations

- Modifications to the plant which could affect emergency planning
- Recommendations received from other organisations and state agencies.

8.11 Declaration and Termination of Emergency

The declaration of an on-site or off-site emergency will be made by the Main controller or designated deputy of the plant. Sirens shall be used for annunciation of facility emergency as indicated in the document.

The notification for start and termination of the emergency shall be sent to:

- Collector and District Magistrate
- Nearby industries, if any
- Police Superintendent of the area

The message will include the following:

- Identification of the emergency, e g, fire, explosion, etc
- Date and time of the accident
- Details concerning accident of emergency and probable affected areas
- Type of accident

The announcement of termination of the on-site/off-site emergency will be made by the Main Controller or District Collector, respectively, after ensuring that the plant emergency is under control.

8.12 Recovery, Plant Re-entry and Restoration of Services

The recovery and re-entry phase would begin after the declaration of termination of emergency situation. This determination would be made by the Main Controller. The recovery plan should be flexible enough to adapt to existing conditions. All of the conditions that may be encountered in an emergency situation cannot be anticipated in advance. Detailed plans and procedures for recovery operations should be prepared at the time they are needed.

Re-entry operations would be performed by the re-entry team under the leadership of the Main Controller. The team will consist of personnel knowledgeable in procedures and plant layout. In the re-entry planning process, the team will gather available information on the nature of the emergency and its current status through discussions with the operations personnel on duty. Necessary protective clothing and equipment will be available for the team before re-entry is authorised.

Specific procedures for recovering from an emergency and re-entering the plant cannot be provided, since they will have to be determined case by case, depending on the type of accident and the severity of the damage suffered. Nevertheless, provision will be made for the following:

- Organising a re-entry team
- Inspecting the damaged area
- Declaring the emergency concluded and making the "all clear" known to the plant employees and the community
- Deciding which employees should report to work and notifying them
- Beginning an investigation into the causes of the emergency
- Assessing the damage to the plant
- Transferring necessary operations to alternative locations
- Decontaminating the damaged area
- Restoring services to the damaged area
- Clearing up the debris
- Salvaging material and equipment affected by the emergency
- Restoring the parts of the plant affected by the emergency
- Determining responsibilities and instituting possible insurance and damage claims

APPENDIX A

ENVIRONMENTAL CLEARANCES

तार
Telegram : PARYAVARAN,
NEW DELHI
दूरभाष :
Telephone :
टेलेक्स (द्विभाषीय) :
Telex : (bi-lingual) : W-66185 DOE IN
FAX : 4360678
भारत सरकार
पर्यावरण एवं वन मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT & FORESTS
पर्यावरण भवन, सी० जी० ओ० कॉमप्लेक्स
PARYAVARAN BHAWAN, CGO COMPLEX
लोदी रोड, नई दिल्ली - 110003
LODHI ROAD, NEW DELHI-110003

No.J.13011/11/90-IA.II.

November 15 , 1996.

OFFICE MEMORANDUM

Subject: 2 x 520 MW Thermal Power Plant near Visakhapatnam by M/s Hinduja National Power Corporation Limited - Environmental Clearance.

In partial modification to this Ministry's Office Memorandum of even number dated 3rd September, 1996 regarding the above mentioned subject, Para 2(vii) may be read as under:-

"Only beneficiated coal to the tune of 16080 million tonnes/day should be used with average annual ash content supplied by Mahanadi Coalfields Limited not exceeding 34+1-2%. Fly ash generated should be collected in dry form in silos and fully utilised in a phased manner. As indicated in the Environmental Management Plan, increase in the dyke height above 8 m should be undertaken through use of fly ash. For avoiding contamination of ground water, ash pond area should be suitably lined and dyked. As provided in the layout, adequate space should be earmarked for setting up of ash user plants to avoid long distance transportation of fly ash."

2. This issues with the approval of the competent authority.

N Bhat

(Nalini Bhat)
Additional Director

The Managing Director,
Hinduja National Power Corp. Ltd.,
Plot No.974, Road No.50, Jubilee Hills,
HYDERABAD-500033.

भारत सरकार
पर्यावरण एवं वन मंत्रालय
Government of India
Ministry of Environment & Forests

दूरभाष :
Telephone : 4360478
तार :
Telegram : PARYAVARAN, NEW DELHI
पर्यावरण भवन, सी. जी. ओ. कॉमप्लेक्स
PARYAVARAN BHAWAN, C.G.O. COMPLEX
लोदी रोड, नई दिल्ली-110003
LODI ROAD, NEW DELHI-110003

No:J-13011/11/90-IA-II(T)

Sept. 10, 1996

CORRIGENDUM

Reference is invited to our OM of even No. dated 3rd September, 1996 regarding environmental clearance to Thermal Power plant near Visakhapatnam by M/s Hinduja National Power Corporation Ltd.

The installed capacity indicated as 2x250 MW should be read as 2x520 MW.

The inconvenience caused is regretted.

(NALINI BHAT)
ADDITIONAL DIRECTOR

The Managing Director,
Hinduja National Power Corporation Ltd.
Plot 974, Road No. 50,
Jubilee Hills,
HYDERABAD-500033.

Copy for confirmation to:

1. The Secretary, Ministry of Power, Shram Shakti Bhavan, Rafi Marg, New Delhi.
2. The Chairman, Andhra Pradesh Pollution Control Board, IInd Floor, HUDA Complex, Maitrivanum, Ammerpet, Hyderabad-38.
3. The Chairman, Central Electricity Authority, Sewa Bhavan, R.K.Puram, New Delhi.
4. The Chief Conservator of Forests, Regional Office, Bangalore.
5. The Chairman, Central Pollution Control Board, Parivesh Bhavan, CBD-cum-Office Complex, East Arjun Nagar, Delhi.
6. Guard File.

(NALINI BHAT)
ADDITIONAL DIRECTOR

तार :
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भारत सरकार
पर्यावरण एवं वन मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT & FORESTS
पर्यावरण भवन, सी. जी. ओ. कॉम्प्लेक्स
PARYAVARAN BHAWAN, C.G.O. COMPLEX
लोदी रोड, नई दिल्ली-110003
LODHI ROAD, NEW DELHI-110003

No.J.13011/11/90-IA-II(T)

September 3, 1996

OFFICE MEMORANDUM

Subject: 2x250 MW Thermal Power Plant near Visakhapatnam by M/s Hinduja National Power Corporation Limited - Environmental Clearance.

Reference is invited to letter No.HNPC/APSEB dated 20th September, 1995 and No.HNPC/Clear dated 26th July, 1996 from the Hinduja National Power Corporation Limited (HNPCL) regarding the above mentioned project.

2. The proposal for the setting up of the 1040 MW Coal Based Thermal Power Project has been examined from environmental angle and clearance is hereby accorded subject to effective implementation of the following safeguard measures:-

i) All the conditions stipulated by Andhra Pradesh pollution Control Board vide their letter No.19/PCB/C.Estt./RO/VSP/AEE/ VIII/95-4433 dated 13th November, 1995 should be strictly implemented.

ii) A Bi-flue stack of 275 m with continuous stack monitoring system should be installed.

iii) Electrostatic precipitator having efficiency of not less than 99.8% should be installed and it should be ensured that particulate emissions would not exceed the prescribed limit of 150 mg/Nm3.

iv) Once through cooling system should be provided and the rise in temperature should be maintained within 5 degrees centigrade of the ambient water. The proposed pipeline for sea water intake and outlet should conform to the regulations of the Coastal Zone Notification of February, 1991. Desalination plant should be provided for meeting the water requirement of the power project and other auxiliary activities.

v) Adequate space should be provided for installation of flue gas desulphurisation plant in future for control of sulphur-di-oxide.

vi) Acquisition of land should be restricted to 2682 acres including 890 acres for ash disposal.

vii) Only beneficiated coal to the tune of 16080 MT/Day should be used with average ash content not exceeding 34%. Fly ash generated should be collected in dry form in dry form in silos and fully utilised in a phased manner. As indicated in the Environmental Management Plan, increase in the dyke height above 8 m should be undertaken through use of fly ash. For avoiding contamination of ground water, ash pond area should be suitably lined and dyked. As provided in the layout, adequate space should be earmarked for setting up of ash user plants to avoid long distance transportation of fly ash.

viii) Noise level should be limited to 85 dBA and regular maintenance of equipments be undertaken. For people working in the area of generator halls and other high noise areas, ear plugs should be provided.

ix) For controlling fugitive dust, regular sprinkling of water in coal handling and other vulnerable areas of the plant should be ensured.

x) Afforestation plan should be formulated in consultation with the local DFO and implemented by creating a greenbelt of 500 m along the sea side from High Tide Line. A strip of greenbelt of 150-200 m should also be created along the ash pond area and about 100 m in available spaces within the colony along the roads etc. A norm of 1500-2000 trees per ha should be followed and aftercare and monitoring should also be ensured.

xi) Continuous monitoring of ground water should be undertaken by establishing good network of observation wells in consultation with the Central Ground Water Board. Results and data collected should be analysed to ascertain the status of water quality and findings should be submitted for evaluation.

xii) All effluents generated in various plant activities should be collected in the Central Effluent Treatment Plant and treated to ensure adherence to specified standards of discharge. The concept of zero discharge should be adopted to a maximum possible exten.

xiii) Keeping in view the fact that 2x500 MW thermal power plant by M/s. National Thermal Power Corporation Limited proposed in the vicinity of 1040 MW thermal power project, common facilities for coal transportation, laying of rail lines etc. should be worked out with mutual consultation to avoid duplication of facilities and acquisition of additional land.

xiv) A financial provision of Rs.250 crores should be provided for implementation of environmental mitigative measures with adequate scope for its enhancement in future. These funds should not be diverted for any other activities and separate account should be maintained.

xv) Regular monitoring for SPM, SO2 and NOX around the power plant may be carried out and records maintained. The data so collected should be properly analysed and submitted to the Ministry every six months.

xvi) Full cooperation should be extended to the Scientists/ Officers from the Regional Office of the Ministry at Bangalore and also to the State Pollution Control Board who would be monitoring the compliance of environmental status. Complete set of impact assessment report and the Management Plans should be forwarded to the Regional Office for their use during monitoring.

xvii) Monitoring Committee should be constituted for reviewing the compliance to various safeguard measures by involving recognised local NGOs, Pollution Control Board Experts etc.

3. The Ministry reserves the right to revoke the clearance if conditions stipulated are not implemented to the satisfaction of the Ministry.

4. For any deviation or alteration in the project proposed from those submitted to this Ministry for clearance, a fresh reference should be made to the Ministry to assess the adequacy of the conditions imposed and to add additional environmental protection measures required, if any.

5. The above stipulations would be enforced among others under the Water (Prevention and Control of Pollution) Act, 1974, the Air (prevention and Control of Pollution) Act, 1981, the Environment (Protection) Act, 1986, the Public Liability Insurance Act, 1991, the Impact Assessment Notification of January, 1994 and its amendments.

(Nalini Bhat)
Additional Director

The Managing Director,
Hinduja National Power Corporation Limited,
Plot 974, Road No.50, Jubilee Hills,
HYDERABAD-500033

ANDHRA PRADESH POLLUTION CONTROL BOARD
2nd Floor, HUDA Complex, Maitrivanam, S.R. Nagar, HYDERABAD – 500 038.

Phones : 291120
294043
293278
Fax : 040-293261
Grams : Kalushya Nivarana

BY REGD.POST WITH ACK DUE

LR.NO.19/PCB/C.Estt/RO-VSP/AEE(N)/96-1880 DT. 18-4-96

To

M/s. Hinduja National Power Corporation Ltd.,
Visakhapatnam Coal Fired Power Station,
IIIrd floor, 94 Minerva House,
Sorojini Devi Road,
Secunderabad - 500 003.

Sir,

Sub: PCB - NOC Cell II - Amendments to the installation Capacity specified in the CFE - Reg.

Ref: 1.T.O.Order NO.19/PCB/Estt/Ro/VSP/AEE-VIII/95- 4433, dt. 11-95.

2.Your letter No.HNPC/clear; dt. 19/26 Feb-'96.

* * *

With reference to the letter 2nd cited, it is to inform that the representation submitted by you with regards to the enhancement of installed capacity from 1000 MW to 1040 MW was examined by the Technical Committee along with the compliance report of CFE and recommended the following amendment to the CFE issued vide reference 1st cited.

"The Board has no objection to setup 1040 MW Power Plant as against 1000 MW "

You are also requested to ensure that other conditions stipulated in Consent for Establishment are complied before obtaining Consent for Trail Production.

Yours faithfully,

MEMBER SECRETARY

CONSENT ORDER FOR ESTABLISHMENT

(TEXT OF LETTER RECEIVED FROM ANDHRA PRADESH POLLUTION CONTROL BOARD, HYDERABAD)

Order No. 19/PCB/C.Estt.RO/VSP/AEE-VIII/95-4433 dated 13.11.1995

Sub. : M/s Hinduja National Power Corporation Ltd., Visakhapatnam Dist - Consent for Establishment Under Sec. 25 of Water (P&C of P) Act, 1974 and under Sec. 21 of Air (P&C of P) Act, 1981 - Issued - Reg. :

1. NOC applied by APSEB by APSEB vide letter no. SE(Plg)/410/cast TPS 2x500 MW/ 48/89 dated. 3.3.89.
2. R.O.'s inspection report vide letter no. PCB/ROV/Tech/V-103/577/89, dated 31.8.89.
3. NOC of the Board issued to M/s APSEB vide Letter no. 190/PCB/1697/89-1678 dated. 16.3.90.
4. Letter from M.S., APSEB addressed to this office for transfer of NOC in favour of HNPCL vide letter no. 50/IPC/211/F4(CLR)/B.No.520/95, dated 19.7.95.
5. Your letter No. HNPC/Clearance, dated. 20.7.95.

I. In the reference 3rd cited, APPCB has issued NO OBJECTION CERTIFICATE (consent for establishment) to set up a coast based Thermal Power Plant - 1000 MW (2 x500 MW) between Chipurupalle (V) and Visakhapatnam Steel Plant. In the reference 5th cited, you have forwarded the letter addressed by Member Secretary. APSEB requesting this office to transfer the NOC (Consent for Establishment) of the above project in favour of M/s Hinduja National Power Corporation Ltd (M/s HNPCL).

2. The 2x500 MW coast based Thermal Power Plant is proposed to be located between Chipurupalle (V) and M/s Visakhapatnam Steel Plant in Visakhapatnam District.

3. In view of the above, the CONSENT FOR ESTABLISHMENT of A.P.Pollution Control Board issued for the above project in favour of APSEB vide reference 3rd cited is transferred to M/s Hinduja National Power Corporation Ltd. This order is issued to produce power as mentioned at Para (I).

4. This order is issued from pollution control point of view only. Zoning and other regulations are not considered. The industry shall obtain necessary clearances from the concerned departments.

5. This Consent Order now issued is subject to the conditions mentioned in Schedule 'A'. These conditions are over and above the conditions stipulated in the reference 3rd cited

Sd/-
For MEMBER SECRETARY

Encl. : Schedule 'A'

To

M/s Hinduja National Power Corporation Ltd, (HNPCL)
Plot No. 974, Road No.50
Jubilee Hills.
Hyderabad - 500 033

SCHEDULE -A

1. Trees shall be planted and maintained in the vacant spaces of the premises at least in an area of 4 times the built up area of the industry. Tree plantation shall be the first item to be taken up before starting construction. Area of plantation shall be such that it replenishes the amount of oxygen consumed by process operations and consequent release of pollutants into atmosphere.

2. The industry shall recycle the ash pond and D.M. plant effluents.

3. The industry shall treat the cooling waste waters to the marine coastal standards and the domestic waste waters to the on land for irrigation standards stipulated under Environmental (Protection) Rules, 1986 as amended upto date, notified under Environment (Protection) Act, 1986 by Ministry of Environment and Forests, Govt. of India.

4. The run-off water from coal yard shall be treated to onland for irrigation standards before final disposal.

5. The industry shall discharge the cooling water into sea through a suitable drain/sub-marine pipeline.

6. The industry shall treat the domestic effluents by adopting suitable technologies such as oxidation ponds, aerated lagoons etc., and discharge the treated effluents on land for the irrigation/gardening.

7. The cooling water used in the once through system if treated with Biocide will effect the Biota of the sea and fishing also, in the proximity of the discharge point. It should be controlled by properly designed out fall into the sea.

8. The temperature rise shall be minimal at the cooling water discharge point and shall meet the standards prescribed under E(P) Act.

9. The industry shall either procure washed coal or set up a coal washery for the thermal power plant.

10. The industry shall install appropriate control equipment to control the stack emissions to meet the following emission standards :

    - Particulate matter - 115 mg/Nm^3

11. The industry shall install stacks of 275 m height as stipulated by MoEF, Govt. of India.

12. The industry shall install suitable control equipment/facilities in the coal handling plant and dust suppression in all coal and material handling areas shall be achieved through appropriate measures.

13. The industry shall submit the detailed proposals on Effluent Treatment and Air Pollution Control Equipment for Board's perusal within 2 months from the date of issue of this letter.

14. The industry shall construct and commission the effluent treatment plant and install air pollution control equipment along with the commissioning of the industry. All the units of the ETP shall be impervious to prevent ground water pollution.

15. The industry shall submit a comprehensive EIA report covering three seasons for the 1000 MW plant within 14 months from the date of issue of this letter.

16. The industry shall plan for complete utilisation of the fly ash right from the date of commissioning of the plant.

17. The industry shall make arrangements to prevent fly ash from being air borne from the fly ash dumps.

18. The industry shall provide adequate space for installing flue gas desulphurisation system (FGD System) in their layout, so that the same can be installed as and when prescribed by APPCB.

19. The SO2 and SPM discharge into the atmosphere from this area, will be high, in view of the congregation of the large number of other industries such as M/s Visakhapatnam Steel Plant, two proposed refineries and a Thermal Power Plant (M/s Simhadri Thermal Power Plant of APSEB). In view of this, the industry shall use low sulphur Indian Coal.

20. The industry shall take all steps to see that the end products of burning of the fuel does not create any pollution problem in the environment. The ambient air quality standards for industrial area shall be satisfied. Three air quality stations shall be installed at appropriate locations in consultation with APPCB.

21. Fire protection measures shall be adopted to control spontaneous conbustion within the coal yard

22. The industry shall dispose of the solid wastes to the satisfaction of the Board after obtaining prior approval.

23. There shall not be any perceptible odour outside the industry's premises, creating nuisance to public and other environment. The industry shall adopt control measures at all stages where odour is likely to be generated.

24. a) Suitable automatic flow measuring devices and monitoring equipments shall be installed.

b) Continuous monitoring and recording devices shall be installed to measure SPM & SO_2 concentration in the power plant stacks.

25. The industry shall provide sampling ports for all the stacks with removable dummy of not less than 15 cm diameter in the stack at a distance of 8 times the diameter of the stack from the nearest constraint such as bends etc., and should provide a platform with suitable ladder, below one meter of sampling port, to accommodate three persons with instruments. The industry shall also provide a 5 amp., 250 V plug point on the platform.

26. The industry shall provide interlocking arrangements between the process and pollution control equipments in such a way that, whenever the tolerance limits prescribed by the Board are exceeded, the process comes to halt.

27. Separate power connection with energymeter shall be provided for the pollution control equipments and record of power consumption and chemicals consumption for the operation of pollution control equipment shall be maintained separately.

28. The progress of construction of the main process unit should be in proportion to the installation of pollution control measures and the plantation.

29. Main process unit should be located at the centre of site as far as possible and the entire site should be enclosed by tall growing green plantation, preferably of species having broad leaf area.

30. All the rules and regulations notified by Ministry of Environment & Forests, Government of India in respect of noise pollution control measures shall be followed to avoid nuisance to public.
The ambient Noise level shall not exceed 75 dB(A).

31. The generator shall be installed in a closed area with a silencer and suitable noise absorption system so as to comply with the following noise level standards.

75 dB(A) at a distance of 5 m from the source.

32. The industry shall install minimum stack height to the D.G. Set as per C.P.C.B. guidelines. The minimum height of stack shall be calculated based on the following formula.

$H = h + 0.2\sqrt{KVA}$
H = height of stack in mts.

h = height of the building in mts., where the DG set is installed.
KVA = Total Generator capacity in KVA

33. All the rules and regulations notified by Ministry of Environment and Forests, Government of India in respect of Manufacture, Storage and Import of Hazardous chemicals promulgated under Environment (Protection) Act., 1986 shall be followed.

34. All the rules and regulations notified by Ministry of Environment and Forests, Government of India in respect of Management and Handling of hazardous wastes promulgated under Environment (Protection) Act., 1986 shall be followed.

35. All the rules and regulations notified by Ministry of Law and Justice, Government of India, regarding the Public Liability Insurance Act., 1991 shall be followed.

36. The industries shall establish an Environmental Cell, headed by an Environmental Engineer, for Environmental Management in the industry.

37. The industry shall appoint a Horticulturist for looking after tree plantation work and further maintenance.

38. The industry is liable to pay compensation for any environmental damage caused by it, as fixed by Collector and District Magistrate, as civil liability.

39. If at any time during inspection of Pollution Control Board Officers or officials of licensing/servicing departments if it is found that the industry is not complying with any of the above conditions, this NOC is liable for cancellation without notice and all the services rendered and license issued shall be liable for cancellation without further notice.

40. The industry shall report progress on implementation of the project to this office, Regional Office, A. P. Pollution Control Board, Visakhapatnam, regularly.

41. The applicant shall obtain consent for trial production before the industry goes into trial production.

42. The applicant shall obtain consents for operation regularly from APPCB, as required under section 25/26 of the Water (Prevention and Control of Pollution) Act, 1974 and under section 21/22 of the Air (Prevention and Control of Pollution) Act, 1981, for operation of the industry, before starting commercial production.

43. The applicant shall comply with and carry out conditions issued by the Board in this consent order scrupulously. The applicant is liable for legal action as per the provisions of the relevant acts in case of non-compliance of any conditions of the consent order.

44. Notwithstanding anything contained in this conditional letter of consent, the Board hereby reserve its right and power Under sec.27 (2) of Water (Prevention and Control of Pollution) Act, 1974 and Under Sec. 21(4) of Air (Prevention and Control of Pollution) Act, 1981 to review any or all the conditions imposed herein and to make such alternation as deemed fit and stipulate any additional conditions for the purpose of the Act by the Board.

45. The applicant shall exhibit the consent of the Board in the factory premises at a conspicuous place for the information of the inspecting officers of different departments.

Sd/-
for MEMBER SECRETARY

APPENDIX B

QUESTIONNAIRE FOR SOCIO-ECONOMIC SURVEY

1. Name of village/town :
   Street & door number/Survey number :

2. Name(s) and age(s) of respondent and his/her family members :

3. Profession/occupation of respondent :

4. Educational status of the respondent and each member of the family:

	Male	Female
Primary		
High school		
Degree		
Post-graduate		
Other professional courses		

5. Whether joint family or not :

6. Family members living outside the village/town:

Name	Relation	Age	Place of migration	Occupation

7. Employment status of each member of respondent's household:

Name	Nature of job	Place of work	Approx monthly income

8. Own house/rented house :

9. Source of drinking and bathing water :

10. Toilet facilities
    Separate toilet in house : flush-out/dry/pit
    Outside toilet : flush-out/dry/pit
    Sharing with neighbours : flush-out/dry/pit
    If yes, how many neighbours : flush-out/dry/pit

11. Monthly household income (Rupees) : (<500, 501-1000, 1001-2000, 2001-5000, >5000)

    Monthly expenditure (commodities and others): (<500, 501-1000, 1001-2000, 2001-5000, >5000)

    Annual expenditure (clothing, house maintenance, education, agricultural inputs, etc)

12. Details of family's health:
    common illnesses
    chronic illnesses
    deaths in recent past / reason for death

13. Health problems in the surrounding area:

Disease	Type of occurrence	Month of occurrence	Affected individuals (children, male/female, elderly)
Malaria			
Brain fever			
Cholera			
Chicken pox			
Jaundice			
Chest disorder			
Dysentery/diarrhoea			
Skin disorders			
Parasitic attack			
Deformity			
Sexually transmitted diseases			
Filaria			
Others			

14. Major environmental problems in surrounding area

15. Conditions of the region according to the respondent:
    Environmental aspects:
    Health is good
    No major diseases found
    No mosquito problem
    No rodent problem
    No dog menace
    No pig problem
    No water contamination
    Solid waste/garbage does not accumulate
    No air pollution/foul smell
    No dust problem
    No drainage overflow
    No noise problem

No noise problem
Facilities and employment:
Good water quality
Good health-care facilities
Good schools for children
Good employment opportunities

15. Conditions of the region according to the respondent (continued):
Social problems:
No caste problem
No problem of theft/robbery
No problem of any other type of crime
No alcoholism
No feudalism/bonded labour

16. Industries located in the surrounding area: Names of industries and nature

17. Problems due to existing industries :

18. Any knowledge of the proposed power plant of HNPCL :

19. Any perceived benefit due to proposed plant of HNPCL (employment opportunities, secondary growth, small scale business, etc) :

20. Any perceived problems due to HNPCL's project :

21. Opinion about HNPCL's project : Welcome or not ?

APPENDIX C

WATER QUALITY MONITORING RESULTS

Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Palavalasa Pond (SW1)					Indian Standards (IS 2296)				
Parameter	Winter	Premonsoon	Monsoon	Postmonsoon	Avg(year)	Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
pH (pH units)	7.6	9.04	7.72	7.8	8.0	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.1	32.20	32.33	29.3	30.5	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	1.0	3.65	2.23	2.2	2.3	NS	NS	NS	NS	
Conductivity (micromhos/cm)	689	1378	224	309	650	NS	NS	1000	3000	
Turbidity (NTU)	38	50	63	[illegible]	48	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	3.6	0.0	4.5	4.0	3.0	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	153	260	117	113	160	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	7.2	1.4	4.8	5.6	4.7	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	6.4	48.6	10.2	8.1	18.3	3.0	3.0	NS	NS	
Chemical Oxygen Demand	18.0	96.5	17.3	13.0	36.2	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.49	1.85	0.54	0.7	0.9	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	1.2	5.06	0.52	0.7	1.9	NS	NS	NS	NS	
Ammonical Nitrogen	1.0	1.86	0.32	0.5	0.9	NS	NS	1.2	NS	
Nitrate Nitrogen	4.5	3.85	6.07	3.9	4.6	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.1	0.64	0.05	0.0	0.2	NS	NS	NS	NS	
Oil and Grease	0.00	1.20	0.00	0.0	0.3	0.1	0.1	0.1	NS	
Boron	0.01	1.11	0.02	0.03	0.29	NS	NS	NS	2	
Phenolic Compounds	0.00	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	171	230	80	85	141	NS	NS	NS	NS	
Total Suspended Solids	19	58	45	35	39	NS	NS	NS	NS	
Total Dissolved Solids	479	872	158	223	433	NS	NS	NS	2100	
Chlorides	180	330	59	65	158	600	600	NS	600	
Sulphates	251	66	5	6	82	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	105	90	40	35	67	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	66	140	40	48	73	NS	NS	NS	NS	
Sodium	90	173	31	44	84	NS	NS	NS	1	
Potassium	16.4	21.8	7.4	5.6	12.8	NS	NS	NS	NS	
Arsenic	0.000	0.020	0.006	0.000	0.006	0.2	0.2	NS	NS	
Manganese	0.000	0.139	0.008	0.002	0.037	NS	NS	NS	NS	
Iron	0.740	1.290	3.833	2.744	2.152	NS	NS	NS	NS	
Copper	0.005	0.070	0.047	0.012	0.034	NS	NS	NS	NS	
Mercury	0.150	0.000	0.000	0.000	0.038	NS	NS	NS	NS	
Barium	0.000	0.006	0.000	0.000	0.001	NS	NS	NS	NS	
Silver	0.000	0.007	0.028	0.000	0.009	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.009	0.000	0.001	0.003	0.1	0.1	NS	NS	
Zinc	0.010	0.024	0.033	0.010	0.019	NS	NS	NS	NS	
Nickel	0.000	0.005	0.009	0.002	0.004	NS	NS	NS	NS	
Cadmium	0.000	0.009	0.011	0.001	0.005	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	7	12	15	10	11	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.072	0.007	0.004	0.021	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.05	11.38	0.03	0.14	2.90	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Borrapeta tank (SW2)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.5	9.59	7.81	8.4	8.3	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.1	33.03	32.40	30.0	30.0	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	4.4	3.27	3.76	[illegible]	2.9	NS	NS	NS	NS	
Conductivity (micromhos/cm)	230	685	213	285	353	NS	NS	1000	3000	
Turbidity (NTU)	49	69	106	75	75	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	4.9	[illegible]	9.8	0.0	3.7	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	[illegible]	133	98	99	111	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.8	5.3	6.6	6.3	6.3	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	7.0	16.8	3.0	6.4	8.3	3.0	3.0	NS	NS	
Chemical Oxygen Demand	12.5	25.5	4.8	11.4	13.5	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	0.84	2.69	0.36	0.76	1.2	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	1.2	3.52	0.23	0.9	1.5	NS	NS	NS	NS	
Ammonical Nitrogen	0.9	2.06	0.15	0.5	0.9	NS	NS	1.2	NS	
Nitrate Nitrogen	4.1	4.84	3.45	3.4	4.0	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.2	0.48	0.00	0.0	0.2	NS	NS	NS	NS	
Oil and Grease	0.00	0.50	0.00	0.00	0.1	0.1	0.1	0.1	NS	
Boron	0.00	0.31	0.02	0.02	0.09	NS	NS	NS	2	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	96	91	68	94	87	NS	NS	NS	NS	
Total Suspended Solids	24	48	36	34	36	NS	NS	NS	NS	
Total Dissolved Solids	174	461	141	196	243	NS	NS	NS	2100	
Chlorides	46	135	44	62	72	600	600	NS	600	
Sulphates	9	31	6	5	13	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	39	41	38	40	39	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	43	48	30	54	44	NS	NS	NS	NS	
Sodium	20	142	17	36	54	NS	NS	NS	1	
Potassium	2.8	29.5	10.1	1.7	11.0	NS	NS	NS	NS	
Arsenic	0.000	0.011	0.006	0.000	0.004	0.2	0.2	NS	NS	
Manganese	0.000	0.073	0.011	0.003	0.022	NS	NS	NS	NS	
Iron	1.065	0.752	1.150	1.218	1.046	NS	NS	NS	NS	
Copper	0.004	0.039	0.018	0.009	0.017	NS	NS	NS	NS	
Mercury	0.250	0.000	0.000	0.000	0.063	NS	NS	NS	NS	
Barium	0.000	0.005	0.000	0.000	0.001	NS	NS	NS	NS	
Silver	0.000	0.006	0.010	0.000	0.004	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.001	0.017	0.011	0.002	0.008	0.1	0.1	NS	NS	
Zinc	0.009	0.017	0.030	0.007	0.015	NS	NS	NS	NS	
Nickel	0.000	0.005	0.006	0.002	0.003	NS	NS	NS	NS	
Cadmium	0.000	0.004	0.007	0.000	0.003	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	10	10	9	5	9	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.041	0.007	0.006	0.014	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.06	2.66	0.00	0.13	0.71	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location			Kaniti reservoir (SW3)			Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	8.1	9.31	9.15	8.7	8.8	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	27.9	31.10	30.30	29.8	29.8	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.4	3.43	1.48	1.9	1.8	NS	NS	NS	NS	
Conductivity (micromhos/cm)	445	280	252	342	330	NS	NS	1000	3000	
Turbidity (NTU)	12	43	81	57	48	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	0.1	0.0	0.0	0.0	0.0	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	171	129	128	162	148	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	7.3	6.8	7.5	7.0	7.1	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	3.2	6.3	1.0	2.7	3.3	3.0	3.0	NS	NS	
Chemical Oxygen Demand	8.2	21.6	2.4	4.9	9.3	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	0.76	1.87	0.28	0.81	0.9	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.5	2.30	0.16	0.6	0.9	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	1.37	0.08	0.4	0.5	NS	NS	1.2	NS	
Nitrate Nitrogen	1.4	5.35	1.96	2.6	2.8	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.34	0.00	0.0	0.1	NS	NS	NS	NS	
Oil and Grease	0.00	0.46	0.00	0.00	0.1	0.1	0.1	0.1	NS	
Boron	0.00	1.10	0.01	0.00	0.28	NS	NS	NS	2	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	149	95	101	142	122	NS	NS	NS	NS	
Total Suspended Solids	10	38	28	37	29	NS	NS	NS	NS	
Total Dissolved Solids	327	196	170	234	232	NS	NS	NS	2100	
Chlorides	104	56	50	60	67	600	600	NS	600	
Sulphates	13	11	8	9	10	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	95	50	48	49	60	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	42	45	53	93	58	NS	NS	NS	NS	
Sodium	56	43	27	39	41	NS	NS	NS	1	
Potassium	10.8	3.3	4.7	0.8	4.9	NS	NS	NS	NS	
Arsenic	0.000	0.009	0.000	0.000	0.002	0.2	0.2	NS	NS	
Manganese	0.000	0.049	0.003	0.001	0.013	NS	NS	NS	NS	
Iron	0.853	0.490	0.569	0.608	0.630	NS	NS	NS	NS	
Copper	0.006	0.035	0.013	0.002	0.014	NS	NS	NS	NS	
Mercury	0.150	0.000	0.000	0.000	0.038	NS	NS	NS	NS	
Barium	0.000	0.004	0.000	0.000	0.001	NS	NS	NS	NS	
Silver	0.000	0.006	0.003	0.000	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.003	0.010	0.023	0.002	0.009	0.1	0.1	NS	NS	
Zinc	0.002	0.010	0.017	0.005	0.008	NS	NS	NS	NS	
Nickel	0.000	0.003	0.000	0.000	0.001	NS	NS	NS	NS	
Cadmium	0.000	0.005	0.005	0.000	0.002	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	4	7	5	3	5	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.013	0.001	0.000	0.003	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.01	0.50	0.00	0.04	0.14	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.0^0	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Deshapatrunipalem tank (SW4)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.8	8.90	8.41	8.3	8.3	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	29.4	34.30	33.30	30.2	31.8	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	3.7	3.15	2.30	1.7	2.7	NS	NS	NS	NS	
Conductivity (micromhos/cm)	332	397	105	157	248	NS	NS	1000	3000	
Turbidity (NTU)	60	70	94	67	73	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	2.8	0.0	0.0	0.8	0.9	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	134	137	66	74	103	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.8	6.1	6.6	6.6	6.5	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	5.3	13.1	2.3	5.7	6.6	3.0	3.0	NS	NS	
Chemical Oxygen Demand	12.8	22.7	4.0	8.3	12.0	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	0.30	1.69	0.06	0.40	0.6	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.4	2.76	0.06	0.6	1.0	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	1.46	0.04	0.4	0.5	NS	NS	1.2	NS	
Nitrate Nitrogen	1.5	6.37	1.33	2.3	2.9	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.3	0.35	0.00	0.0	0.2	NS	NS	NS	NS	
Oil and Grease	0.00	0.73	0.00	0.00	0.2	0.1	0.1	0.1	NS	
Boron	0.01	1.04	0.01	0.00	0.26	NS	NS	NS	2	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	141	125	57	62	96	NS	NS	NS	NS	
Total Suspended Solids	28	60	39	30	39	NS	NS	NS	NS	
Total Dissolved Solids	224	263	71	109	166	NS	NS	NS	2100	
Chlorides	76	80	26	35	54	600	600	NS	600	
Sulphates	19	19	2	2	11	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	92	75	34	28	57	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	49	50	23	34	39	NS	NS	NS	NS	
Sodium	26	46	9	19	25	NS	NS	NS	1	
Potassium	4.3	18.4	2.8	1.0	6.6	NS	NS	NS	NS	
Arsenic	0.000	0.006	0.006	0.000	0.003	0.2	0.2	NS	NS	
Manganese	0.000	0.035	0.007	0.001	0.011	NS	NS	NS	NS	
Iron	0.296	0.737	0.788	0.833	0.664	NS	NS	NS	NS	
Copper	0.010	0.028	0.008	0.002	0.012	NS	NS	NS	NS	
Mercury	0.250	0.000	0.000	0.000	0.063	NS	NS	NS	NS	
Barium	0.000	0.005	0.000	0.000	0.001	NS	NS	NS	NS	
Silver	0.000	0.004	0.014	0.000	0.005	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.001	0.009	0.037	0.003	0.012	0.1	0.1	NS	NS	
Zinc	0.007	0.008	0.020	0.007	0.010	NS	NS	NS	NS	
Nickel	0.000	0.003	0.006	0.000	0.002	NS	NS	NS	NS	
Cadmium	0.000	0.004	0.005	0.000	0.002	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	4	8	10	5	7	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.011	0.005	0.004	0.005	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.01	0.83	0.01	0.05	0.22	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/l, or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Kalapaka tank (SH5)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.7	9.70	8.32	9.0	8.7	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.7	33.02	31.30	29.3	31.1	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	5.9	3.13	2.06	2.4	3.4	NS	NS	NS	NS	
Conductivity (micromhos/cm)	435	786	256	304	445	NS	NS	1000	3000	
Turbidity (NTU)	85	63	41	35	56	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	3.0	0.0	7.2	0.0	2.5	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	127	172	114	118	133	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	5.8	5.1	7.0	6.5	6.1	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	10.5	14.3	2.2	5.9	8.2	3.0	3.0	NS	NS	
Chemical Oxygen Demand	20.7	24.2	3.9	8.8	14.4	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	0.98	2.20	1.28	0.99	1.4	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.6	3.35	1.92	2.3	2.0	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	2.06	1.30	1.5	1.3	NS	NS	1.2	NS	
Nitrate Nitrogen	1.8	6.37	3.59	3.8	3.9	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.4	1.03	0.00	0.0	0.4	NS	NS	NS	NS	
Oil and Grease	0.00	0.000	0.00	0.00	0.0	0.1	0.1	0.1	NS	
Boron	0.00	0.30	0.03	0.03	0.09	NS	NS	NS	2	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	119	130	98	101	112	NS	NS	NS	NS	
Total Suspended Solids	41	48	36	27	38	NS	NS	NS	NS	
Total Dissolved Solids	289	508	156	206	290	NS	NS	NS	2100	
Chlorides	109	158	54	76	99	600	600	NS	600	
Sulphates	57	38	7	7	27	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	87	60	61	48	64	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	32	77	37	53	50	NS	NS	NS	NS	
Sodium	44	106	28	35	53	NS	NS	NS	1	
Potassium	8.8	19.2	8.3	5.2	10.4	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.026	0.010	0.000	0.009	NS	NS	NS	NS	
Iron	1.800	1.408	2.370	1.900	1.870	NS	NS	NS	NS	
Copper	0.005	0.027	0.009	0.003	0.011	NS	NS	NS	NS	
Mercury	0.350	0.000	0.000	0.000	0.088	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.005	0.010	0.001	0.004	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.013	0.008	0.002	0.006	0.1	0.1	NS	NS	
Zinc	0.061	0.012	0.020	0.004	0.024	NS	NS	NS	NS	
Nickel	0.000	0.004	0.003	0.001	0.002	NS	NS	NS	NS	
Cadmium	0.000	0.005	0.002	0.000	0.002	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	11	13	9	5	9	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.009	0.005	0.005	0.005	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.21	2.65	0.00	0.06	0.73	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Barinikam tank (SWC)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.6	8.48	7.70	8.2	8.0	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.7	34.95	32.90	31.5	32.0	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.5	3.72	1.70	1.7	1.9	NS	NS	NS	NS	
Conductivity (micromhos/cm)	334	701	153	295	371	NS	NS	1000	3000	
Turbidity (NTU)	55	69	54	36	53	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	3.5	0.0	11.5	0.0	3.7	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	118	168	79	142	127	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.5	5.2	6.9	6.5	6.3	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	3.9	15.7	3.6	3.9	6.7	3.0	3.0	NS	NS	
Chemical Oxygen Demand	9.7	27.3	5.8	6.1	12.2	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	1.24	3.28	0.40	0.72	1.4	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.4	3.59	2.23	2.6	2.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.2	2.40	1.60	1.8	1.5	NS	NS	1.2	NS	
Nitrate Nitrogen	1.1	4.83	3.36	4.1	3.3	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	2.16	0.06	0.0	0.6	NS	NS	NS	NS	
Oil and Grease	0.00	0.000	0.00	0.00	0.0	0.1	0.1	0.1	NS	
Boron	0.02	1.69	0.03	0.02	0.44	NS	NS	NS	2	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	96	152	47	90	96	NS	NS	NS	NS	
Total Suspended Solids	28	50	44	35	39	NS	NS	NS	NS	
Total Dissolved Solids	238	466	101	204	252	NS	NS	NS	2100	
Chlorides	76	168	35	49	82	600	600	NS	600	
Sulphates	19	26	3	6	14	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	68	72	25	50	54	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	28	80	21	40	42	NS	NS	NS	NS	
Sodium	32	109	15	30	47	NS	NS	NS	1	
Potassium	6.9	26.7	2.1	1.4	9.3	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.042	0.012	0.002	0.014	NS	NS	NS	NS	
Iron	0.840	1.757	2.020	1.586	1.551	NS	NS	NS	NS	
Copper	0.003	0.024	0.011	0.002	0.010	NS	NS	NS	NS	
Mercury	0.250	0.000	0.000	0.000	0.063	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.005	0.006	0.000	0.003	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.001	0.009	0.008	0.002	0.005	0.1	0.1	NS	NS	
Zinc	0.003	0.020	0.020	0.006	0.012	NS	NS	NS	NS	
Nickel	0.000	0.005	0.004	0.001	0.003	NS	NS	NS	NS	
Cadmium	0.000	0.026	0.004	0.000	0.007	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	6	14	8	4	8	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.019	0.005	0.006	0.008	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.22	2.69	0.00	0.04	0.74	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Nalla tank (SW7)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	6.0	9.81	8.11	8.2	8.0	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	21.7	32.00	33.38	29.9	29.2	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	5.5	4.50	2.00	2.1	3.5	NS	NS	NS	NS	
Conductivity (micromhos/cm)	624	2810	403	440	1069	NS	NS	1000	3000	
Turbidity (NTU)	74	80	69	59	71	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	1.5	0.0	4.5	0.0	1.5	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	104	740	145	180	292	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	4.7	5.1	3.1	6.1	4.7	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	7.0	22.0	9.0	6.4	11.1	3.0	3.0	NS	NS	
Chemical Oxygen Demand	15.9	30.0	14.8	9.9	17.6	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	0.75	1.88	0.63	0.82	1.0	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.3	3.90	3.04	2.9	2.5	NS	NS	NS	NS	
Ammonical Nitrogen	0.2	2.58	1.76	2.0	1.6	NS	NS	1.2	NS	
Nitrate Nitrogen	1.4	5.80	3.82	4.1	3.8	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.3	0.54	0.21	0.1	0.3	NS	NS	NS	NS	
Oil and Grease	0.00	0.000	0.00	0.00	0.0	0.1	0.1	0.1	NS	
Boron	0.01	2.64	0.04	0.06	0.69	NS	NS	NS	2	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	105	100	86	117	102	NS	NS	NS	NS	
Total Suspended Solids	25	65	59	27	44	NS	NS	NS	NS	
Total Dissolved Solids	406	1896	256	285	711	NS	NS	NS	2100	
Chlorides	109	430	45	73	164	600	600	NS	600	
Sulphates	35	80	12	9	34	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	67	50	42	55	53	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	39	50	42	63	48	NS	NS	NS	NS	
Sodium	59	940	33	45	269	NS	NS	NS	1	
Potassium	9.4	13.0	2.7	2.1	6.8	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.002	0.000	0.001	0.2	0.2	NS	NS	
Manganese	0.000	0.040	0.020	0.003	0.016	NS	NS	NS	NS	
Iron	0.465	1.580	1.498	1.367	1.227	NS	NS	NS	NS	
Copper	0.001	0.027	0.015	0.003	0.011	NS	NS	NS	NS	
Mercury	0.175	0.000	0.000	0.000	0.044	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.002	0.008	0.002	0.003	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.001	0.015	0.012	0.004	0.008	0.1	0.1	NS	NS	
Zinc	0.001	0.012	0.018	0.010	0.010	NS	NS	NS	NS	
Nickel	0.000	0.004	0.002	0.001	0.002	NS	NS	NS	NS	
Cadmium	0.000	0.002	0.004	0.002	0.002	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	2	17	11	6	9	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.012	0.007	0.009	0.007	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.85	3.08	0.04	0.10	1.02	NS	NS	NS	NS	
Alpha Emitters (microCurie/ml)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Thikkavanipalem creek (SW8)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.8	8.66	8.26	8.2	8.2	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.1	32.73	31.90	29.1	30.9	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.3	2.38	1.88	2.0	1.6	NS	NS	NS	NS	
Conductivity (micromhos/cm)	38975	42047	24838	23345	32301	NS	NS	1000	3000	
Turbidity (NTU)	56	41	40	43	45	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	2.7	0.0	8.4	0.0	2.8	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	160	132	144	263	175	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	5.1	4.3	3.5	3.4	4.1	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	7.1	34.8	26.0	24.3	23.1	3.0	3.0	NS	NS	
Chemical Oxygen Demand	16.7	73.2	43.8	44.3	44.5	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	1.94	2.66	0.80	1.14	1.6	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.4	2.07	1.31	3.0	1.7	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	1.10	0.92	1.7	1.0	NS	NS	1.2	NS	
Nitrate Nitrogen	1.9	2.24	2.90	3.1	2.5	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.1	0.92	0.00	0.0	0.3	NS	NS	NS	NS	
Oil and Grease	0.00	0.000	0.00	0.00	0.0	0.1	0.1	0.1	NS	
Boron	0.01	1.80	0.86	0.13	0.70	NS	NS	NS	2	
Phenolic Compounds	0.00	0.01	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	6918	7133	4822	2985	5464	NS	NS	NS	NS	
Total Suspended Solids	32	41	41	29	36	NS	NS	NS	NS	
Total Dissolved Solids	31600	40962	23078	21042	29170	NS	NS	NS	2100	
Chlorides	15725	25127	11912	11317	16020	600	600	NS	600	
Sulphates	2570	3167	1936	1770	2361	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	2630	1440	966	677	1428	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	4288	5693	3656	2308	3986	NS	NS	NS	NS	
Sodium	10420	10998	7390	6562	8843	NS	NS	NS	1	
Potassium	421.3	481.3	204.9	310.0	354.4	NS	NS	NS	NS	
Arsenic	0.000	0.035	0.006	0.003	0.011	0.2	0.2	NS	NS	
Manganese	0.000	0.164	0.039	0.009	0.053	NS	NS	NS	NS	
Iron	2.200	5.560	2.302	2.257	3.080	NS	NS	NS	NS	
Copper	0.002	0.184	0.040	0.010	0.059	NS	NS	NS	NS	
Mercury	0.350	0.000	0.000	0.000	0.088	NS	NS	NS	NS	
Barium	0.000	0.003	0.000	0.000	0.001	NS	NS	NS	NS	
Silver	0.000	0.023	0.040	0.009	0.018	NS	NS	NS	NS	
Selenium	0.000	0.010	0.000	0.000	0.003	0.05	0.05	NS	NS	
Lead	0.003	0.199	0.026	0.014	0.061	0.1	0.1	NS	NS	
Zinc	0.083	0.639	0.080	0.053	0.214	NS	NS	NS	NS	
Nickel	0.002	0.098	0.023	0.006	0.032	NS	NS	NS	NS	
Cadmium	0.001	0.065	0.018	0.005	0.022	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	7	8	6	6	7	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.035	0.000	0.003	0.010	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.26	5.08	0.11	0.69	1.54	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Yeleru canal (SW9)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	8.2	9.13	8.77	9.0	8.8	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.7	34.08	32.10	31.1	31.5	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.4	2.67	1.84	2.3	1.8	NS	NS	NS	NS	
Conductivity (micromhos/cm)	844	1089	448	471	713	NS	NS	1000	3000	
Turbidity (NTU)	41	52	33	37	41	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	1.4	0.0	0.0	0.0	0.3	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	178	361	222	215	244	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	7.4	6.7	6.5	6.2	6.7	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	2.8	5.0	4.9	4.4	4.3	3.0	3.0	NS	NS	
Chemical Oxygen Demand	8.6	7.9	10.1	7.3	8.5	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	1.51	1.61	0.43	0.71	1.1	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.6	1.14	1.68	2.1	1.4	NS	NS	NS	NS	
Ammonical Nitrogen	0.5	0.56	1.04	1.5	0.9	NS	NS	1.2	NS	
Nitrate Nitrogen	1.7	2.44	2.16	2.5	2.2	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.2	0.26	0.00	0.0	0.1	NS	NS	NS	NS	
Oil and Grease	0.00	0.000	0.00	0.00	0.0	0.1	0.1	0.1	NS	
Boron	0.01	0.11	0.02	0.02	0.04	NS	NS	NS	2	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	170	142	151	194	164	NS	NS	NS	NS	
Total Suspended Solids	18	40	36	33	32	NS	NS	NS	NS	
Total Dissolved Solids	550	727	292	325	474	NS	NS	NS	2100	
Chlorides	121	126	71	51	92	600	600	NS	600	
Sulphates	51	80	16	17	41	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	106	74	76	54	78	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	64	64	75	140	86	NS	NS	NS	NS	
Sodium	36	82	49	38	51	NS	NS	NS	1	
Potassium	5.2	6.5	4.6	2.0	4.6	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.019	0.012	0.002	0.008	NS	NS	NS	NS	
Iron	0.314	1.382	0.856	0.830	0.845	NS	NS	NS	NS	
Copper	0.003	0.035	0.011	0.002	0.013	NS	NS	NS	NS	
Mercury	0.175	0.000	0.000	0.000	0.044	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.010	0.002	0.003	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.001	0.007	0.010	0.001	0.005	0.1	0.1	NS	NS	
Zinc	0.007	0.010	0.012	0.005	0.008	NS	NS	NS	NS	
Nickel	0.000	0.004	0.004	0.000	0.002	NS	NS	NS	NS	
Cadmium	0.000	0.003	0.005	0.000	0.002	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	3	31	7	7	12	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.010	0.006	0.004	0.005	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.11	0.27	0.01	0.11	0.13	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Surface water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling Location	Appikonda creek (SW10)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.7	8.67	8.33	8.2	8.2	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.1	32.3	32.2	29.6	30.5	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	6.0	2.92	1.46	2.1	3.1	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1197	1280	735	757	992	NS	NS	1000	3000	
Turbidity (NTU)	596	192	59	64	228	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	2.8	0.0	0.0	0.0	0.7	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	289	203	154	221	217	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	4.2	4.5	5.4	6.0	5.0	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	53.0	23.6	10.6	8.0	23.8	3.0	3.0	NS	NS	
Chemical Oxygen Demand	113.3	40.1	19.4	11.5	46.0	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	5.09	1.94	0.53	0.66	2.1	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	2.2	1.72	1.21	1.8	1.7	NS	NS	NS	NS	
Ammonical Nitrogen	1.3	1.09	0.77	1.4	1.2	NS	NS	1.2	NS	
Nitrate Nitrogen	7.3	3.16	2.00	2.2	3.7	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.2	0.11	0.00	0.0	0.1	NS	NS	NS	NS	
Oil and Grease	0.00	1.34	0.00	0.00	0.3	0.1	0.1	0.1	NS	
Boron	0.01	0.61	0.01	0.01	0.16	NS	NS	NS	2	
Phenolic Compounds	0.01	0.02	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	323	246	158	196	231	NS	NS	NS	NS	
Total Suspended Solids	147	111	51	31	85	NS	NS	NS	NS	
Total Dissolved Solids	745	2047	479	561	958	NS	NS	NS	2100	
Chlorides	180	177	124	155	159	600	600	NS	600	
Sulphates	155	93	30	27	76	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	165	117	89	95	116	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	79	129	69	101	95	NS	NS	NS	NS	
Sodium	127	146	101	104	119	NS	NS	NS	1	
Potassium	19.3	11.2	8.6	9.1	12.0	NS	NS	NS	NS	
Arsenic	0.011	0.054	0.008	0.003	0.019	0.2	0.2	NS	NS	
Manganese	0.016	0.043	0.024	0.007	0.022	NS	NS	NS	NS	
Iron	1.390	1.865	3.132	3.688	2.519	NS	NS	NS	NS	
Copper	0.024	0.250	0.041	0.025	0.085	NS	NS	NS	NS	
Mercury	0.275	0.000	0.000	0.000	0.069	NS	NS	NS	NS	
Barium	0.000	0.008	0.000	0.000	0.002	NS	NS	NS	NS	
Silver	0.000	0.010	0.016	0.003	0.007	NS	NS	NS	NS	
Selenium	0.000	0.004	0.000	0.000	0.001	0.05	0.05	NS	NS	
Lead	0.014	0.107	0.035	0.005	0.040	0.1	0.1	NS	NS	
Zinc	0.226	0.155	0.089	0.057	0.132	NS	NS	NS	NS	
Nickel	0.010	0.046	0.012	0.003	0.018	NS	NS	NS	NS	
Cadmium	0.004	0.022	0.008	0.001	0.009	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	59	20	6	4	22	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.004	0.001	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	7.99	3.53	0.57	1.04	3.28	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Palavalasa Cyclone Shelter(GW1)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.4	7.64	7.80	7.8	7.7	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	27.0	30.8	29.8	28.9	29.1	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	6800	6450	5695	5211	6039	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.52	2.20	2.1	1.3	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	7.4	5.63	2.84	2.3	4.5	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	933	678	852	804	817	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	5.4	6.4	7.2	7.2	6.5	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	4.2	0.85	1.95	0.7	1.9	3	3	NS	NS	
Chemical Oxygen Demand	6.1	1.88	3.10	1.3	3.1	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	1.7	1.66	1.57	1.3	1.6	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.1	0.19	0.09	0.2	0.1	NS	NS	NS	NS	
Ammonical Nitrogen	0.1	0.18	0.07	0.2	0.1	NS	NS	1.2	NS	
Nitrate Nitrogen	0.4	1.98	1.13	1.4	1.2	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.39	0.00	0.00	0.1	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	835	805	722	618	745	NS	NS	NS	NS	
Total Suspended Solids	2	4	4	2	3	NS	NS	NS	NS	
Total Dissolved Solids	4388	4187	3754	3494	3956	NS	NS	NS	2100	
Chlorides	1710	1772	1528	1239	1562	600	600	NS	600	
Sulphates	678	298	227	251	363	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	616	158	150	76	250	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	244	647	572	543	501	NS	NS	NS	NS	
Sodium	1052	1282	1072	853	1065	NS	NS	NS	1	
Potassium	161.5	59.3	25.3	12.1	64.6	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.502	0.218	0.043	0.038	0.200	NS	NS	NS	NS	
Copper	0.001	0.095	0.002	0.001	0.025	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.009	0.007	0.002	0.004	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.008	0.021	0.004	0.008	0.1	0.1	NS	NS	
Zinc	0.004	0.022	0.021	0.010	0.014	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.001	0.001	0.001	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	3	2	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.016	0.008	0.005	0.003	0.008	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Palavalasa village (GW2)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.9	8.11	8.17	8.4	8.1	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	26.9	30.9	30.5	29.8	29.5	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1823	2235	2425	2501	2246	NS	NS	1000	3000	
Turbidity (NTU)	0.6	0.45	1.56	1.9	1.1	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	2.2	1.40	0.30	0.0	1.0	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	654	655	774	786	717	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	7.0	6.7	7.1	7.2	7.0	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.4	1.12	1.45	0.6	0.9	3	3	NS	NS	
Chemical Oxygen Demand	0.6	2.36	1.60	0.7	1.3	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	1.2	1.66	2.20	2.0	1.8	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.1	0.23	0.14	0.2	0.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.1	0.20	0.12	0.1	0.1	NS	NS	1.2	NS	
Nitrate Nitrogen	0.9	1.82	1.38	1.5	1.4	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.05	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	344	237	230	252	266	NS	NS	NS	NS	
Total Suspended Solids	2	4	5	4	4	NS	NS	NS	NS	
Total Dissolved Solids	1580	1509	1545	1670	1576	NS	NS	NS	2100	
Chlorides	550	453	460	499	491	600	600	NS	600	
Sulphates	205	145	130	148	157	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	124	80	74	66	86	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	220	157	156	186	180	NS	NS	NS	NS	
Sodium	223	511	286	285	326	NS	NS	NS	1	
Potassium	33.0	24.7	22.9	13.9	23.6	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.350	0.389	0.032	0.040	0.203	NS	NS	NS	NS	
Copper	0.003	0.011	0.003	0.002	0.004	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.002	0.009	0.002	0.003	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.006	0.000	0.001	0.002	0.1	0.1	NS	NS	
Zinc	0.003	0.014	0.029	0.014	0.015	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.001	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	2	2	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.041	0.004	0.004	0.003	0.013	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Devada (GW3)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	6.9	6.97	7.10	7.1	7.0	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.0	31.0	29.8	29.1	30.0	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1067	1093	920	962	1010	NS	NS	1000	3000	
Turbidity (NTU)	0.5	0.38	1.40	1.8	1.0	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	12.9	13.03	13.66	14.9	13.6	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	371	312	338	378	350	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.8	6.8	6.9	6.8	6.8	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.6	1.06	0.00	0.0	0.4	3	3	NS	NS	
Chemical Oxygen Demand	1.3	2.88	0.00	0.0	1.0	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.2	1.58	1.57	1.3	1.2	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.2	0.25	0.00	0.0	0.1	NS	NS	NS	NS	
Ammonical Nitrogen	0.2	0.21	0.00	0.0	0.1	NS	NS	1.2	NS	
Nitrate Nitrogen	1.3	1.47	1.29	1.0	1.3	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.19	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	407	372	362	404	386	NS	NS	NS	NS	
Total Suspended Solids	2	0	2	2	2	NS	NS	NS	NS	
Total Dissolved Solids	716	738	609	644	677	NS	NS	NS	2100	
Chlorides	190	242	154	174	190	600	600	NS	600	
Sulphates	73	77	58	46	63	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	246	220	194	174	209	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	162	150	168	230	178	NS	NS	NS	NS	
Sodium	101	135	97	113	112	NS	NS	NS	1	
Potassium	15.8	16.7	15.3	8.3	14.0	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.066	0.088	0.036	0.031	0.055	NS	NS	NS	NS	
Copper	0.001	0.007	0.000	0.003	0.003	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.011	0.002	0.003	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.000	0.000	0.000	0.000	0.1	0.1	NS	NS	
Zinc	0.000	0.009	0.017	0.016	0.010	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	2	0	2	1	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.145	0.005	0.000	0.000	0.038	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Deshapatrunipalem (GW4)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.3	7.69	7.94	7.7	7.7	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	27.6	29.9	29.3	29.0	28.9	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	930	850	750	727	814	NS	NS	1000	3000	
Turbidity (NTU)	0.4	0.42	1.40	1.7	1.0	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	8.0	3.87	1.23	8.7	5.5	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	425	333	296	323	344	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.3	6.8	7.2	7.1	6.8	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	1.1	0.88	2.00	0.9	1.2	3	3	NS	NS	
Chemical Oxygen Demand	1.6	2.55	3.60	1.6	2.3	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	2.7	1.50	1.33	1.2	1.7	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.0	0.17	0.00	0.4	0.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.0	0.13	0.00	0.3	0.1	NS	NS	1.2	NS	
Nitrate Nitrogen	0.4	1.60	1.24	1.2	1.1	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.1	0.11	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	347	307	272	275	300	NS	NS	NS	NS	
Total Suspended Solids	1	5	4	2	3	NS	NS	NS	NS	
Total Dissolved Solids	629	649	496	497	568	NS	NS	NS	2100	
Chlorides	125	127	100	117	117	600	600	NS	600	
Sulphates	51	41	18	22	33	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	201	142	120	94	139	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	151	148	152	151	151	NS	NS	NS	NS	
Sodium	73	91	61	74	75	NS	NS	NS	1	
Potassium	12.8	15.5	12.1	9.4	12.4	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.480	0.272	0.044	0.054	0.212	NS	NS	NS	NS	
Copper	0.006	0.012	0.010	0.001	0.007	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.007	0.002	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.000	0.000	0.000	0.000	0.1	0.1	NS	NS	
Zinc	0.009	0.005	0.016	0.011	0.010	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	2	2	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.227	0.005	0.010	0.003	0.061	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Kalapaka GW5)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.4	7.23	7.28	7.4	7.3	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.1	30.4	30.1	28.7	29.8	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	2613	3344	3176	3437	3142	NS	NS	1000	3000	
Turbidity (NTU)	0.4	0.50	1.18	2.0	1.0	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	7.2	9.43	10.50	8.2	8.8	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	468	378	490	585	480	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.6	7.0	6.8	7.2	6.9	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.5	1.98	0.70	1.0	1.1	3	3	NS	NS	
Chemical Oxygen Demand	1.2	3.30	1.35	1.8	1.9	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	3.3	1.20	0.79	1.0	1.6	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.0	0.17	0.23	0.0	0.1	NS	NS	NS	NS	
Ammonical Nitrogen	0.0	0.15	0.21	0.0	0.1	NS	NS	1.2	NS	
Nitrate Nitrogen	0.3	1.73	1.31	1.7	1.3	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.14	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	718	788	888	790	796	NS	NS	NS	NS	
Total Suspended Solids	1	3	3	3	2	NS	NS	NS	NS	
Total Dissolved Solids	1809	2040	1995	2037	1970	NS	NS	NS	2100	
Chlorides	625	867	938	798	807	600	600	NS	600	
Sulphates	225	229	225	211	222	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	315	295	160	225	249	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	403	493	728	562	547	NS	NS	NS	NS	
Sodium	285	600	637	458	495	NS	NS	NS	1	
Potassium	47.5	44.3	54.0	28.2	43.5	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.257	0.273	0.085	0.048	0.166	NS	NS	NS	NS	
Copper	0.000	0.016	0.004	0.002	0.005	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.005	0.013	0.002	0.005	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.009	0.000	0.000	0.002	0.1	0.1	NS	NS	
Zinc	0.003	0.008	0.027	0.014	0.013	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	2	3	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.025	0.006	0.000	0.004	0.009	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Pittavanipalem (GW6)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.1	7.41	7.38	7.3	7.3	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.9	30.8	29.6	28.7	29.5	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1488	1402	1542	1543	1494	NS	NS	1000	3000	
Turbidity (NTU)	0.2	0.50	1.86	2.1	1.2	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	10.7	6.83	8.06	8.2	8.4	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	343	313	378	311	336	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.2	6.9	7.0	7.2	6.8	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.8	2.02	1.40	0.7	1.2	3	3	NS	NS	
Chemical Oxygen Demand	1.4	2.82	1.90	1.4	1.9	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	1.3	1.06	1.33	1.1	1.2	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.0	0.08	0.09	0.2	0.1	NS	NS	NS	NS	
Ammonical Nitrogen	0.0	0.07	0.09	0.2	0.1	NS	NS	1.2	NS	
Nitrate Nitrogen	0.4	1.27	1.02	1.3	1.0	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.05	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	402	398	444	431	419	NS	NS	NS	NS	
Total Suspended Solids	1	4	3	2	3	NS	NS	NS	NS	
Total Dissolved Solids	1094	941	1005	1029	1017	NS	NS	NS	2100	
Chlorides	355	318	372	360	351	600	600	NS	600	
Sulphates	114	109	132	123	119	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	198	187	148	145	169	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	169	212	296	287	241	NS	NS	NS	NS	
Sodium	192	206	195	211	201	NS	NS	NS	1	
Potassium	31.4	16.3	17.2	11.2	19.0	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.412	0.268	0.040	0.036	0.189	NS	NS	NS	NS	
Copper	0.005	0.009	0.002	0.000	0.004	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.004	0.004	0.002	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.005	0.002	0.000	0.002	0.1	0.1	NS	NS	
Zinc	0.002	0.007	0.011	0.007	0.007	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	2	3	3	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.010	0.005	0.050	0.015	0.020	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Chinnapalem (GW7)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.6	8.11	7.91	7.8	7.9	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	27.7	31.1	30.7	29.6	29.8	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1390	1124	1115	1557	1296	NS	NS	1000	3000	
Turbidity (NTU)	0.1	0.62	1.50	1.6	1.0	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	3.9	0.00	2.55	3.1	2.4	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	471	343	412	411	409	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.7	7.4	6.9	7.2	7.1	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.2	0.70	1.60	0.4	0.7	3	3	NS	NS	
Chemical Oxygen Demand	0.4	2.10	2.33	0.8	1.4	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.5	1.07	1.41	0.8	1.0	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.6	0.31	0.11	0.1	0.3	NS	NS	NS	NS	
Ammonical Nitrogen	0.5	0.24	0.11	0.1	0.3	NS	NS	1.2	NS	
Nitrate Nitrogen	2.2	2.01	0.97	1.5	1.7	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.02	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	473	303	342	403	380	NS	NS	NS	NS	
Total Suspended Solids	1	4	3	3	3	NS	NS	NS	NS	
Total Dissolved Solids	1043	754	727	1105	907	NS	NS	NS	2100	
Chlorides	338	220	240	443	310	600	600	NS	600	
Sulphates	92	220	106	143	140	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	254	138	102	121	154	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	206	153	240	283	221	NS	NS	NS	NS	
Sodium	188	191	163	213	189	NS	NS	NS	1	
Potassium	29.9	14.8	13.5	10.0	17.0	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.160	0.355	0.039	0.045	0.150	NS	NS	NS	NS	
Copper	0.003	0.007	0.001	0.001	0.003	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.006	0.002	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.005	0.001	0.000	0.001	0.1	0.1	NS	NS	
Zinc	0.004	0.004	0.013	0.005	0.007	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	2	5	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.011	0.006	0.004	0.003	0.006	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Islampeta (GW8)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	6.7	6.97	6.75	6.7	6.8	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.5	31.6	30.5	29.5	30.5	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1219	954	1095	1082	1088	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.57	1.50	2.1	1.1	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	15.6	12.78	17.02	17.3	15.7	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	243	133	166	149	172	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.2	6.8	6.8	7.0	6.7	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.7	1.92	1.86	1.2	1.4	3	3	NS	NS	
Chemical Oxygen Demand	1.2	3.30	3.36	2.3	2.5	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.2	0.99	1.48	1.3	1.0	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.2	0.22	0.19	0.2	0.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.2	0.18	0.19	0.2	0.2	NS	NS	1.2	NS	
Nitrate Nitrogen	1.4	1.37	1.16	1.7	1.4	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.02	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	352	275	324	329	320	NS	NS	NS	NS	
Total Suspended Solids	1	5	3	3	3	NS	NS	NS	NS	
Total Dissolved Solids	796	640	722	715	718	NS	NS	NS	2100	
Chlorides	324	233	293	285	284	600	600	NS	600	
Sulphates	109	82	87	66	86	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	214	185	158	219	194	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	125	92	168	113	124	NS	NS	NS	NS	
Sodium	161	146	143	138	147	NS	NS	NS	1	
Potassium	29.0	11.6	8.9	3.2	13.2	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.190	0.189	0.041	0.040	0.115	NS	NS	NS	NS	
Copper	0.000	0.011	0.003	0.001	0.004	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.008	0.002	0.003	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.010	0.005	0.008	0.006	0.1	0.1	NS	NS	
Zinc	0.005	0.008	0.018	0.011	0.011	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	3	4	3	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.047	0.006	0.120	0.030	0.051	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Barinikam (GW9)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.5	7.72	7.73	7.8	7.7	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	27.7	30.4	30.1	29.6	29.4	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1218	1558	1333	1140	1312	NS	NS	1000	3000	
Turbidity (NTU)	0.2	0.47	1.78	2.1	1.1	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	6.4	3.73	5.84	3.3	4.8	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	450	445	500	429	456	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.1	6.8	7.0	6.9	6.7	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	1.2	0.60	1.20	1.1	1.0	3	3	NS	NS	
Chemical Oxygen Demand	2.1	1.62	2.00	1.7	1.9	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	1.0	1.97	1.35	1.1	1.4	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.1	0.17	0.21	0.3	0.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.1	0.15	0.21	0.2	0.2	NS	NS	1.2	NS	
Nitrate Nitrogen	0.6	1.34	0.90	1.2	1.0	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.12	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	290	428	390	332	360	NS	NS	NS	NS	
Total Suspended Solids	1	0	2	2	1	NS	NS	NS	NS	
Total Dissolved Solids	847	1051	891	779	892	NS	NS	NS	2100	
Chlorides	190	288	248	222	237	600	600	NS	600	
Sulphates	131	126	94	42	98	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	122	97	122	99	110	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	169	333	268	233	251	NS	NS	NS	NS	
Sodium	94	235	171	141	160	NS	NS	NS	1	
Potassium	16.5	34.6	42.8	25.0	29.7	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.200	0.188	0.108	0.136	0.158	NS	NS	NS	NS	
Copper	0.007	0.007	0.002	0.002	0.004	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.007	0.002	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.007	0.001	0.000	0.002	0.1	0.1	NS	NS	
Zinc	0.004	0.012	0.022	0.020	0.014	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	3	3	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.015	0.003	0.000	0.000	0.004	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	VUDA colony (GW10)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.1	7.31	7.32	7.4	7.3	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.5	30.1	29.5	29.3	29.3	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1629	1529	1547	1584	1572	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.58	2.14	2.0	1.2	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	10.5	8.27	9.60	9.3	9.4	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	329	322	374	367	348	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.6	7.0	7.2	7.1	7.0	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.3	0.68	0.60	0.9	0.6	3	3	NS	NS	
Chemical Oxygen Demand	0.7	1.36	1.00	1.6	1.2	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.8	1.02	1.41	1.1	1.1	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	1.2	0.44	0.30	0.2	0.5	NS	NS	NS	NS	
Ammonical Nitrogen	1.1	0.41	0.29	0.2	0.5	NS	NS	1.2	NS	
Nitrate Nitrogen	4.9	1.39	0.90	1.5	2.2	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.1	0.05	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	420	480	570	424	473	NS	NS	NS	NS	
Total Suspended Solids	1	0	3	3	2	NS	NS	NS	NS	
Total Dissolved Solids	1159	1043	1020	1027	1062	NS	NS	NS	2100	
Chlorides	316	315	322	348	325	600	600	NS	600	
Sulphates	120	126	130	92	117	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	291	270	296	148	251	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	129	210	274	274	222	NS	NS	NS	NS	
Sodium	183	165	133	194	169	NS	NS	NS	1	
Potassium	32.9	22.7	13.3	14.4	20.8	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.178	0.175	0.118	0.067	0.134	NS	NS	NS	NS	
Copper	0.003	0.004	0.001	0.001	0.002	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.009	0.006	0.002	0.004	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.006	0.004	0.008	0.004	0.1	0.1	NS	NS	
Zinc	0.006	0.013	0.020	0.011	0.012	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	2	3	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.007	0.003	0.000	0.011	0.005	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Raja Reddy Farm (GW11)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.7	8.00	8.18	8.0	7.9	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.1	30.7	29.5	29.3	29.4	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1508	1591	1405	1524	1507	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.63	2.00	1.9	1.2	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	3.8	1.80	5.00	6.6	4.3	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	567	560	534	542	551	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.8	7.2	7.0	7.0	7.0	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.3	0.27	0.83	1.4	0.7	3	3	NS	NS	
Chemical Oxygen Demand	0.7	0.60	1.33	2.2	1.2	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.4	1.76	1.77	1.2	1.3	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.2	0.30	0.15	0.3	0.3	NS	NS	NS	NS	
Ammonical Nitrogen	0.2	0.23	0.15	0.3	0.2	NS	NS	1.2	NS	
Nitrate Nitrogen	1.5	1.61	1.38	2.3	1.7	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.05	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	363	337	278	298	319	NS	NS	NS	NS	
Total Suspended Solids	1	0	4	3	2	NS	NS	NS	NS	
Total Dissolved Solids	1113	1072	920	1032	1034	NS	NS	NS	2100	
Chlorides	303	272	268	250	273	600	600	NS	600	
Sulphates	122	128	111	81	110	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	162	85	82	88	104	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	201	252	196	211	215	NS	NS	NS	NS	
Sodium	152	263	193	176	196	NS	NS	NS	1	
Potassium	26.6	16.8	5.2	18.1	16.6	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.755	0.145	0.130	0.136	0.292	NS	NS	NS	NS	
Copper	0.004	0.007	0.003	0.003	0.004	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.007	0.009	0.005	0.005	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.007	0.000	0.000	0.002	0.1	0.1	NS	NS	
Zinc	0.005	0.014	0.025	0.018	0.016	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	3	3	3	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.013	0.002	0.008	0.007	0.008	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Vada Chipurapalli (GW12)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.3	7.47	7.52	7.4	7.4	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.0	30.5	29.0	30.2	29.9	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1339	1303	1296	1315	1313	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.52	1.65	1.9	1.1	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	7.4	7.60	8.53	8.3	8.0	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	420	412	443	331	401	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	7.0	7.0	7.2	7.2	7.1	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.1	0.80	0.00	0.2	0.3	3	3	NS	NS	
Chemical Oxygen Demand	0.3	1.56	0.00	0.3	0.5	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.0	0.56	1.71	1.3	0.9	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.0	0.31	0.20	0.3	0.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.0	0.27	0.20	0.2	0.2	NS	NS	1.2	NS	
Nitrate Nitrogen	0.5	0.97	1.18	1.1	1.0	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.05	0.03	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	459	420	450	459	447	NS	NS	NS	NS	
Total Suspended Solids	1	0	3	3	2	NS	NS	NS	NS	
Total Dissolved Solids	943	880	854	888	891	NS	NS	NS	2100	
Chlorides	245	262	295	287	272	600	600	NS	600	
Sulphates	129	106	90	66	97	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	137	132	115	148	133	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	322	288	335	326	318	NS	NS	NS	NS	
Sodium	134	147	185	165	158	NS	NS	NS	1	
Potassium	22.7	13.8	7.6	12.0	14.0	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.079	0.128	0.123	0.164	0.123	NS	NS	NS	NS	
Copper	0.001	0.036	0.010	0.001	0.012	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.027	0.002	0.007	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.003	0.000	0.000	0.001	0.1	0.1	NS	NS	
Zinc	0.003	0.009	0.011	0.011	0.008	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	3	3	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.009	0.002	0.000	0.000	0.003	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Utagaddapalem (GW13)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.4	7.76	8.02	7.9	7.8	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	27.3	30.4	29.1	28.9	28.9	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	896	779	732	912	830	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.67	1.96	1.8	1.2	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	6.2	2.50	0.53	6.0	3.8	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	366	342	388	405	375	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.7	6.7	6.8	7.1	6.8	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	5.2	0.43	0.64	0.7	1.7	3	3	NS	NS	
Chemical Oxygen Demand	1.5	1.00	1.16	1.4	1.2	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.3	1.83	0.69	0.5	0.8	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.3	0.32	0.59	0.5	0.4	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	0.26	0.55	0.4	0.4	NS	NS	1.2	NS	
Nitrate Nitrogen	1.6	1.68	1.68	2.9	2.0	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.06	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	302	249	248	277	269	NS	NS	NS	NS	
Total Suspended Solids	0	0	4	4	2	NS	NS	NS	NS	
Total Dissolved Solids	663	525	491	600	570	NS	NS	NS	2100	
Chlorides	109	98	96	128	108	600	600	NS	600	
Sulphates	83	40	23	37	46	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	93	108	132	116	112	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	159	141	116	161	144	NS	NS	NS	NS	
Sodium	96	108	105	79	97	NS	NS	NS	1	
Potassium	11.4	5.0	3.3	1.1	5.2	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.425	0.114	0.068	0.092	0.175	NS	NS	NS	NS	
Copper	0.003	0.017	0.005	0.002	0.007	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.005	0.001	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.017	0.004	0.002	0.006	0.1	0.1	NS	NS	
Zinc	0.009	0.018	0.034	0.017	0.019	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	2	3	3	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.049	0.006	0.010	0.006	0.017	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Jalarpeta (GW14)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	6.9	7.24	7.63	7.4	7.3	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	29.8	30.6	29.2	29.2	29.7	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1249	1452	1003	1236	1235	NS	NS	1000	3000	
Turbidity (NTU)	0.4	0.48	1.29	1.8	1.0	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	12.8	8.63	5.21	13.4	10.0	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	301	268	374	232	294	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.8	7.2	6.9	7.1	7.0	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.2	0.60	1.29	1.0	0.7	3	3	NS	NS	
Chemical Oxygen Demand	0.4	1.60	0.79	1.8	1.1	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.1	1.08	1.16	1.1	0.8	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.2	0.29	0.33	0.4	0.3	NS	NS	NS	NS	
Ammonical Nitrogen	0.2	0.24	0.30	0.4	0.3	NS	NS	1.2	NS	
Nitrate Nitrogen	1.5	1.36	1.45	1.9	1.5	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.05	0.02	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	315	383	342	324	341	NS	NS	NS	NS	
Total Suspended Solids	1	0	2	8	3	NS	NS	NS	NS	
Total Dissolved Solids	858	973	684	820	834	NS	NS	NS	2100	
Chlorides	189	403	177	283	263	600	600	NS	600	
Sulphates	67	104	60	64	74	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	161	202	119	161	161	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	154	181	215	177	182	NS	NS	NS	NS	
Sodium	115	239	132	165	163	NS	NS	NS	1	
Potassium	18.4	18.6	7.8	3.5	12.1	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.125	0.091	0.179	0.069	0.116	NS	NS	NS	NS	
Copper	0.001	0.009	0.007	0.002	0.005	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.008	0.007	0.003	0.004	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.012	0.004	0.003	0.005	0.1	0.1	NS	NS	
Zinc	0.000	0.015	0.016	0.014	0.011	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	2	2	3	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.010	0.003	0.013	0.005	0.008	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Mutyalammapalem (GW15)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.4	7.73	7.85	7.7	7.7	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.1	30.8	29.0	29.8	29.9	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	833	1027	945	1046	963	NS	NS	1000	3000	
Turbidity (NTU)	0.1	0.50	1.52	1.7	0.9	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	5.9	4.15	3.34	5.2	4.6	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	229	168	236	197	207	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.7	7.0	6.7	6.9	6.8	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.2	0.30	1.00	0.9	0.6	3	3	NS	NS	
Chemical Oxygen Demand	0.5	0.74	1.86	1.5	1.1	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.1	1.14	1.30	1.3	0.9	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	1.2	0.87	0.42	0.4	0.7	NS	NS	NS	NS	
Ammonical Nitrogen	1.1	0.63	0.41	0.3	0.6	NS	NS	1.2	NS	
Nitrate Nitrogen	4.4	1.60	0.88	1.9	2.2	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.04	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	335	333	344	350	341	NS	NS	NS	NS	
Total Suspended Solids	1	0	4	3	2	NS	NS	NS	NS	
Total Dissolved Solids	786	689	615	694	696	NS	NS	NS	2100	
Chlorides	222	224	236	223	226	600	600	NS	600	
Sulphates	74	54	52	40	55	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	162	193	220	175	187	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	174	140	132	175	155	NS	NS	NS	NS	
Sodium	133	122	109	119	121	NS	NS	NS	1	
Potassium	22.3	10.0	6.2	2.2	10.2	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.290	0.156	0.078	0.077	0.150	NS	NS	NS	NS	
Copper	0.000	0.010	0.006	0.002	0.005	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.008	0.002	0.003	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.014	0.019	0.002	0.009	0.1	0.1	NS	NS	
Zinc	0.001	0.014	0.035	0.015	0.016	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	3	4	3	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.011	0.004	0.002	0.006	0.006	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Niraj Petrochemicals (GW16)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.2	7.32	7.41	7.2	7.3	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.5	32.7	29.3	31.2	30.9	NS	NS	NS	NS	
Colour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	960	889	856	822	882	NS	NS	1000	3000	
Turbidity (NTU)	0.4	0.58	2.18	1.8	1.3	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	8.8	8.37	10.80	14.2	10.5	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	544	358	466	351	430	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.7	7.0	6.5	6.9	6.8	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.5	0.65	2.00	1.1	1.0	3	3	NS	NS	
Chemical Oxygen Demand	1.0	2.10	3.24	1.8	2.0	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.2	1.65	1.33	1.5	1.2	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.3	0.30	0.67	0.5	0.4	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	0.27	0.56	0.4	0.4	NS	NS	1.2	NS	
Nitrate Nitrogen	2.2	0.84	1.26	2.2	1.6	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.05	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	285	307	326	319	309	NS	NS	NS	NS	
Total Suspended Solids	0	0	7	4	3	NS	NS	NS	NS	
Total Dissolved Solids	677	592	565	543	594	NS	NS	NS	2100	
Chlorides	110	95	108	136	112	600	600	NS	600	
Sulphates	21	35	48	31	34	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	156	133	132	80	125	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	109	173	194	239	179	NS	NS	NS	NS	
Sodium	54	78	77	77	72	NS	NS	NS	1	
Potassium	9.3	9.3	6.7	5.0	7.6	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.370	0.109	0.058	0.063	0.150	NS	NS	NS	NS	
Copper	0.000	0.013	0.015	0.009	0.009	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.007	0.005	0.003	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.013	0.021	0.014	0.012	0.1	0.1	NS	NS	
Zinc	0.000	0.011	0.035	0.036	0.020	NS	NS	NS	NS	
Nickel	0.000	0.000	0.002	0.000	0.001	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.003	0.001	0.001	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	3	3	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.015	0.002	0.008	0.012	0.009	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Dalaipalem (GW17)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.8	8.16	8.25	8.0	8.0	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	26.8	30.8	28.9	29.7	29.0	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	NIL	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	791	817	762	717	772	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.68	2.08	2.3	1.3	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	3.4	0.80	NIL	5.1	3.1	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	374	290	328	364	339	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	NIL	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	7.2	7.2	6.9	7.2	7.1	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.1	0.30	0.82	1.0	0.5	3	3	NS	NS	
Chemical Oxygen Demand	0.1	0.73	1.44	1.6	1.0	NS	NS	NS	NS	
Cyanides	0.0	0.00	NIL	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.1	1.65	1.25	0.9	1.0	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	NIL	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.0	0.15	0.16	0.3	0.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.0	0.11	0.15	0.2	0.1	NS	NS	1.2	NS	
Nitrate Nitrogen	0.6	0.54	0.83	1.4	0.9	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.07	NIL	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	NIL	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.01	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	NIL	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	185	165	182	195	182	NS	NS	NS	NS	
Total Suspended Solids	0	0	4	4	2	NS	NS	NS	NS	
Total Dissolved Solids	535	552	513	489	522	NS	NS	NS	2100	
Chlorides	120	161	132	119	133	600	600	NS	600	
Sulphates	36	30	15	21	25	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	92	92	82	66	83	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	94	73	110	129	101	NS	NS	NS	NS	
Sodium	60	141	147	91	110	NS	NS	NS	1	
Potassium	11.2	7.7	5.7	1.0	6.4	NS	NS	NS	NS	
Arsenic	0.000	0.000	NIL	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	NIL	0.000	0.000	NS	NS	NS	NS	
Iron	0.293	0.543	0.270	0.063	0.292	NS	NS	NS	NS	
Copper	0.006	0.014	0.004	0.001	0.006	NS	NS	NS	NS	
Mercury	0.000	0.000	NIL	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	NIL	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.008	0.002	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	NIL	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.016	0.002	0.001	0.005	0.1	0.1	NS	NS	
Zinc	0.004	0.012	0.016	0.009	0.010	NS	NS	NS	NS	
Nickel	0.000	0.000	NIL	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	NIL	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	0	2	2	1	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	NIL	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	NIL	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.005	0.001	0.006	0.008	0.005	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	NIL	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	NIL	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(Units are in mg/L unless otherwise indicated)

Sampling location	Salt pans (GW18)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (units)	6.7	6.69	6.84	6.4	6.7	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	31.2	31.1	31.8	30.8	31.2	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	70293	92979	99400	118033	95176	NS	NS	1000	3000	
Turbidity (NTU)	0.5	0.93	1.30	1.4	1.0	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	15.6	15.48	19.40	18.8	17.3	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	274	165	303	729	367	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	4.5	5.8	3.9	3.8	4.5	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	7.5	4.17	8.80	7.9	7.1	3	3	NS	NS	
Chemical Oxygen Demand	14.5	9.38	16.00	12.8	13.2	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.1	1.15	1.25	1.3	1.0	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.3	0.68	1.75	1.8	1.1	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	0.59	1.55	1.3	0.9	NS	NS	1.2	NS	
Nitrate Nitrogen	2.2	2.09	2.20	3.0	2.4	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.1	0.02	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.83	0.09	0.0	0.2	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	19153	20250	16800	17700	18476	NS	NS	NS	NS	
Total Suspended Solids	2	0	3	4	2	NS	NS	NS	NS	
Total Dissolved Solids	84005	90175	66440	108733	87338	NS	NS	NS	2100	
Chlorides	48270	53900	49950	52608	51182	600	600	NS	600	
Sulphates	4470	3167	2980	2804	3355	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	4363	3683	2395	2650	3273	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	14783	16067	14405	15050	15076	NS	NS	NS	NS	
Sodium	25363	29543	31100	36175	30545	NS	NS	NS	1	
Potassium	564.0	453.0	440.0	495.0	488.0	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.330	0.557	0.560	0.098	0.386	NS	NS	NS	NS	
Copper	0.006	0.226	0.113	0.007	0.088	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.012	0.000	0.003	NS	NS	NS	NS	
Silver	0.000	0.065	0.006	0.013	0.021	NS	NS	NS	NS	
Selenium	0.000	0.000	0.085	0.000	0.021	0.05	0.05	NS	NS	
Lead	0.000	0.199	0.223	0.005	0.107	0.1	0.1	NS	NS	
Zinc	0.006	0.224	0.024	0.011	0.066	NS	NS	NS	NS	
Nickel	0.000	0.031	0.001	0.000	0.008	NS	NS	NS	NS	
Cadmium	0.000	0.000	4.000	0.000	1.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	3	4	0	4	3	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.075	0.389	0.090	0.102	0.164	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Opp HZL gate (GW19)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.3	6.70	6.77	6.6	6.9	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	29.4	30.7	29.1	29.7	29.7	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1384	1185	1296	1509	1343	NS	NS	1000	3000	
Turbidity (NTU)	0.4	0.43	2.30	2.1	1.3	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	8.0	13.43	18.04	19.0	14.6	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	260	180	214	197	213	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.8	7.2	7.0	7.0	7.0	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	2.0	0.40	0.68	1.9	1.3	3	3	NS	NS	
Chemical Oxygen Demand	3.8	0.98	1.92	3.5	2.5	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.6	1.56	1.44	1.3	1.2	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.9	0.30	0.07	0.1	0.3	NS	NS	NS	NS	
Ammonical Nitrogen	0.9	0.27	0.07	0.1	0.3	NS	NS	1.2	NS	
Nitrate Nitrogen	3.7	1.31	0.58	1.5	1.8	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.09	0.05	0.06	0.1	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	372	414	528	611	481	NS	NS	NS	NS	
Total Suspended Solids	0	0	4	148	38	NS	NS	NS	NS	
Total Dissolved Solids	1004	819	858	861	885	NS	NS	NS	2100	
Chlorides	308	222	274	324	282	600	600	NS	600	
Sulphates	87	63	50	71	68	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	165	213	220	204	201	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	208	201	308	407	281	NS	NS	NS	NS	
Sodium	172	134	122	148	144	NS	NS	NS	1	
Potassium	35.7	10.6	4.0	2.0	13.1	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.798	0.343	0.233	0.150	0.381	NS	NS	NS	NS	
Copper	0.000	0.009	0.007	0.004	0.005	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.005	0.002	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.009	0.004	0.002	0.004	0.1	0.1	NS	NS	
Zinc	0.001	0.010	0.017	0.013	0.010	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.002	0.001	0.001	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	0	2	0	1	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.012	0.002	0.000	0.009	0.006	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Anakapalli (GW20)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.3	7.29	7.51	7.4	7.4	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	28.2	30.0	30.0	28.9	29.3	NS	NS	NS	NS	
Colour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	624	806	766	638	708	NS	NS	1000	3000	
Turbidity (NTU)	0.4	0.50	2.62	3.6	1.8	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	7.7	10.20	7.32	8.4	8.4	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	266	257	322	273	279	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.8	7.0	6.8	7.0	6.9	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	1.5	1.02	1.20	1.4	1.3	3	3	NS	NS	
Chemical Oxygen Demand	2.8	1.86	2.36	2.4	2.3	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.0	0.0	0.01	0.01	NS	NS	
Phosphates	0.8	1.09	1.42	1.2	1.1	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.0	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.0	0.31	0.30	0.4	0.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.0	0.27	0.28	0.3	0.2	NS	NS	1.2	NS	
Nitrate Nitrogen	0.7	0.92	0.92	2.4	1.2	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.18	0.06	0.05	0.1	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.0	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.0	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	180	272	306	242	250	NS	NS	NS	NS	
Total Suspended Solids	0	0	5	5	3	NS	NS	NS	NS	
Total Dissolved Solids	461	555	518	438	493	NS	NS	NS	2100	
Chlorides	111	140	146	263	165	600	600	NS	600	
Sulphates	54	31	26	17	32	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	109	168	148	93	130	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	72	103	158	149	120	NS	NS	NS	NS	
Sodium	54	99	83	61	74	NS	NS	NS	1	
Potassium	40.7	8.7	4.0	1.6	13.7	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.483	0.281	0.188	0.150	0.276	NS	NS	NS	NS	
Copper	0.004	0.011	0.011	0.003	0.007	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.006	0.002	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.006	0.002	0.001	0.002	0.1	0.1	NS	NS	
Zinc	0.008	0.007	0.017	0.003	0.009	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	2	2	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.013	0.002	0.041	0.059	0.029	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

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UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Madatur (GW21)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.3	7.45	7.54	7.5	7.4	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	31.1	31.2	30.5	29.8	30.7	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.000	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	679	620	612	685	649	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.58	2.92	3.1	1.7	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	8.0	7.73	6.96	7.8	7.6	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	328	295	356	350	332	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.000	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.5	7.3	7.2	7.1	7.0	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	1.5	0.00	0.40	0.3	0.5	3	3	NS	NS	
Chemical Oxygen Demand	2.5	0.00	0.80	0.7	1.0	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.000	0.0	0.01	0.01	NS	NS	
Phosphates	1.1	1.90	1.18	0.8	1.2	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.000	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.0	0.39	0.21	0.8	0.3	NS	NS	NS	NS	
Ammonical Nitrogen	0.0	0.33	0.21	0.6	0.3	NS	NS	1.2	NS	
Nitrate Nitrogen	0.6	0.93	0.93	1.9	1.1	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.09	0.00	0.000	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.000	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.000	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.000	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	169	184	208	253	204	NS	NS	NS	NS	
Total Suspended Solids	0	0	3	4	2	NS	NS	NS	NS	
Total Dissolved Solids	474	422	417	447	440	NS	NS	NS	2100	
Chlorides	94	54	58	78	71	600	600	NS	600	
Sulphates	64	12	17	14	27	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	107	105	102	117	108	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	62	80	106	148	99	NS	NS	NS	NS	
Sodium	42	95	73	65	69	NS	NS	NS	1	
Potassium	7.5	9.1	5.3	3.7	6.4	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.505	0.510	0.196	0.128	0.335	NS	NS	NS	NS	
Copper	0.000	0.009	0.025	0.005	0.010	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.009	0.000	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.012	0.004	0.001	0.004	0.1	0.1	NS	NS	
Zinc	0.001	0.015	0.014	0.005	0.009	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	3	3	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.006	0.000	0.004	0.005	0.004	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Ragavanipalem (GW22)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.5	7.62	7.51	7.6	7.6	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.5	31.2	30.0	29.8	30.4	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.00	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1456	1139	1300	1171	1266	NS	NS	1000	3000	
Turbidity (NTU)	0.6	0.60	2.58	2.7	1.6	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	5.7	6.17	7.74	5.5	6.3	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	490	407	482	467	462	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.00	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.3	7.0	7.1	7.0	6.8	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.8	0.33	0.22	0.3	0.4	3	3	NS	NS	
Chemical Oxygen Demand	1.8	0.92	0.48	0.6	1.0	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	0.2	1.95	1.37	0.92	1.1	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.7	0.48	0.20	0.49	0.5	NS	NS	NS	NS	
Ammonical Nitrogen	0.7	0.36	0.20	0.5	0.4	NS	NS	1.2	NS	
Nitrate Nitrogen	3.6	1.05	0.81	1.8	1.8	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.0	0.35	0.14	0.00	0.1	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.00	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.00	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	325	285	324	310	311	NS	NS	NS	NS	
Total Suspended Solids	1	0	5	3	2	NS	NS	NS	NS	
Total Dissolved Solids	1018	771	859	766	854	NS	NS	NS	2100	
Chlorides	250	188	256	247	235	600	600	NS	600	
Sulphates	215	67	42	41	91	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	172	118	118	101	127	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	153	167	206	209	184	NS	NS	NS	NS	
Sodium	134	190	152	147	156	NS	NS	NS	1	
Potassium	25	10	9.12	7	12.6	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.00	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.00	0.000	NS	NS	NS	NS	
Iron	0.665	0.256	0.100	0.099	0.280	NS	NS	NS	NS	
Copper	0.001	0.011	0.009	0.005	0.006	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.00	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.00	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.008	0.00	0.002	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.00	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.014	0.021	0.005	0.010	0.1	0.1	NS	NS	
Zinc	0.002	0.013	0.014	0.007	0.009	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.00	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.00	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	0	3	3	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.00	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.00	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.006	0.002	0.003	0.004	0.003	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Lankelapalem (GW23)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.8	8.32	8.04	7.8	8.0	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	26.3	30.5	29.9	29.5	29.1	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.000	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1309	1140	1084	1146	1170	NS	NS	1000	3000	
Turbidity (NTU)	0.6	0.70	2.16	2.3	1.4	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	2.0	0.00	1.70	4.40	2.0	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	413	308	368	442	383	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.000	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.9	7.1	7.0	7.2	7.0	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.1	0.54	0.33	0.8	0.4	3	3	NS	NS	
Chemical Oxygen Demand	0.3	1.32	0.70	1.4	0.9	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.000	0.0	0.01	0.01	NS	NS	
Phosphates	0.5	1.50	1.58	1.3	1.2	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.000	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.9	0.42	0.35	0.5	0.5	NS	NS	NS	NS	
Ammonical Nitrogen	0.8	0.31	0.35	0.4	0.5	NS	NS	1.2	NS	
Nitrate Nitrogen	4.0	1.83	1.42	2.4	2.4	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.1	0.97	0.36	0.000	0.4	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.000	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.000	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.000	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	548	388	416	428	445	NS	NS	NS	NS	
Total Suspended Solids	1	0	4	2	2	NS	NS	NS	NS	
Total Dissolved Solids	985	764	709	1869	1082	NS	NS	NS	2100	
Chlorides	273	191	212	220	224	600	600	NS	600	
Sulphates	124	65	30	35	64	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	309	178	146	115	187	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	239	544	250	313	337	NS	NS	NS	NS	
Sodium	140	134	111	112	124	NS	NS	NS	1	
Potassium	25	33	31.06	21.7	27.7	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	1.000	0.579	0.193	0.131	0.476	NS	NS	NS	NS	
Copper	0.001	0.011	0.004	0.002	0.005	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.005	0.009	0.000	0.004	NS	NS	NS	NS	
Selenium	0.000	0.008	0.000	0.000	0.002	0.05	0.05	NS	NS	
Lead	0.000	0.022	0.022	0.002	0.011	0.1	0.1	NS	NS	
Zinc	0.000	0.015	0.017	0.008	0.010	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	2	2	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.012	0.003	0.001	0.002	0.004	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Duvvada (GW24)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.8	8.12	12.30	8.0	9.1	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	30.9	31.2	24.9	30.8	29.4	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	1445	1396	1201	1315	1339	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.83	1.73	2.7	1.4	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	2.1	0.60	3.38	0.4	1.6	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	613	472	408	582	518	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.4	7.1	7.0	7.2	6.9	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.9	0.53	0.29	0.2	0.5	3	3	NS	NS	
Chemical Oxygen Demand	1.6	1.20	0.67	0.4	1.0	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0	0.0	0.01	0.01	NS	NS	
Phosphates	1.0	0.98	1.18	1.09	1.0	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.0	0.25	0.47	0.74	0.4	NS	NS	NS	NS	
Ammonical Nitrogen	0.0	0.22	0.43	0.6	0.3	NS	NS	1.2	NS	
Nitrate Nitrogen	1.4	1.10	1.98	2.1	1.6	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.1	0.06	0.32	0.00	0.1	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.00	0.0	0.1	0.1	0.1	NS	
Boron	0.0	0.00	0.00	0.00	0.0	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	300	161	397	162	255	NS	NS	NS	NS	
Total Suspended Solids	1	0	2	3	1	NS	NS	NS	NS	
Total Dissolved Solids	1068	933	817	918	934	NS	NS	NS	2100	
Chlorides	233	202	236	237	227	600	600	NS	600	
Sulphates	133	91	60	52	84	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	115	71	170	53	102	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	185	90	290	109	168	NS	NS	NS	NS	
Sodium	133	316	137	254	210	NS	NS	NS	1	
Potassium	22	10	21.11	3	14.0	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.530	0.506	0.394	0.203	0.408	NS	NS	NS	NS	
Copper	0.000	0.019	0.006	0.001	0.007	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.009	0.004	0.000	0.003	NS	NS	NS	NS	
Selenium	0.000	0.011	0.000	0.000	0.003	0.05	0.05	NS	NS	
Lead	0.000	0.028	0.014	0.004	0.012	0.1	0.1	NS	NS	
Zinc	0.002	0.014	0.011	0.005	0.008	NS	NS	NS	NS	
Nickel	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	3	2	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.005	0.004	0.005	0.004	0.004	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Groundwater quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Appikonda (GW25)					Public water supplies	Bathing ghats	Fish culture	Irrigation	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Indian Standards (IS 2296)				
pH (pH units)	7.4	7.61	7.89	7.8	7.7	6.0-9.0	6.0-9.0	6.0-9.0	5.5-9.0	
Temperature (Celsius)	26.9	30.4	29.2	28.0	28.6	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	NS	NS	NS	NS	
Colour (Hazen units)	0.0	0.00	0.00	0.000	0.0	NS	NS	NS	NS	
Conductivity (micromhos/cm)	879	772	744	791	796	NS	NS	1000	3000	
Turbidity (NTU)	0.3	0.58	1.20	2.3	1.1	NS	NS	NS	NS	
Acidity (mgCaCO3/L)	7.1	5.88	3.70	2.9	4.9	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	355	250	298	305	302	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.00	0.0	NS	NS	NS	NS	
Dissolved Oxygen	6.8	7.1	7.2	7.3	7.1	3.0	3.0	3.0	NS	Ref (1)
Biochemical Oxygen Demand	0.3	0.52	0.00	0.33	0.3	3	3	NS	NS	
Chemical Oxygen Demand	0.7	1.28	0.00	0.65	0.6	NS	NS	NS	NS	
Cyanides	0.0	0.00	0.00	0.00	0.0	0.01	0.01	NS	NS	
Phosphates	0.4	0.94	1.52	0.9	0.9	NS	NS	NS	NS	
Hexavalent Chromium	0.0	0.00	0.00	0.00	0.0	0.05	0.05	NS	NS	Total Cr
Total Kjeldahl Nitrogen	0.3	0.40	0.00	0.192	0.2	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	0.32	1.30	0.2	0.5	NS	NS	1.2	NS	
Nitrate Nitrogen	2.1	1.70	1.61	3.1	2.1	50	50	NS	NS	as NO3
Nitrite Nitrogen	0.1	0.04	0.00	0.00	0.0	NS	NS	NS	NS	
Oil and Grease	0.0	0.00	0.00	0.00	0.0	0.1	0.1	0.1	NS	
Boron	0.0	1.59	0.00	0.00	0.4	NS	NS	NS	2	
Phenolic Compounds	0.0	0.00	0.00	0.00	0.0	0.005	0.005	NS	NS	
Total Hardness (mgCaCO3/L)	287	255	284	306	283	NS	NS	NS	NS	
Total Suspended Solids	1	0	4	4	2	NS	NS	NS	NS	
Total Dissolved Solids	635	520	490	533	544	NS	NS	NS	2100	
Chlorides	158	127	164	163	153	600	600	NS	600	
Sulphates	44	26	29	19	29	NS	NS	NS	1000	
Calcium (mgCaCO3/L)	180	135	158	142	154	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	85	120	126	163	123	NS	NS	NS	NS	
Sodium	83	113	119	92	102	NS	NS	NS	1	
Potassium	14	7	6.83	6.2	8.5	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	0.2	0.2	NS	NS	
Manganese	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Iron	0.255	0.360	0.226	0.190	0.258	NS	NS	NS	NS	
Copper	0.003	0.014	0.005	0.001	0.005	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Barium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Silver	0.000	0.000	0.004	0.000	0.001	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	0.05	0.05	NS	NS	
Lead	0.000	0.012	0.000	0.000	0.003	0.1	0.1	NS	NS	
Zinc	0.001	0.017	0.016	0.006	0.010	NS	NS	NS	NS	
Nickel	0.000	0.004	0.000	0.000	0.001	NS	NS	NS	NS	
Cadmium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	3	2	3	2	2	Ref (2)	NS	NS	NS	Ref (2)
Pesticides	0.000	0.000	0.000	0.000	0.000	Absent	Absent	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	
Total Organic Carbon (%)	0.005	0.002	0.000	0.001	0.002	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	

Ref (1): 3 mg/L or 40% saturation value, whichever is higher

Ref (2): Not 5000, with 5% of the samples with value 20000 and 20% of the samples with value 5000

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Visakh Outer Harbour (MW1)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg (year)	Coastal waters criteria					
pH (pH units)	8.5	8.44	8.28	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.5	27.03	27.53	27.7	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	35628	37245	36667	31275	35204	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.5	0.83	3.77	4.9	2.5	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	225	139	123	135	155	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.4	5.3	6.3	5.8	5.9	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	2.0	21.4	12.33	12.7	12.1	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	4.8	39.2	24.67	18.5	21.8	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	0.88	0.99	1.33	1.17	1.1	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	2.0	3.36	2.87	2.1	2.6	NS	NS	NS	NS	NS	
Ammonical Nitrogen	1.7	2.14	1.48	1.5	1.7	NS	NS	NS	NS	NS	
Nitrate Nitrogen	3.1	2.35	2.15	2.5	2.5	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.07	0.02	0.1	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.47	1.80	1.12	1.1	0.1	NS	NS	10	Ref (6)	
Boron	0.01	2.46	3.69	3.84	2.5	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	4332	5700	5743	4796	5143	NS	NS	NS	NS	NS	
Total Suspended Solids	4	6	6	7	6	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	34678	35792	35290	30005	33941	NS	NS	NS	NS	NS	
Chlorides	14338	20415	18687	14850	17072	NS	NS	NS	NS	NS	
Sulphates	3335	2958	2730	2276	2825	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	1110	1107	900	770	972	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	4740	4595	4810	4026	4543	NS	NS	NS	NS	NS	
Sodium	10443	10538	10067	9140	10047	NS	NS	NS	NS	NS	
Potassium	419	376	353	335	371	NS	NS	NS	NS	NS	
Arsenic	0.000	0.010	0.000	0.000	0.003	NS	NS	NS	NS	NS	
Manganese	0.033	0.146	0.038	0.008	0.056	NS	NS	0.500	NS	NS	
Iron	0.144	0.313	0.115	0.061	0.158	NS	NS	0.500	NS	NS	
Copper	0.030	0.323	0.137	0.038	0.132	NS	NS	NS	NS	NS	
Mercury	0.000	0.005	0.000	0.000	0.001	0.010	NS	NS	NS	NS	
Barium	0.000	0.010	0.002	0.001	0.003	NS	NS	NS	NS	NS	
Silver	0.000	0.133	0.002	0.001	0.034	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.048	0.000	0.012	NS	NS	NS	NS	NS	
Lead	0.033	0.445	0.034	0.008	0.130	0.010	NS	NS	NS	NS	
Zinc	0.030	0.601	0.117	0.024	0.193	NS	NS	NS	NS	NS	
Nickel	0.034	0.102	0.014	0.001	0.038	NS	NS	NS	NS	NS	
Cadmium	0.026	0.142	0.006	0.002	0.044	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	3	8	8	5	6	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.102	2.510	1.157	0.697	1.116	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Yerada beach (MW2)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.5	8.41	8.29	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	26.9	27.13	27.63	27.9	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	35198	40465	36400	31654	35929	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.3	1.05	4.80	4.5	2.7	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	243	146	117	130	159	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.6	5.8	6.3	6.0	6.2	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	1.7	17.2	11.33	11.8	10.5	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	4.1	35.3	34.00	18.6	23.0	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.65	1.25	1.35	1.07	1.3	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	1.2	3.23	2.88	2.0	2.3	NS	NS	NS	NS	NS	
Ammonical Nitrogen	1.2	1.93	1.63	1.4	1.5	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.9	2.18	2.36	2.5	2.5	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.06	0.02	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.64	1.60	0.64	1.0	0.1	NS	NS	10	Ref (6)	
Boron	0.00	3.15	3.90	3.84	2.7	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5840	5683	5763	4890	5544	NS	NS	NS	NS	NS	
Total Suspended Solids	3	6	6	6	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	34250	38858	35440	30462	34752	NS	NS	NS	NS	NS	
Chlorides	18468	22523	18860	15124	18744	NS	NS	NS	NS	NS	
Sulphates	3098	3103	2597	2306	2776	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	973	1070	903	786	933	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	4868	4613	4860	4104	4611	NS	NS	NS	NS	NS	
Sodium	10347	11007	10017	9212	10146	NS	NS	NS	NS	NS	
Potassium	423	398	359	334	379	NS	NS	NS	NS	NS	
Arsenic	0.000	0.007	0.000	0.000	0.002	NS	NS	NS	NS	NS	
Manganese	0.007	0.061	0.031	0.005	0.026	NS	NS	0.500	NS	NS	
Iron	0.167	0.170	0.105	0.062	0.126	NS	NS	0.500	NS	NS	
Copper	0.011	0.228	0.125	0.033	0.099	NS	NS	NS	NS	NS	
Mercury	0.000	0.003	0.000	0.000	0.001	0.010	NS	NS	NS	NS	
Barium	0.000	0.006	0.002	0.001	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.106	0.003	0.002	0.028	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.067	0.000	0.017	NS	NS	NS	NS	NS	
Lead	0.014	0.291	0.031	0.009	0.086	0.010	NS	NS	NS	NS	
Zinc	0.015	0.471	0.125	0.029	0.160	NS	NS	NS	NS	NS	
Nickel	0.007	0.061	0.006	0.001	0.019	NS	NS	NS	NS	NS	
Cadmium	0.004	0.089	0.003	0.001	0.024	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	4	7	9	6	6	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.105	2.410	1.527	0.736	1.194	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.0	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Gangavaram (MW3)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.4	8.53	8.27	8.2	8.4	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.0	27.25	27.37	27.8	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	35920	36783	35787	31478	34992	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.3	1.23	5.57	4.0	2.8	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	231	136	123	132	155	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.5	5.9	6.3	6.1	6.2	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	2.0	14.4	13.00	10.2	9.9	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	5.5	83.9	37.67	16.6	35.9	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.31	1.30	1.53	1.04	1.3	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.6	2.62	2.71	1.7	1.9	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.6	1.57	1.40	1.3	1.2	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.8	2.23	2.69	2.4	2.5	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.05	0.03	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	3.00	2.00	0.00	1.3	0.1	NS	NS	10	Ref (6)	
Boron	0.04	3.01	3.83	3.71	2.6	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5980	5647	5760	4902	5572	NS	NS	NS	NS	NS	
Total Suspended Solids	3	6	7	5	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	34800	35380	35043	36398	35405	NS	NS	NS	NS	NS	
Chlorides	18935	21272	18733	15162	18526	NS	NS	NS	NS	NS	
Sulphates	3124	2975	2533	2282	2728	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	870	1117	917	802	926	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	5110	4530	4843	4100	4646	NS	NS	NS	NS	NS	
Sodium	10542	10702	9750	8988	9995	NS	NS	NS	NS	NS	
Potassium	419	383	366	343	378	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.003	0.063	0.034	0.006	0.027	NS	NS	0.500	NS	NS	
Iron	0.170	0.223	0.114	0.055	0.141	NS	NS	0.500	NS	NS	
Copper	0.010	0.237	0.143	0.045	0.109	NS	NS	NS	NS	NS	
Mercury	0.000	0.002	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.006	0.004	0.002	0.003	NS	NS	NS	NS	NS	
Silver	0.000	0.111	0.005	0.001	0.029	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.082	0.000	0.021	NS	NS	NS	NS	NS	
Lead	0.007	0.269	0.029	0.010	0.079	0.010	NS	NS	NS	NS	
Zinc	0.013	0.405	0.116	0.021	0.139	NS	NS	NS	NS	NS	
Nickel	0.009	0.031	0.012	0.002	0.013	NS	NS	NS	NS	NS	
Cadmium	0.001	0.063	0.004	0.001	0.017	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	5	5	10	7	7	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.058	2.065	1.570	0.715	1.102	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Steel Plant Guest House (MW4)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.3	8.48	8.28	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.2	27.35	27.07	28.0	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	36380	40412	36767	31749	36327	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.2	1.03	5.30	4.0	2.6	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	213	135	123	134	151	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.3	6.2	6.3	6.2	6.2	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	2.9	13.2	11.33	10.2	9.4	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	6.6	28.7	35.33	18.4	22.2	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.09	1.44	1.36	0.97	1.2	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.4	2.39	2.71	1.6	1.8	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.4	1.60	1.61	1.1	1.2	NS	NS	NS	NS	NS	
Nitrate Nitrogen	3.0	2.36	2.53	2.4	2.6	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.18	0.03	0.0	0.1	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.54	1.80	0.40	0.9	0.1	NS	NS	10	Ref (6)	
Boron	0.03	3.15	3.74	3.71	2.7	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	6013	5785	5780	4894	5618	NS	NS	NS	NS	NS	
Total Suspended Solids	4	6	6	5	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	35003	38942	35717	30427	35022	NS	NS	NS	NS	NS	
Chlorides	19275	22958	19067	15184	19121	NS	NS	NS	NS	NS	
Sulphates	3297	3153	2797	2538	2946	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	815	1083	930	810	910	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	5198	4702	4850	4084	4708	NS	NS	NS	NS	NS	
Sodium	10594	11513	10003	9126	10309	NS	NS	NS	NS	NS	
Potassium	419	411	369	337	384	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.002	0.042	0.028	0.008	0.020	NS	NS	0.500	NS	NS	
Iron	0.124	0.319	0.108	0.067	0.154	NS	NS	0.500	NS	NS	
Copper	0.028	0.297	0.127	0.041	0.123	NS	NS	NS	NS	NS	
Mercury	0.000	0.003	0.000	0.000	0.001	0.010	NS	NS	NS	NS	
Barium	0.000	0.005	0.002	0.001	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.129	0.002	0.001	0.033	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.076	0.000	0.019	NS	NS	NS	NS	NS	
Lead	0.007	0.270	0.036	0.012	0.081	0.010	NS	NS	NS	NS	
Zinc	0.022	0.369	0.115	0.026	0.133	NS	NS	NS	NS	NS	
Nickel	0.017	0.035	0.009	0.001	0.015	NS	NS	NS	NS	NS	
Cadmium	0.016	0.059	0.003	0.001	0.020	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	3	6	7	5	5	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.079	2.263	1.460	0.680	1.120	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Steel Plant SW boundary (MW5)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.3	8.33	8.24	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.2	27.83	27.00	27.8	27.5	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	36820	36852	36136	31546	35339	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.1	0.83	5.03	4.0	2.5	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	215	138	121	135	152	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.8	6.2	6.2	6.2	6.3	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	2.4	13.6	12.00	9.5	9.4	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	6.4	27.3	20.00	13.9	16.9	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	0.92	1.34	1.20	0.92	1.1	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.5	3.57	2.71	1.7	2.1	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.5	2.37	1.72	1.1	1.4	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.9	2.43	2.47	2.4	2.6	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.07	0.02	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.04	1.40	0.72	0.8	0.1	NS	NS	10	Ref (6)	
Boron	0.00	3.04	3.65	3.69	2.6	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	6235	5650	5850	4890	5656	NS	NS	NS	NS	NS	
Total Suspended Solids	3	5	7	5	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	33091	35445	34597	30331	33366	NS	NS	NS	NS	NS	
Chlorides	19225	21533	18680	15054	18623	NS	NS	NS	NS	NS	
Sulphates	3399	3010	2820	2304	2883	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	1158	1043	953	796	988	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	5078	4607	4897	4094	4669	NS	NS	NS	NS	NS	
Sodium	10703	10623	10020	9313	10165	NS	NS	NS	NS	NS	
Potassium	441	381	353	333	377	NS	NS	NS	NS	NS	
Arsenic	0.000	0.010	0.000	0.000	0.003	NS	NS	NS	NS	NS	
Manganese	0.000	0.014	0.018	0.005	0.009	NS	NS	0.500	NS	NS	
Iron	0.107	0.108	0.091	0.058	0.091	NS	NS	0.500	NS	NS	
Copper	0.017	0.453	0.104	0.042	0.154	NS	NS	NS	NS	NS	
Mercury	0.000	0.002	0.000	0.000	0.001	0.010	NS	NS	NS	NS	
Barium	0.000	0.005	0.001	0.002	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.039	0.006	0.002	0.012	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.023	0.198	0.014	0.008	0.061	0.010	NS	NS	NS	NS	
Zinc	0.021	0.252	0.084	0.026	0.095	NS	NS	NS	NS	NS	
Nickel	0.024	0.026	0.003	0.001	0.013	NS	NS	NS	NS	NS	
Cadmium	0.006	0.040	0.002	0.001	0.012	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	4	4	7	4	5	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.070	1.894	1.077	0.788	0.957	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Appikonda (MW6)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.3	8.46	8.27	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.1	27.62	27.13	27.8	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	35485	39520	36796	31656	35864	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.3	0.90	6.93	4.1	3.1	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	223	130	126	133	153	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.5	5.6	6.3	6.2	6.2	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	2.0	18.3	10.00	9.7	10.0	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	5.8	33.2	17.00	14.4	17.6	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.15	1.51	1.26	0.93	1.2	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.3	3.58	2.85	1.7	2.1	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	2.30	1.70	1.1	1.3	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.4	2.48	2.44	2.4	2.4	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.06	0.03	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	0.95	1.20	0.00	0.5	0.1	NS	NS	10	Ref (6)	
Boron	0.01	2.73	3.72	3.68	2.5	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5988	5733	5913	4908	5636	NS	NS	NS	NS	NS	
Total Suspended Solids	2	6	7	4	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	34091	37983	35753	30472	34575	NS	NS	NS	NS	NS	
Chlorides	18355	22417	18867	15100	18685	NS	NS	NS	NS	NS	
Sulphates	3036	3055	2843	2298	2808	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	943	1045	940	804	933	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	5295	4697	4973	4104	4767	NS	NS	NS	NS	NS	
Sodium	10431	10863	10000	9276	10143	NS	NS	NS	NS	NS	
Potassium	415	380	347	331	368	NS	NS	NS	NS	NS	
Arsenic	0.000	0.008	0.000	0.000	0.002	NS	NS	NS	NS	NS	
Manganese	0.007	0.024	0.017	0.007	0.014	NS	NS	0.500	NS	NS	
Iron	0.117	0.113	0.095	0.054	0.095	NS	NS	0.500	NS	NS	
Copper	0.029	0.315	0.109	0.041	0.123	NS	NS	NS	NS	NS	
Mercury	0.000	0.001	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.004	0.002	0.001	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.046	0.005	0.001	0.013	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.013	0.214	0.032	0.010	0.067	0.010	NS	NS	NS	NS	
Zinc	0.021	0.212	0.078	0.026	0.084	NS	NS	NS	NS	NS	
Nickel	0.025	0.034	0.005	0.002	0.017	NS	NS	NS	NS	NS	
Cadmium	0.002	0.032	0.002	0.001	0.009	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	3	5	8	6	6	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.056	2.613	1.197	0.732	1.149	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	HNPCL site (500 m) (MW7)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.3	8.39	8.23	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	26.9	27.63	27.07	28.0	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	39789	37007	36537	31568	36225	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.4	0.68	6.07	4.3	2.9	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	221	136	124	136	154	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.6	6.5	6.3	6.3	6.4	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	1.4	9.8	11.00	8.9	7.8	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	4.6	18.0	20.33	13.5	14.1	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.21	1.43	1.29	0.90	1.2	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.3	3.61	2.65	1.5	2.0	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.2	2.30	1.65	0.9	1.3	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.8	2.72	2.70	2.3	2.6	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.06	0.04	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.20	2.00	0.00	0.8	0.1	NS	NS	10	Ref (6)	
Boron	0.02	2.80	3.60	3.63	2.5	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	6100	5763	5817	4862	5636	NS	NS	NS	NS	NS	
Total Suspended Solids	4	6	7	5	6	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	36990	35434	35580	30408	34603	NS	NS	NS	NS	NS	
Chlorides	20320	21467	18727	15036	18887	NS	NS	NS	NS	NS	
Sulphates	3038	2972	2727	2290	2756	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	873	1088	913	813	922	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	5228	4675	4903	4049	4714	NS	NS	NS	NS	NS	
Sodium	11094	10395	9770	9188	10112	NS	NS	NS	NS	NS	
Potassium	438	375	341	334	372	NS	NS	NS	NS	NS	
Arsenic	0.000	0.007	0.000	0.000	0.002	NS	NS	NS	NS	NS	
Manganese	0.006	0.026	0.018	0.006	0.014	NS	NS	0.500	NS	NS	
Iron	0.081	0.109	0.089	0.060	0.085	NS	NS	0.500	NS	NS	
Copper	0.021	0.285	0.103	0.037	0.111	NS	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.002	0.003	0.001	0.001	NS	NS	NS	NS	NS	
Silver	0.000	0.048	0.005	0.002	0.014	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.008	0.193	0.041	0.011	0.063	0.010	NS	NS	NS	NS	
Zinc	0.013	0.201	0.074	0.025	0.078	NS	NS	NS	NS	NS	
Nickel	0.021	0.068	0.008	0.001	0.025	NS	NS	NS	NS	NS	
Cadmium	0.005	0.040	0.003	0.001	0.012	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	5	7	5	4	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.080	0.925	1.012	0.793	0.702	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	HNPCL site (2 km) (MW8)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.2	8.37	8.27	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.1	27.47	27.07	28.1	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	35426	38547	36587	31600	35540	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.2	0.73	6.47	3.9	2.8	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	215	137	126	133	153	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.3	6.2	6.2	6.3	6.2	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	2.2	16.2	12.27	10.4	10.3	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	5.8	34.7	22.67	16.6	19.9	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.48	1.40	1.39	0.99	1.3	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.3	3.29	2.75	1.6	2.0	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	2.14	1.87	1.0	1.3	NS	NS	NS	NS	NS	
Nitrate Nitrogen	3.4	2.65	2.62	2.4	2.8	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.04	0.04	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	0.73	1.50	0.00	0.6	0.1	NS	NS	10	Ref (6)	
Boron	0.01	3.06	3.67	3.60	2.6	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5993	5660	5810	4852	5579	NS	NS	NS	NS	NS	
Total Suspended Solids	4	5	7	5	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	34461	36985	35490	30400	34334	NS	NS	NS	NS	NS	
Chlorides	19000	22417	18480	14964	18715	NS	NS	NS	NS	NS	
Sulphates	3104	3040	2773	2286	2801	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	945	1027	930	815	929	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	5048	4633	4880	4037	4650	NS	NS	NS	NS	NS	
Sodium	10601	10740	9817	9230	10097	NS	NS	NS	NS	NS	
Potassium	411	389	345	328	368	NS	NS	NS	NS	NS	
Arsenic	0.000	0.005	0.000	0.000	0.001	NS	NS	NS	NS	NS	
Manganese	0.005	0.033	0.014	0.004	0.014	NS	NS	0.500	NS	NS	
Iron	0.089	0.124	0.080	0.057	0.087	NS	NS	0.500	NS	NS	
Copper	0.016	0.248	0.104	0.038	0.101	NS	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.004	0.001	0.001	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.042	0.005	0.002	0.012	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.007	0.223	0.046	0.013	0.072	0.010	NS	NS	NS	NS	
Zinc	0.039	0.215	0.050	0.021	0.081	NS	NS	NS	NS	NS	
Nickel	0.024	0.040	0.007	0.002	0.018	NS	NS	NS	NS	NS	
Cadmium	0.006	0.039	0.004	0.002	0.012	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	2	7	7	6	5	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.062	3.188	0.924	0.777	1.238	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	HNPCL site (5 km) (MW9)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.3	8.47	8.21	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	26.9	27.52	26.87	28.1	27.3	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	35345	36782	35687	31325	34785	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.1	0.75	5.47	3.8	2.5	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	211	140	124	133	152	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.5	6.0	6.3	6.2	6.2	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	1.9	17.1	11.00	9.6	9.9	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	5.1	31.2	19.67	16.0	18.0	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.27	1.22	1.25	0.86	1.2	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.2	3.23	2.60	1.5	1.9	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.1	2.06	1.67	0.9	1.2	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.5	2.01	2.40	2.5	2.4	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.04	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.00	0.90	0.00	0.5	0.1	NS	NS	10	Ref (6)	
Boron	0.02	3.12	3.66	3.62	2.6	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5735	5727	5867	4900	5557	NS	NS	NS	NS	NS	
Total Suspended Solids	3	5	6	5	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	34128	35370	35207	30278	33745	NS	NS	NS	NS	NS	
Chlorides	18450	20967	18433	15008	18215	NS	NS	NS	NS	NS	
Sulphates	3022	3027	2797	2330	2794	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	953	1023	903	802	920	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	4783	4703	4963	4098	4637	NS	NS	NS	NS	NS	
Sodium	10325	10578	9983	9289	10044	NS	NS	NS	NS	NS	
Potassium	418	373	356	322	367	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.009	0.012	0.043	0.006	0.018	NS	NS	0.500	NS	NS	
Iron	0.132	0.105	0.093	0.048	0.094	NS	NS	0.500	NS	NS	
Copper	0.035	0.253	0.075	0.022	0.096	NS	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.007	0.001	0.001	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.103	0.005	0.001	0.027	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.073	0.262	0.036	0.008	0.095	0.010	NS	NS	NS	NS	
Zinc	0.058	0.370	0.097	0.021	0.137	NS	NS	NS	NS	NS	
Nickel	0.013	0.075	0.012	0.001	0.025	NS	NS	NS	NS	NS	
Cadmium	0.008	0.055	0.003	0.001	0.017	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	2	9	6	4	5	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.043	2.467	0.937	0.753	1.050	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Thikkavanipalem rocky outcrop (MW10)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.3	8.47	8.21	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.1	27.68	26.77	28.1	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	37991	38550	36400	31582	36131	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.2	0.87	5.00	3.9	2.5	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	225	139	127	132	156	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.6	6.1	6.3	6.2	6.3	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	1.7	13.9	9.87	10.0	8.9	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	4.7	24.8	20.00	17.2	16.7	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.65	1.30	1.30	0.87	1.3	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.2	3.12	2.73	1.5	1.9	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.1	1.84	1.59	1.0	1.1	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.5	2.28	2.52	2.5	2.4	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.05	0.03	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	0.80	1.20	0.00	0.5	0.1	NS	NS	10	Ref (6)	
Boron	0.02	2.85	3.74	3.59	2.5	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5945	5620	5873	4914	5588	NS	NS	NS	NS	NS	
Total Suspended Solids	2	6	6	4	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	35990	37007	35233	30329	34640	NS	NS	NS	NS	NS	
Chlorides	19350	22157	18433	14992	18733	NS	NS	NS	NS	NS	
Sulphates	3302	3117	2757	2326	2875	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	1095	1060	903	811	967	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	4855	4560	4970	4103	4622	NS	NS	NS	NS	NS	
Sodium	10770	10753	9770	9120	10103	NS	NS	NS	NS	NS	
Potassium	456	382	352	327	379	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.003	0.019	0.036	0.005	0.016	NS	NS	0.500	NS	NS	
Iron	0.206	0.119	0.076	0.054	0.114	NS	NS	0.500	NS	NS	
Copper	0.020	0.215	0.072	0.026	0.083	NS	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.007	0.002	0.001	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.096	0.004	0.001	0.025	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.039	0.309	0.044	0.015	0.102	0.010	NS	NS	NS	NS	
Zinc	0.088	0.347	0.114	0.023	0.143	NS	NS	NS	NS	NS	
Nickel	0.023	0.061	0.010	0.002	0.024	NS	NS	NS	NS	NS	
Cadmium	0.003	0.042	0.004	0.001	0.013	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	2	5	8	5	5	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.082	2.305	0.900	0.794	1.020	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Mutyalammapalem creek mouth (MW11)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.2	8.42	8.23	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.0	27.90	26.97	27.9	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	37145	37715	35833	31424	35529	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.3	0.93	4.73	4.2	2.5	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	221	137	126	133	154	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.1	6.1	6.3	6.2	6.2	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	4.2	14.1	10.33	8.8	9.4	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	5.3	25.4	20.67	15.4	16.7	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	2.54	1.70	1.33	0.86	1.6	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	1.4	3.11	2.70	1.5	2.2	NS	NS	NS	NS	NS	
Ammonical Nitrogen	1.2	1.99	1.68	1.0	1.5	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.8	2.44	2.41	2.5	2.5	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.04	0.02	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.15	0.80	0.00	0.5	0.1	NS	NS	10	Ref (6)	
Boron	0.01	3.24	3.80	3.62	2.7	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5693	5788	5800	4890	5543	NS	NS	NS	NS	NS	
Total Suspended Solids	3	6	9	5	6	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	35818	36216	34670	30149	34213	NS	NS	NS	NS	NS	
Chlorides	19450	21323	18133	14896	18451	NS	NS	NS	NS	NS	
Sulphates	3155	3028	2673	2306	2791	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	1153	1148	900	794	999	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	4540	4640	4900	4096	4544	NS	NS	NS	NS	NS	
Sodium	10719	10558	9760	9125	10040	NS	NS	NS	NS	NS	
Potassium	449	369	360	332	378	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.007	0.020	0.034	0.005	0.017	NS	NS	0.500	NS	NS	
Iron	0.217	0.150	0.077	0.065	0.127	NS	NS	0.500	NS	NS	
Copper	0.025	0.215	0.077	0.024	0.085	NS	NS	NS	NS	NS	
Mercury	0.000	0.001	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.005	0.001	0.001	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.091	0.004	0.001	0.024	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.025	0.250	0.036	0.012	0.080	0.010	NS	NS	NS	NS	
Zinc	0.112	0.303	0.113	0.025	0.138	NS	NS	NS	NS	NS	
Nickel	0.007	0.055	0.013	0.003	0.019	NS	NS	NS	NS	NS	
Cadmium	0.005	0.041	0.003	0.001	0.013	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	4	6	7	5	5	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.061	2.210	0.987	0.816	1.018	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	NE of HNPCL plant site (MW12)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.3	8.43	8.26	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.2	27.60	26.83	27.8	27.4	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	37841	37445	35897	31430	35653	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.3	1.00	5.20	4.2	2.7	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	215	135	120	128	150	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.5	6.2	6.3	6.3	6.3	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	1.6	13.0	11.50	9.9	9.0	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	4.8	26.5	21.00	12.0	16.1	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	2.48	1.51	1.36	0.91	1.6	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.8	2.96	2.75	1.5	2.0	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.6	1.86	1.77	1.0	1.3	NS	NS	NS	NS	NS	
Nitrate Nitrogen	3.1	2.42	2.29	2.4	2.6	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.03	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.17	1.50	0.00	0.7	0.1	NS	NS	10	Ref (6)	
Boron	0.01	2.91	3.79	3.60	2.6	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5920	5873	5803	4862	5615	NS	NS	NS	NS	NS	
Total Suspended Solids	3	6	7	5	5	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	36230	36073	35303	30336	34486	NS	NS	NS	NS	NS	
Chlorides	20218	21503	18600	15088	18852	NS	NS	NS	NS	NS	
Sulphates	10067	3097	2853	2318	4584	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	1068	1163	907	798	984	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	15048	4710	4897	4064	7179	NS	NS	NS	NS	NS	
Sodium	10625	10529	10040	9244	10109	NS	NS	NS	NS	NS	
Potassium	439	388	375	335	384	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.006	0.013	0.030	0.005	0.013	NS	NS	0.500	NS	NS	
Iron	0.209	0.155	0.087	0.064	0.128	NS	NS	0.500	NS	NS	
Copper	0.031	0.227	0.065	0.030	0.088	NS	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.005	0.001	0.001	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.088	0.005	0.002	0.024	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.023	0.258	0.041	0.018	0.085	0.010	NS	NS	NS	NS	
Zinc	0.089	0.299	0.114	0.028	0.132	NS	NS	NS	NS	NS	
Nickel	0.011	0.059	0.009	0.002	0.020	NS	NS	NS	NS	NS	
Cadmium	0.006	0.039	0.002	0.001	0.012	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	2	7	8	5	5	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.083	2.400	1.073	0.843	1.100	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Pudimadaka (MW13)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.2	8.40	8.22	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.3	28.32	26.93	27.9	27.6	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	40005	39308	36567	31481	36840	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.2	0.88	6.20	4.4	2.9	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	209	131	129	135	151	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.6	6.2	6.5	6.3	6.4	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	1.2	13.3	9.13	9.1	8.2	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	3.4	24.9	14.33	13.8	14.1	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	2.59	1.58	1.47	1.11	1.7	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.9	2.75	2.53	1.6	2.0	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.8	1.97	1.65	1.1	1.4	NS	NS	NS	NS	NS	
Nitrate Nitrogen	3.5	2.11	2.50	2.4	2.6	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.04	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	0.80	1.50	0.00	0.6	0.1	NS	NS	10	Ref (6)	
Boron	0.02	3.12	3.83	3.64	2.7	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	5778	5700	5720	4892	5522	NS	NS	NS	NS	NS	
Total Suspended Solids	3	6	8	6	6	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	38760	38117	35483	30434	35698	NS	NS	NS	NS	NS	
Chlorides	20975	22250	17967	14866	19014	NS	NS	NS	NS	NS	
Sulphates	4076	3175	2780	2296	3082	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	1210	1072	877	802	990	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	4568	4628	4843	4090	4532	NS	NS	NS	NS	NS	
Sodium	11314	10777	9900	9226	10304	NS	NS	NS	NS	NS	
Potassium	473	374	359	331	384	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.003	0.014	0.049	0.007	0.018	NS	NS	0.500	NS	NS	
Iron	0.214	0.145	0.083	0.067	0.127	NS	NS	0.500	NS	NS	
Copper	0.015	0.262	0.022	0.019	0.079	NS	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.009	0.003	0.002	0.003	NS	NS	NS	NS	NS	
Silver	0.000	0.049	0.004	0.002	0.014	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.011	0.225	0.017	0.007	0.065	0.010	NS	NS	NS	NS	
Zinc	0.031	0.334	0.047	0.021	0.108	NS	NS	NS	NS	NS	
Nickel	0.012	0.049	0.014	0.003	0.020	NS	NS	NS	NS	NS	
Cadmium	0.002	0.063	0.004	0.002	0.018	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	2	5	4	4	3	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.037	1.708	1.112	0.808	0.916	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Kothapatnam (MW14)					Coastal waters criteria					
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
pH (pH units)	6.1	8.37	8.20	8.2	7.7	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	21.0	28.37	26.97	28.0	26.1	NS	NS	NS	NS	NS	
Odour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	28905	38505	36407	31469	33821	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.2	0.87	7.00	4.2	3.1	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	160	130	127	135	138	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	4.8	6.2	6.4	6.2	5.9	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	1.0	13.3	10.00	9.3	8.4	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	3.1	25.6	16.67	14.0	14.8	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.26	1.54	1.38	1.06	1.3	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.3	2.90	2.61	1.6	1.8	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.3	2.03	1.68	1.0	1.2	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.2	2.27	2.71	2.4	2.4	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.05	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	1.00	1.00	0.00	0.5	0.1	NS	NS	10	Ref (6)	
Boron	0.02	3.09	3.92	3.67	2.7	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	4315	5897	5820	4886	5229	NS	NS	NS	NS	NS	
Total Suspended Solids	3	5	10	5	6	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	27810	37019	35313	30434	32644	NS	NS	NS	NS	NS	
Chlorides	15000	21415	17747	14834	17249	NS	NS	NS	NS	NS	
Sulphates	2498	3227	2823	2307	2714	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	653	1143	883	792	868	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	3663	4753	4937	4094	4362	NS	NS	NS	NS	NS	
Sodium	8542	10603	9950	9247	9586	NS	NS	NS	NS	NS	
Potassium	354	377	376	335	360	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.011	0.016	0.038	0.007	0.018	NS	NS	0.500	NS	NS	
Iron	0.193	0.133	0.095	0.069	0.122	NS	NS	0.500	NS	NS	
Copper	0.009	0.218	0.020	0.019	0.067	NS	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.006	0.001	0.002	0.002	NS	NS	NS	NS	NS	
Silver	0.000	0.049	0.004	0.001	0.013	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.010	0.250	0.018	0.007	0.071	0.010	NS	NS	NS	NS	
Zinc	0.044	0.331	0.046	0.024	0.111	NS	NS	NS	NS	NS	
Nickel	0.007	0.042	0.013	0.003	0.016	NS	NS	NS	NS	NS	
Cadmium	0.003	0.079	0.003	0.001	0.022	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	1	4	6	3	3	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.046	1.760	1.013	0.788	0.902	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Marine water quality around HNPCL plant site (all seasons averages)

(All units are in mg/L unless otherwise indicated)

Sampling location	Chepalapalem near Tantadi (MW15)					Class SW-I	Class SW-II	Class SW-III	Class SW-IV	Class SW-V	Remarks
Parameter	Winter	Premonsoon	Monsoon	Post monsoon	Avg(year)	Coastal waters criteria					
pH (pH units)	8.1	8.42	8.26	8.2	8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	
Temperature (Celsius)	27.1	27.82	27.03	28.1	27.5	NS	NS	NS	NS	NS	
Colour	UO	UO	UO	UO	UO	0	0	0	0	Ref (5)	
Colour (Hazen units)	0.0	0.00	0.00	0.0	0.0	0	0	0	0	Ref (5)	
Conductivity (micromhos/cm)	38438	40907	36900	31556	36950	NS	NS	NS	NS	NS	
Turbidity (NTU)	0.3	0.87	7.13	4.3	3.2	NS	30	30	NS	NS	
Acidity (mgCaCO3/L)	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Alkalinity (mgCaCO3/L)	203	137	125	132	149	NS	NS	NS	NS	NS	
Residual Chlorine	0.0	0.00	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Dissolved Oxygen	6.4	6.2	6.4	6.3	6.3	Ref (1)	Ref (3)	Ref (4)	Ref (4)	Ref (4)	
Biochemical Oxygen Demand	0.9	12.3	8.83	9.2	7.8	NS	3.0	NS	5	NS	
Chemical Oxygen Demand	3.2	23.4	14.67	13.7	13.7	NS	NS	NS	NS	NS	
Cyanides	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Phosphates	1.59	1.47	1.39	1.02	1.4	NS	NS	NS	NS	NS	
Hexavalent Chromium	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Kjeldahl Nitrogen	0.5	2.97	2.71	1.5	1.9	NS	NS	NS	NS	NS	
Ammonical Nitrogen	0.4	2.04	1.63	1.0	1.3	NS	NS	NS	NS	NS	
Nitrate Nitrogen	2.7	2.45	2.63	2.4	2.5	NS	NS	NS	NS	NS	
Nitrite Nitrogen	0.0	0.05	0.00	0.0	0.0	NS	NS	NS	NS	NS	
Oil and Grease	0.00	0.75	1.80	0.00	0.6	0.1	NS	NS	10	Ref (6)	
Boron	0.03	3.16	3.95	3.66	2.7	NS	NS	NS	NS	NS	
Phenolic Compounds	0.00	0.00	0.00	0.00	0.0	NS	NS	NS	NS	NS	
Total Hardness (mgCaCO3/L)	6155	5790	5800	3820	5391	NS	NS	NS	NS	NS	
Total Suspended Solids	3	6	9	5	6	Ref (2)	NS	NS	NS	NS	
Total Dissolved Solids	37280	39356	35712	30499	35711	NS	NS	NS	NS	NS	
Chlorides	20438	23007	18233	14904	19145	NS	NS	NS	NS	NS	
Sulphates	3328	3415	2880	2326	2987	NS	NS	NS	NS	NS	
Calcium (mgCaCO3/L)	1053	1080	900	800	958	NS	NS	NS	NS	NS	
Magnesium (mgCaCO3/L)	5103	4698	4900	4078	4695	NS	NS	NS	NS	NS	
Sodium	10803	11198	10010	9253	10316	NS	NS	NS	NS	NS	
Potassium	475	389	372	340	394	NS	NS	NS	NS	NS	
Arsenic	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Manganese	0.005	0.021	0.038	0.007	0.017	NS	NS	0.500	NS	NS	
Iron	0.254	0.117	0.088	0.049	0.127	NS	NS	0.500	NS	NS	
Copper	0.014	0.239	0.019	0.022	0.073	NS	NS	NS	NS	NS	
Mercury	0.000	0.000	0.000	0.000	0.000	0.010	NS	NS	NS	NS	
Barium	0.000	0.008	0.002	0.001	0.003	NS	NS	NS	NS	NS	
Silver	0.000	0.057	0.004	0.001	0.016	NS	NS	NS	NS	NS	
Selenium	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Lead	0.013	0.268	0.019	0.009	0.077	0.010	NS	NS	NS	NS	
Zinc	0.040	0.313	0.053	0.023	0.107	NS	NS	NS	NS	NS	
Nickel	0.010	0.036	0.011	0.005	0.015	NS	NS	NS	NS	NS	
Cadmium	0.003	0.075	0.004	0.002	0.021	0.010	NS	NS	NS	NS	
Total Coliforms (MPN/100 mL)	2	5	8	4	4	NS	100	500	500	500	Ref (7)
Pesticides	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Polyaromatic Hydrocarbons	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Total Organic Carbon (%)	0.101	1.668	0.920	0.798	0.872	NS	NS	NS	NS	NS	
Alpha Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	
Beta Emitters (microCurie/mL)	0.000	0.000	0.000	0.000	0.000	NS	NS	NS	NS	NS	

Ref (1): 5 mg/L or 60% saturation value, whichever is higher

Ref (2): None from sewage or industrial waste origin

Ref (3): 4 mg/L or 50% saturation value, whichever is higher

Ref (4): 3 mg/L or 40% saturation value, whichever is higher

Ref (5): None, except for such small amounts that may result from discharge of appropriately treated sewage and/or industrial waste

Ref (6): None in such concentrations that would impair any usages specifically assigned to this class

Class SW-I: For salt pans, shell fishing, mariculture, and ecologically sensitive zone

Class SW-II: For bathing, contact water sports, and commercial fishing

Class SW-III: For industrial cooling, recreation (non-contact), and aesthetics

Class SW-IV: For harbour waters

Class SW-V: For navigation and controlled waste disposal

NS = Standard not specified

UO = Unobjectionable

Exhibit D.1. Currents in Bay of Bengal near HNPCL site

Exhibit D.2. Current speed distribution observed at Appikonda

15 m depth persists for most of the year, with more significant variations below this depth. Even in the more inshore regions influenced by the discharge plume, it is likely that isothermal conditions will predominate. A similar trend is also found for salinity varitions with depth; namely variations are small over the top 10-15 m of the water column. These observations suggest that ambient stratification may be neglected in this study.

D.4 Wind Effects

Winds may influence the CW discharge plume in three ways:

1. Wind-induced flows. Surface winds will induce flows in the sea. If the wind has an onshore or offshore component, it may result in vertical circulation at the shoreline. It is unclear from the data available what is the significance of these wind-induced currents. FASETS[5] state that

> "No relationship is found to exist between the observed current direction and velocity and prevalent wind direction. This shows that no wind-generated currents are present in the sea to [current speeds of] 1 m/s."

The float track currents reported by MMS, however, appear to show some wind influence. CORMIX is unable to model an offshore component of current. Nevertheless, as the ambient currents used here are based on the measured float track results, any effect of wind on along-shore current magnitude will be implicitly included.

2. Wind-induced turbulent mixing. Surface wind shear will induce turbulence in the sea, which in turn will increase the rate of dilution of the plume. CORMIX advises that for conservative estimates, a wind speed of 2 m/s should be used to determine ambient turbulent diffusivities, and this value has been used for this study. (By comparison, the meteorological data collated by FASETS for a 30 year period show that the mean wind speed at Visakhapatnam varied between about 2 m/s during winter months and 4 m/s during summer months.)

3. Enhanced surface heat loss. As surface winds increase, the rate of turbulent transport of heat away from the water surface, and consequently the rate of cooling of the water, also increases. In

[5] FASETS India, 1994, Visakhapatnam Thermal Power Station, Coastal/Offshore Database. Report submitted to Black and Veatch International.

this study, however, the conservative assumption of no atmospheric heat exchange was made.

D.5 Discharge Parameters

The proposed CW discharge was assumed to be a horizontal surface discharge at approximately 45° to the coastline, directed towards ESE. The discharge parameters were derived from the information about the preliminary outfall design provided by the EPC contractor, as follows:

Parameter	Value assumed
CW flow rate (m^3/s)	67.75
CW temperature rise (°C)	5.0
Outfall width (m)	20
Outfall depth (m)	2
Increase in salinity in discharge (%)	0.6

This outfall was represented in CORMIX as a surface discharge at an angle of 45° ESE to the coastline.

The preliminary design (Exhibit D.3) prepared by the EPC contractor shows a system of culverts which discharge to the sea through a rectangular area of 20 m × 2 m, with about 1.4 m of water cover above the top of the culverts at mean water level. These culverts would be located in a trapezoidal channel of mean width 32 m, and water depth 3.5 m, both defined at mean water level. CORMIX3 requires that the discharge be represented as a rectangular outfall located at the water surface. This cannot be done in an unambiguous manner as without detailed modelling of the near-to-outfall hydrodynamics it cannot be known whether the discharge retains the culvert dimensions (20 m × 2 m) or expands to fill the trapezoidal channel. For this study, therefore, the two limiting cases were used:

"narrow" case: 20 m × 2 m outfall
"wide" case: 32 m × 3.5 m outfall

The discharge velocity, and hence the penetration into the crossflow, is significantly different in the two cases (1.7 m/s for the "narrow" case and 0.6 m/s for the "wide" case). Results obtained using both these cases are presented in Section 4.2.3 of this report.

Exhibit D3. Preliminary engineering design of outfall
(Subject to change during detailed engineering)

TESTS CONDUCTED BY TCS

E.1 Leachate Tests

To assess if heavy metals would (a) leach into the groundwater under the ash pond and (b) be discharged into the Bay of Bengal through ash recirculation water blowdown, TCS conducted two fly ash leachate tests. Fly ash was collected from the Visakhapatnam Steel Plant (VSP), since VSP also uses Talcher coal which HNPCL plans to use.

In the first test, 50 g of the fly ash were boiled with 200 mL of distilled water. In the second test, 50 g of fly ash were kept in contact with 300 mL of sea water for 24 hours, because sea water would be used to carry ash in the form of a slurry. Concentrations of heavy metals were then determined in filtered samples. The amounts of heavy metals that would be leached out from 200 g fly ash in 1 L of water (assuming 1:5 proportion of ash slurry for dumping) were computed. The computed values are listed below.

Parameter	Concentration in filtered sample (mg/L)			
	FA+SW	FA+DW	SW	ΔC [{FA+SW}-SW]
Zinc	0.130	0.074	0.008	0.122
Cadmium	0.003	0.002	0.003	--
Nickel	0.065	0.037	0.020	0.045
Iron	0.168	0.072	0.100	0.068
Copper	0.046	0.020	0.022	0.024
Lead	0.032	0.014	0.012	0.020

FA = Fly ash, SW = Sea water used for this test, DW = Distilled water
ΔC = Increase in concentration due to leaching from ash

It can be seen from the above table that the amount of zinc leaching out from ash to sea water was greater than those of other heavy metals. Cadmium did not leach out from ash into the sea water. Selenium, arsenic, and mercury were not detected.

The heavy metals leaching into the sea water due to contact with ash will get diluted considerably when the ash water is mixed with cooling water before being discharged into the sea. The concentrations of heavy metals in the final discharge can be calculated as follows:

$$C_{FD} = \frac{(Q_{CW} \times C_{CW}) + (Q_{AW} \times C_{AW})}{Q_{CW} + Q_{AW}}$$

Where:

C_{FD} = Concentration of metal in final discharge
Q_{CW} = Quantity of cooling water discharge (including brine)
C_{CW} = Concentration of metal in cooling water stream
Q_{AW} = Quantity of ash water blowdown
C_{AW} = Concentration of metal in ash water

The concentrations of heavy metals in the final discharge calculated using the above equation are tabulated below. The standards for each parameter in drinking water and in industrial effluents for discharge into sea are also listed for comparison.

Parameter	Concentration (mg/L)				
	SW* (Average)	ΔC+SW (Average)	Final discharge	IS 2490**	IS 10500***
Zinc	0.119	0.241	0.120	15	5
Nickel	0.038	0.083	0.038	2.0	--
Iron	0.099	0.167	0.099	--	0.3
Copper	0.170	0.194	0.170	3.0	0.05
Lead	0.123	0.143	0.123	1.0	0.1

*Average of samples collected over 12 months (2 samples per month) during 1995-96
** Tolerance limits in industrial effluents for discharge into marine coastal areas
*** tolerance limits in drinking water

The above table indicates that the increase in the concentrations of metals due to fly ash in the final discharge will be insignificant, chiefly due to the very high volume (5821917 m^3/d) of the cooling water + brine stream which will dilute the low volume (28800 m^3/d) of ash water stream before discharge to the sea. In any case, the concentrations of metals will be much less than that respective standards for discharge into the sea. Moreover, as shown by the water quality model, the water discharged from the outfall will get diluted rapidly. Therefore, the impact of ash disposal on marine water quality would be insignificant.

The possilibity of ash water leachate reaching groundwater, and even if it reaches, the possiblity of contamination of wells on the landward side of the HNPCL site is extremely remote (details given in the following section). In the highly unlikely event of leachate percolating into groundwater, the concentrations of various metals in the leachate (FA+SW) will likely be considerably lower than the tolerance limits in drinking water for most metals, since by the time the leachate reaches the groundwater table, it is likely that some heavy metals will be adsorbed in the clay lining. The metal concentrations will reduce further when the leachate

gets diluted by the groundwater. Therefore ash water leachates are not expected to affect the groundwater quality in the area significantly.

To monitor the effect of ash pond leachates on groundwater quality, groundwater quality in the area will be monitored on a regular basis. Any changes in the concentrations of heavy metals could be detected during this routine monitoring, and appropriate remedial measures could be taken in case concentrations of certain heavy metals appear to be increasing.

E.2 Leach Pit Tests

In case leachates from ash pond reach the groundwater table, they would then travel along with the groundwater. To assess the possibility of this impact, groundwater flow and direction at the proposed ash pond site were determined using leach pit tests at 3 locations (NW, S, and NE from the centre of the ash pond site), as described below.

One pit was dug at the centre and eight pits were dug in eight directions from the central pit (using magnet). The central pit was larger (60 to 85 cm dia) and the eight surrounding pits were smaller (10 cm dia). The distance between the central pit and the surrounding pits was 25 cm (boundary to boundary). All pits were dug deep enough so that the depth of standing water column was 0.4 m in each pit. Two kg of Analar grade NaCl were added to the central pit and conductivity was measured in all eight surrounding pits as a function of time. In addition, with original pit water, conductivity was measured for various concentrations of NaCl (from 0 g/L to the maximum concentration in the central pit).

The results of the leach pit tests along with the dimensions of the central pits are given below.

Location of Central Pit (from centre of proposed ash pond)	NW	S	NE
Diameter of central pit (cm)	80	60	85
Depth of central pit (m)	1.2	1.85	1.52
Depth of water column in central pit (cm)	45	45	47
Diameter of each observation pit (cm)	10	10	10
Probable direction of GW flow (towards)	S	N or NW	E or S
GW flow velocity (cm/s)	2.7×10^{-4}	3.17×10^{-4}	3.08×10^{-4}
Difference in peak conductivity between upstream and downstream pits (%)	0.80	1.14	3.7
Observation pit distance, boundary to boundary (cm)	24	25	25

After analysing the above data, the following conclusions were drawn:

- Due to low Reynolds Number, molecular diffusion and advective dispersion were found to be of the same order. The concentration-Vs-time curves in the observation pits conformed to the expected superposition of isotropic molecular diffusion and downstream dominant advective dispersion.
- Conductivity-Vs-time curves for the eight observation pits diverged in the middle and tended to converge to pre- and post-salt flux concentrations, thus strengthening the logic of the test.
- For each set of dispersion pits, concentration-Vs-time curve for the downstream observation pit crowned over the curves of other observation pits. These observations indicated that the GW flow direction was towards the middle of the ash pond.
- Because of terrain features of the proposed ash pond area GW flow direction towards the centre of the site, as found from the above tests, is justified.

E.3 Clay Column Test

A bench-scale column test was performed in the laboratory for evaluation of adsorption and dispersion coefficients of the clay particles in the proposed ash pond area. For this test, a PVC column, 50 cm dia and 1 m long, was fitted with water-tight cap and tappings. It was filled at the bottom with polystyrene beads to a depth of 3 cm over which a plastic mesh of 1 mm openings was placed. A clay layer of 5 cm length was packed over the mesh. Over the clay layer, another mesh was placed. The synthetic leachate was prepared by adding 50 gm ash in 300 mL sea water (collected from the Bay of Bengal, near the project site) and keeping those in contact for 2 days. This was then filtered and loaded over the clay sample in the PVC column. The head was maintained at 45 cm. The effluent coming out of the clay column was collected for 2 days. A total of 17 mL of effluent were collected.

The results from the test are given below:

- Volume of leachate collected : 17 mL
- Area of clay column : 19.63 cm^2
- Velocity of flow through clay : 5×10^{-6} cm/s

From these results, the permeability coefficient was calculated using Darcy's equation:

$$V = k(\delta h/\delta s)$$

$$\therefore\ k = V/(\delta h/\delta s)$$
$$= 5\times10^{-6}/(45/5)$$
$$= 4.2\times10^{-5}\ \text{cm/s}$$

The k value obtained during the clay column test is comparable with the values reported by Black & Veatch International[1].

[1] Black and Veatch International, 1995, Onshore Subsurface Investigation Interpretive Report.

FLORA-FAUNA SURVEY

To assess the existing status of the biological environment of the area within a 30 km radius of the HNPCL plant site, a detailed flora-fauna survey, covering four seasons, was carried out during 1995-96. Terrestrial, marine, and aquatic flora-fauna, as well as avi fauna were studied during this survey. The methodology of the survey including sampling procedures is given in Chapter 1. A summary of the survey results is presented in Section 3.5 of this report. Details of the survey observations are presented in this appendix.

Within a 30 km radius of the HNPCL plant site, about 30-40% of the area is under water (primarily Bay of Bengal). About 10-20% area is under settlements, industries, aquaculture farms, and hilly tracts.

F.1 Terrestrial Ecology

The HNPCL site is located in Visakhapatnam district, where some parts of the Eastern *Ghat* hill ranges run diagonally from northeast to southwest. The various terrestrial habitats in the area are as follows:

- hill forest
- swamps with thorny forest
- urban settlement
- village settlement with orchards
- agricultural plantation
- coastal dune vegetation
- mud flat
- salt pans and aquaculture

F.1.1 Forest Cover

Within 30 km radius of the project site, a few forests exist as recorded by the State Forest Department. None are within the core zone of the project site. The nearest reserve forest is 12 km away. Details of these forests are given in the following table:

Name of the forest	Approximate area in ha (as assessed in 1994-95)	Radial Distance from site (km)
Pudimadaka	62.00	12
Narava	1630.88	18
Kambalakonda	7862.21	30
Potukonda	2232.88	25
Yerrakonda	730.05	20
Naliakonda	1996.84	15

*Source: Working Plan for the Forest of Visakhapatnam District (1994-95 to 2003-2004), Office of the Conservator of Forests, Andhra Pradesh

F.1.2 Vegetation

The coastal vegetation is mainly of three types:

- vegetation of open coast
- vegetation of saline marshes
- vegetation of the rocky coast

The plants in the open coast are *Spinifex littoreus, Ipomoea pescapra, Launea sarmentosa*, and *Hydrophyllas maritima*, all acting as binders. Next to this zone are *Pandus fascicularis, Borassus flabellifier*, along with plantations of *Casuarina equisetifolia*. Next to this zone, in open places, plants such as *Calotropis gigantea, Trachys muricata, Phyla nudiflora*, and *Tephrosia purpurea* are observed. The vegetation found in the saline marshes are bushes of *Avicinnia alba, Sesuvium protulacastrum, Acanthus ilicifolius*, and *Seudea maritima*, etc. In the rocky coastal areas, *Synostemon bacciformis, Streblus asper, Echinops echinatus, Pisonia aculeata*, and *Maba bukifolia*, etc are found. In the plains *Borassus flabellifer, Phoenix sylvestris, Anacardium occidentale, Tamarindus indica, Cassia fistula*, and *Wrightia tinctoria* etc are found along with the shrubby vegetation comprising *Carissia spinarum, Eugenea bracteata, Holoarrhena antidysenterica, Corisandra pinnata, zizyphus oenoplia, Jatropha gossypifolia, Pavetta indica*, etc. The herbaceous vegetation of the plains and cultivated areas are mostly weeds, such as *Cassia occidentalis, Croton bonplandianum, Catharanthus roseus, Euphorbia hirta, Argemone mexicana, Phyllanthus simpla, Ammania baccifera, Eclipta alba, Sida acuta, Gomphrena decumbeno, and Ludwigia parviflora*, etc.

The vegetation of hilly regions was found to be affected by shifting cultivation practised by the local villagers, as well as by grazing and burning of the area. As a result, most of the hilly tracts have thorny bushes with isolated trees. Except for some patches which are undisturbed for ethnic reasons, most of the forest

in the hills within the buffer region were found to be cleared up. The upper canopy of some undisturbed patches is primarily composed of *Mangifera indica, Michelia champaka, Schleichera oleosa, Bombax ceiba, Syzygium cumini, Albizzia chinensis, Albizzia odoratissima, Toona ciliata, Terminalia tomentosa, Terminalia belerica, Tamarindus indica, Pterocarpus marsupium, Ficus racemosa, Ficus cunia,* etc. The middle canopy is mainly composed of *Phylanthus emblica, Langerstoemia parviflora, Feronia limonia, Dillenia pentagyna, Gmelina arborea, Cassia fistula,* and *Careya roboraea.* The shrubby layer is composed of *Woodfordia fruitcosa, Leea robusta, Zizyphus oenopha, Casearia elliptica, Mimosa rabicaulis, Gardenia gummifera, Solanum erianthum, Clerodendron serratum, Sarcococca trinervia, and Murraya paniculata.*

The undergrowth comprises herbs and undershrub such as *Barleria cristata, Tephrosia purpurea, Breynia retusa, Crotalaria calycina, Neopeltendra suberosa,* and also woody climbers such as *Hiptage bengalensis, Acacia sinuata, Acacia ingisia,* etc. In addition, there are several species of grasses, such as *Artistida setacea, Brachiaria ramosa, Cymbopogan flexuosum, Eragrostis coarctata, Heteropogan contortus, Ischaemum indicum, Paspalum scrobiculatum,* etc, which grow in the thorny forest and swamps.

F.1.3 Other Flora

The area around the HNPCL site has several species of flora. A checklist of dominant plant species is presented in Table F.1. Maximum species variation was noticed in the hill forest region and village orchards.

Most of the flora are of tropical type with wide range of distribution. *Endemic species were not encountered in the study area.* A number of exotics are also naturalised in the local flora. Most of the cultivated species are not included in the checklist. They are listed under agriculture.

Towards the coast, the HNPCL project site is covered with a fair growth of cashew and *Casuarina* plantations. A part of the proposed ash pond area harbours swampy vegetation predominated by *Prosopis juliflora.*

A small patch of mangrove forests was observed in the mouth of Meghadrigedda reservoir opposite Naval Dockyard (about 20-25 km from the project site). Two species of *Avecinea*, and one spe-

cies of *Exocorea* and *Saudea* were noticed in these mangrove patches.

F.1.4 Phytosociological Analysis

Phytosociological analysis was conducted at the following five locations:

i. Beach vegetation near Palavalasa
ii. Beach vegetation near Pudimadaka
iii. Hill forests of Naliakonda Reserve Forest
iv. Kambalikonda Reserve Forest
v. Narava Reserve Forest

At each of the above locations, a 10 m × 10 m area was surveyed. The numbers of each plant species present in the areas were noted for determination of frequency, density, and abundance of species.

In all of the zones surveyed, two tiers were observed: upper tree canopy followed by either shrub layer or herb layer. The beach vegetation was dominated by *Casuarina equisetifolia* and *Anacardium occidentale* trees, while the hill forest areas were dominated by deciduous or semi-deciduous trees, wich some evergreen patches. The species observed during this survey are presented in Table F.2.

The leaf litter fall in certain regions of the beach forest was observed to be higher than even in hill forests. Both kinds of forests were found to be degraded at places, and dominated by shrubs. In both core and buffer zone, a number of village settlement with orchards and plantation were observed.

F.1.5 Plants of Medicinal and Ethnobotanical Importance

Plants of medicinal and ethnobotanical importance were also surveyed in the area around the HNPCL site. *Many of these species were found to be growing naturally in the wild, but none can be considered rare.* A complete list of species is given in Table F.3.

F.1.6 Rare and Endangered Species

Most of the plant species recorded during this survey commonly occur in other habitats as well. Only a few plants could be

Table F.1. Common flora around HNPCL plant site

Scientific name	Common Name	Occurrence in sites						Abundance
		1	2	3	4	5	6	
Bombax ceiba (T)	Simal	+	+	-	+	-	-	VC
Mangifera indica (T)	Mango	+	+	-	+	-	-	VC
Peltaphorum inerme (T)	Radhachura	+	+	-	-	-	-	VC
Syzgium cumini (T)	Jaman	+	+	-	+	-	-	VC
Tectona grandis (T)	Teak	+	-	-	+	-	-	C
Azadirachta indica (T)	Neem	+	+	-	+	-	-	VC
Delonix regia (T)	Gulmohar	+	+	-	-	-	-	VC
Tamarindus indica (T)	Tamarind	+	+	-	+	-	-	VC
Albizia procera (T)	Siris	+	+	-	+	-	-	VC
Cocos nucifera (T)	Coconut	+	+	-	-	-	-	VC
Tarminalia catappa (T)	Katbadam	+	+	-	-	-	-	C
Polyalthia longifolia (T)	Deodar	+	+	-	-	-	-	VC
Ficus benghalensis (T)	Banian	+	+	-	-	-	-	VC
Ficus religiosa (T)	Pipal	+	+	-	-	-	-	VC
Dalbergia sisso (T)	Sisoo	+	+	-	-	-	-	VC
Artocarpus integrifolia (T)	Jackfruit	+	+	-	+	-	-	C
Erythrina arborescense (T)	Mather	+	+	-	-	-	-	C
Thespetia pupalnea (T)	Habul	+	+	-	-	-	-	F
Sapindus emerginatus (T)	Ritha	+	+	-	+	-	-	R
Pongamia pinnata (T)	Karanj	+	+	-	+	-	-	F
Acacua auriculiformis (T)	Akashmani	+	+	-	+	+	-	C
Eucalyptus globosus (T)	Eucalyptus	+	+	-	+	+	-	C
Moringa pterigospernum (S)	Sajina	-	+	-	-	-	-	F
Borassus flabelifer (T)	Fanpalm	-	+	-	+	+	-	F
Phoenix sylvestris (T)	Datepalm	-	+	+	+	+	-	F
Annona reticulata (S)	Nona	-	-	+	+	-	-	F
Prosopis juliflora (S)	Khejri	-	+	+	+	+	+	C
Calotropis procera (S)	Akanda	-	+	+	-	+	-	F
Lantana camara (S)	Lantana	-	-	+	+	+	-	R
Ipomea fistulosa (S)	Bankalmi	-	+	-	+	+	-	C
Zizyphus oenoplea (S)	Ber	-	-	-	+	-	-	F
Eupatorium odoratum (S)		-	-	+	+	-	-	C
Pandanus fascicularis (S)	Keya	-	-	+	-	-	-	F
Anacardium occidentale (T)	Cashew	-	+	+	+	-	-	F
Casuarina equisetifolia (T)	Jhau	-	-	+	-	-	-	F
Spinifex littoreus (H)		-	-	+	-	-	-	F
Ipomoea biloba (H)		-	-	+	-	-	-	F
Tephrosia purpurea (H)		-	+	+	+	-	-	F
Seudea maritima (H)		-	-	-	-	-	+	F
Streblus asper (S)	Seora	-	-	-	+	-	-	R
Carissa spinarum (S)		-	-	-	+	-	-	R
Holarrhena antidysenterica (S)	Kurchi	-	-	-	+	-	-	R
Cassia occidentalis (H)		-	+	-	+	-	-	F
Michelia champaka (T)	Champa	-	-	-	+	-	-	R
Toona ciliata (T)	Toon	+	-	-	+	-	-	R
Terminalia tomentosa (T)	Asan	+	-	-	+	-	-	F
Ficus cunea (T)	Fig tree	+	+	-	+	-	-	VC
Gmelina arborea (T)	Gamar	+	-	-	+	-	-	F
Schleichera oleosa (T)	Kusum	+	-	-	+	-	-	R
Feronia limonia (T)	Koet bel	+	+	-	+	-	-	R
Woodfordia fruticosa (S)		+	-	-	+	-	-	F
Leea robusta (S)		+	-	-	+	-	-	R

Scientific name	Common Name	Occurrence in sites						Abundance
		1	2	3	4	5	6	
Sarcococca trinervis (S)		-	+	-	+	-	-	R
Murraya paniculata (S)		-	+	-	+	-	-	R
Barteria cristata (H)		-	-	+	+	-	-	F
Paspalum scrobiculatum (H)		-	-	+	+	+	-	C
Bougainvillea spectabilis (S)	Banbahar	+	+	-	-	-	-	F

Note: T=Tree, S=Shrub, H=Herb, VC=Very Common, C=Common, R=Rare, F=Frequent

Details of sites:

1. Urban township area
2. Village orchard
3. Coastal beach forest
4. Hill forest
5. Thorny forest in swamp and wasteland area
6. Forest in mud flat and salt pan area

Table F.2. Phytosociological analysis of vegetation in forest zones around HNPCL plant site

Forest Zone	Species	Frequency	Abundance	Density
A. Beach forest on project site				
	Casuarina equisetifolia	100	8.4	8.4
	Anacardium occidentale	80	2.1	1.7
	Pandanus fascicularis	20	1.0	0.2
	Opuntia spp	50	1.0	0.5
	Calotropis procera	50	1.0	0.5
	Tephrosia purpurea	100	2.3	2.3
	Sida cordifolia	70	2.2	1.6
	Borassus flabellifer	30	1.0	0.3
B. Pudimadaka beach forest				
	Casuarina equisetifolia	100	5.6	5.6
	Anacardium occidentale	40	1.0	0.4
	Borassus flabellifer	30	1.0	0.3
	Calotropis procera	30	1.3	0.4
	Ziziphus oenoplea	20	1.0	0.2
	Opuntia spp	30	1.0	0.3
	Lantana camara	40	1.0	0.4
	Eupatorium odoratum	30	1.0	0.3
C. Naliakonda Reserve Forest				
	Holarrhena antidysenterica	70	3.7	2.6
	Capparis spinosa	70	2.4	1.7
	Calotropis spinosa	40	1.2	0.5
	Eupatorium odoratum	50	2.0	1.0
	Lantana camara	60	1.8	1.1
	Leea robusta	30	1.6	0.5
	Anacardium occidentale	60	1.5	0.9
	Barleria cristata	30	2.3	0.7
	Hyptis suaveolens	50	1.4	0.7
	Tecoma stans	40	1.7	0.7
	Zizyphus oenoplea	40	1.0	0.4
	Azadirachta indica	40	1.0	0.4
D. Kambalikonda Reserve Forest				
	Zizyphus oenoplea	40	1.2	0.5
	Alangium sepium	20	1.0	0.2
	Azadirachta indica	20	1.0	0.2
	Tecoma stans	30	1.0	0.3
	Mangifera indica	30	1.0	0.3
	Schleichera oleosa	20	1.0	0.2
	Borassus flabellifer	20	1.0	0.2
	Eupatorium odoratum	50	2.2	1.1
	Tectona grandis	50	1.0	0.5
	Anacardium occidentale	30	1.0	0.3
	Ficus cunea	40	1.0	0.4
	Sapindus spp	20	1.2	0.7
	Anona reticulata	50	1.2	0.7
	Anogeissus latifolia	20	1.0	0.2
	Holarrhena antidysenterica	50	1.2	0.6
E. Narava Reserve Forest				
	Zizyphus oenoplea	60	1.5	0.9
	Acadia sinuala	30	1.3	0.4
	Tecoma stans	40	1.0	0.4
	Carisa spinanrum	70	1.2	0.9

Forest Zone	Species	Frequency	Abundance	Density
	Azadirachta indica	30	1.0	0.3
	Tephrosia purpurea	60	2.5	1.5
	Aegle marmelos	20	1.0	0.2
	Anona reticulata	50	1.0	0.5
	Borassus flabellifer	20	1.2	0.2
	Cassia occidentalis	70	1.0	0.9
	Strychnos tapetorum	10	1.0	0.1
	Ixora coccinea	20	1.0	0.2
	Barleria cristata	40	1.0	0.3
	Guazuma tomentosa	30	1.0	0.3
	Alangium sepium	20	1.0	0.2

Table F.3. Plants of medicinal and ethnobotanical importance around HNPCL plant site

Species	Common Name	Parts Used	Used for
Acacia nilotica	Babul	Leaf buds	Toothache
Achyranthes aspera	Chirmin	Stem, Root	Toothache, Jaundice
Aegle marmelos	Bel	Fruits, Roots, Leaves	Gastric complaints
Albizia procera	Siris	Root, Bark	Eye problems of Cattles
Anogeissus latifolia	Dhaora	Gum	Bone dislocation, fracture
Bombax ceiba	Simal	Root bark	Pain relieving
Butea monosperma	Palas	Gum	Antidysentric
Feronia limosum	Kabit	Fruit, leaves	Gastric ailments
Phyllanthus emblica	Amala	Fruits	Gastric function
Sapindus leurifolius	Ritha	Fruits	Washing of wollen cloths
Sclileichera oleosa	Kusum	Seeds	Aphrodisiac
Tectona grandis	Sagun	Seeds	Dluretic
Terminalia catappa	Katbadam	Bark	Gastric ailment
Vitex negundo	Nisenda	Seeds, Roots, Leaves	Antirheumatic, Tuberculosis
Moringa pterigosperma	Sagina	Seed	Antidiabetic
Hygrophilla spinosa		Whole plant	Rheumatic pain

considered rare in these habitats. None could be found in the core zone. A checklist of rare and endangered species in the surveyed area is tabulated below.

Species	Rare	Endangered
Hydrophyllax maritima	+	-
Beutea superba	+	-
Terminalia balerica	+	-
Adhatoda vasica	+	-
Nymphea naudheli	+	-
Phyllanthus emblica	+	-
Mimulos orbicularis	-	+
Adina cordifolia	+	-
Acacia catechu	+	-

F.1.7 Agriculture

Agriculture in the area around the HNPCL site is primarily monsoon food crops with few Rabi crops. The major crops are rice, jowar, bajra, ragi, various types of grains, cotton, sugarcane, groundnut, castor, tapioca, tobacco, etc. The *Mandal*wise cropping area for the year 1994-95 is given in the Table F.4. The yield was very poor because of non-intensive cropping.

F.1.8 Fauna

Among terrestrial fauna, butterflies, amphibians, reptiles, birds, and mammals were surveyed in detail. Detailed checklists are given in Tables F.5 through F.10.

During the TCS survey, insects from the order diptera, odonates (Zygoptera, Anisozygoptera), ephinuroptera, lepidoptera, hemiptera, coleoptera, etc, and other invertebrates such as spiders were observed. Among vertebrates, congregations of frogs were observed in water pools at many places. Snakes, both terrestrial and aquatic, were also commonly observed. Consequently, the area also has waders and marsh-dwelling birds. Mud flats and salt pans were observed to harbour migratory waders.

The accumulated leaf litter in the forests around the HNPCL site offers the necessary micro-climate for many soil-inhabiting forms including arthropods, annelids, and molluscs, which were observed during the TCS survey. At more humid patches, sand-flies and biting midges were found to predominate.

The dense cover of cashew and *Casuarina* forest offers adequate protection to the wildlife that inhabits the area. Among vertebrates, *Bufo stomaticus*, *Varanus flavescens*, cobra, krits, Russel's viper, mabuia, *Calotes versicolor*, *Hemidactylas brooki*, etc were observed. Among mammals, blacknaped hare, civet, jackal, Bengal fox, jugle cat, and pugmarks and droppings of hyena were observed. A number of jackals were seen at dusk in a 3.5 km transect on the southeastern boundary of the HNPCL plant site.

A part of the proposed ash pond area harbours swampy vegetation predominated by *Prosopis juliflora*. Due to its periodic inundation by stormwater, this habitat attracts wading and marsh birds, and mammals such as jackals and civets, for foraging as well as nesting and roosting.

F.1.9 Livestock

The major livestock population of the *Mandals* falling under the study area are presented in Table F.11. From this table, it is clear that buffalo and poultry birds were the most common livestock in almost all of the *Mandals*.

F.2 Aquatic Ecology

The common aquatic habitats in the area around the HNPCL site are:

- freshwater reservoirs
- coastal subtidal zones
- coastal littoral zones

F.2.1 Plankton

Plankton were collected from several locations around the HNPCL site. Plankton samples from each location were examined separately for determining the population size. The planktonic load in freshwater, brackish water, and saline water was found to vary widely with respect to species composition and diversity. The results of this survey are given in Table F.12.

F.2.2 Periphytons

The periphytonic algae of a few selected aquatic habitats were collected and examined under the microscope. A checklist was prepared, and is given in Table F.13.

Table F.4. Cropping area of *Mandals* around HNPCL plant site

Mandal	Cropping area (ha)							
	Rice	Bajra	Ragi	All Pulses	Cotton	Sugar Cane	Tapioca	Tobacco
Visakhapatnam	98	96	6	23	13	-	1	-
Pendurthi	1302	1288	148	53	176	25	7	-
Sabbavaram	2443	2317	613	547	516	492	11	-
Paravada	392	2551	1754	285	1	-	110	-
Pedagantyada	20	160	20	23	-	-	-	1
Anakapalli	2765	3099	1833	580	14	234	16	-
Kasimaota	1032	2516	1462	1350	12	1799	-	-
Munagapaka	90	70	4	16	-	-	-	-
Gajuwaka	90	70	4	16	-	-	-	-
Atchuthapuram	1042	2416	823	590	34	1439	30	-
Rambilli	3775	2024	694	410	4	364	-	11

*Source: Office of the Joint Director (Agriculture), Vishakhapatnam District

Table F.5. Butterflies around HNPCL plant site

None of the species listed in this table is listed in the Indian Wildlife Protection Act

Scientific Name	1	2	3	4	5	6	7	8	9	10
Order Lepidoptera										
Charaxes palyxena										+
Eriboea athamus								+	+	
Euthalia lepidea		+								+
Euthalia nais									+	+
Euthalia garuda						+				
Pantoporia perius						+				
Neptis jumbah						+				
Neptis hylas						+				+
Neptis hordonia						+		+		+
Cyrestis thyodamus				+				+		+
Hypolimnas bolina				+		+				
Hypolimnas misippus						+		+		+
Precis lemonias				+		+				+
Precis almana						+				
Precis atlites						+				+
Precis hierla						+				+
Precis orilhyia						+				+
Precis iphita						+		+		
Phalanta phantha		+			+					
Cupha erymanthis						+				
Ergolis ariadne					+					
Ergolis merione										+
Family Papilionidae										
Graphium doson										+
Graphium antiphatos						+				
Graphium nomius						+				
Atrophaneura aristolochiac						+				
Atrophaneura hector										+
Troides helena										+
Chilasa clytia						+		+		
Princeps nephelus									+	
Princeps polymnestor									+	
Princeps polytes					+				+	
Princeps demoleus			+							
Princeps paris	+									
Delias eucharis				+				+		+

(1) Intertidal zone at Pudimadaka (18km)
(2) Sea coast near Appikonda (5km)
(3) Tidal mudflat (4km)
(4) Marsh and aquaculture farm near Thikkavanipalem (3km)
(5) Coastal front (southern end of HNPCL site)
(6) Village plantations at Palavalasa (3km)
(7) Inland water of Yeleru canal (12km)
(8) Nalaikonda Reserve forest (15km)
(9) Narava Reserve forest (18km)
(10) Vizag Township (22km)

Table F.6. List of Insects

Scientific Name	Intertidal	Sea coast	Tidal mudflat	Salt pan aqua-culture & marsh	Village plantations	Inland water	Nalaikonda R.F.	Narava R.F.	Vizag Township
Euscelimena haipage	-	-	-	-	+	-	+	+	-
Criotellix latifron	-	-	-	-	+	-	-	-	-
Euparatettix histricus	-	-	-	-	+	-	+	-	+
Acrida exaltata	-	-	-	+	+	-	-	-	-
Leva cruciata	-	-	-	-	+	-	+	+	+
Aiolopus thalasinus	-	-	-	-	+	-	-	-	-
Gelastorrhinus semipictus	-	-	-	-	+	-	-	-	-
Donopherula collinus	-	-	-	-	+	-	+	+	-
Acrotylus humbertianus	-	-	+	-	-	-	+	-	-
Trilophidia annulata	-	-	-	+	+	+	+	+	-
Oedaleus abruptus	-	-	-	-	+	-	+	-	-
Morophacris fasciata	-	-	-	-	+	-	+	-	+
Spathosternum prasiniferum	-	-	-	-	+	-	+	+	+
Oxyhyla hyla	-	-	-	+	+	-	+	+	+
Oxynitidula	-	-	-	-	+	-	-	-	-

Table F.7. Amphibian species around HNPCL plant site

Common Name / Scientific Name	Inter tidal zone	Sea Coast	Tidal mudflat	Marsh and aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaiconda Reserve Forest	Naraova Reserve Forest	Vizag township	Status in IBWL	Remarks
Winter												
Bufonidae												
Marbled Toad												
Bufo stomaticus	-	-	-	-	+	+	-	-	-	-		Common
Microhylidae												
Saloon Frog												
Uperodon globulosus	-	-	-	-	-	+	-	-	-	-		Common
Ornate Microhyla												
Microhyla ornata	-	+	+	-	+	+	+	-	+	-		Scarce
Ranidae												
Indian Ballfrog												
Limnonectes tigerinus	-	-	+	-	-	-	+	-	-	-		Very Scarce
Green Pondfrog												
Occidozyga	-	-	+	-	-	-	+	-	-	-		Common
Skipping Frog												
O. cyanophlyctis	-	-	+	-	-	-	-	-	-	-		Common
Jerdon Bullfrog												
Limnonectes crassus	-	-	+	-	-	-	+	-	-	-		Scarce
Pre-monsoon												
Bufonidae												
Marbled Toad												
Bufo stomaticus	-	-	-	+	+	+	-	-	-	+		Common
Microhylidae												
Saloon Frog												
Uperodon globulosus	-	-	-	-	-	-	-	-	+	+		Common
Ornate Microhyla												
Microhyla ornata	-	-	-	-	-	-	+	-	+	-		Scarce
Ranidae												
Indian Ballfrog												
Limnonectes tigerinus	-	-	-	+	-	-	+	-	-	-		Very Scarce
Green Pondfrog												
Occidozyga nexadactyla	-	-	-	-	-	-	+	-	+	-		Common
Skipping Frog												
O. cyanophlyctis	-	-	+	+	-	-	+	-	+	-		Common
Jerdon Bullfrog												
Limnonectes crassus	-	-	-	-	-	-	-	-	-	-		Scarce

Common Name / Scientific Name	Inter tidal zone	Sea Coast	Tidal mudflat	Marsh and aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaiconda Reserve Forest	Naraova Reserve Forest	Vizag township	Status in IBWL	Remarks
Monsoon												
Bufonidae												
Ballon Toad												
Uperodon globulossum	-	-	-	+		-	-	-	-	-		Scarce
Ranidae												
Bullfrog												
Rana tigerina	-	-	-	-		-	+	+	-	-		Common
Skipping Frog												
Rana cyanophlyctes	-	-	-	-		-	+	+	-	-		Common
Cricket Frog												
Rana lymnocharys	-	-	-	-		-	+	+	-	-		Common
Post-monsoon												
Bufonidae												
Marbles Toad												
Bufo stomaticus	-	-	-	-		+	-	-	-	-		Scarce
Microhylidae												
Ornate Microhylid												
Microhyla ornata	-	-	-	+		-	-	-	-	+		Common
Ranidae												
Cricket Frog												
Rana limnocharys	-	-	-	-		-	-	-	-	+		Common
Jerdon's Bullfrog												
Limnonictes crassus	-	-	-	-		-	-	-	-	+		Scarce

(1) As per local information this form along with Olive Ridleys regularly visit this beach from Lawson's Bay to Pudumadikoda though in small number

Table F.8. Reptiles around HNPCL plant site

Common Name / Scientific Name	Intertidal Zone	Sea Coast	Tidal Mudflat	Marsh and aquaculture	Coastal Vegetation	Village Plantation	Inland Waterbodies	Nalaikonda R F	Narava R F	Vizag Township	Status in IBWL	Remarks
Winter												
Chelonidae												
Lepoidochelys olivacea		+										(1)
Lissenudae												
Indian Softshell Turtle												
Lissenys punctata	-	-	+	-		-	+	-	-	-	Sch.I	
Brahminy Terrapin												
Hardella thurgii	-	-	-	-	-	-	+	-	-	-	-	Scarce
Gekonidae												
Hemidaehylus brooki	-	-	-	-	+	-	-	-	-	+		
H leschnaulti	-	-	-	-	+	-	-	-	-	-		
Agamidae												
Sitana ponticeriana	-	-	-	-	+	-	-	+	+	-		
Calotes versicolor	-	+	-	-	+	-	-	+	+	+		
Scineidae												
Mabuya bibroni	-	-	-	-	+	-	-	-	+	+		
M macularia	-	+	-	-	+	-	-	+	-	-		
Riopa punctata	-	-	-	-	+	-	-	+	+	-		
Varanidae												
Varanus flavescens	-	-	-	-	+	-	-	-	+	+	Sch I	
Biodae												
Python molurus	-	-	-	-	-	-	-	-	+	-	Sch I	Common
Colubridae												
Ptyas muscosus	-	+	+	-	-	-	+	-	-	+	Sch II	
Lycodon aulicus							+			+		
Ahetulla nasautus	-	-	-	+	+	-	-	-	-	-		Scarce
Elapidae												
Burgarus caeruleus	-	-	+	+	-	-	+	-	+	-		Common
Naja naja	+	+	+	+	+	+	+	+	+	+		
Viperidae												
Vipera russeli	-	-	-	-	+	-	-	+	-	-		Scarce
Pre-monsoon												
Chelonidae												
Green Sea-Turtle,												
Chelonia mydus	-	+	-	-	-	-	-	-	-	-	Sch.I	
Indian softshell Trutle												
Lissemys punctata	-	-	-	-	-	-	+	-	-	+	-	Scarce
Brahminy Terrapin												
Hardella thurgii	-	-	-	-	-	-	+	-	-	-	-	Scarce

Common Name / Scientific Name	Intertidal Zone	Sea Coast	Tidal Mudflat	Marsh and aquaculture	Coastal Vegetation	Village Plantation	Inland Waterbodies	Nalaikonda R F	Narava R F	Vizag Township	Status in IBWL	Remarks
Greconidae												
Brook's Gecko												
Hemidactyius brooki	-	-	-	-	-	-	-	-	+	+		
Agmidae												
Rock Agama												
Sitana ponticeriana	-	-	-	+	+	+	-	-	-	-	-	
Southern Calotes												
Calotes	-	+	+	+	+	-	+	+	+	+		
Scineidae												
Skink												
Mabyua bibroni	-	-	-	-	+	+			+			
M. macularia	-	-	-	-	-	+	-	+	+	+		Scarce
Redrailed Skink												
Riopa punctata												
Varanidae												
Yellow Monitor												
Varanus flavescens	-	-	-	-	+	-	-	+	+	-		Scarce
Colubridae												
Rat Snake												
Ptyas mucosus	-	-	+	-	-	-	-	-	-	-		Scarce
Wolf Snake												
Lycodon aulicus												Reported
Green Whip Snake												
Ahetula nasautus												Reported
Elapidae												
Common Krait												
Bungarus caeruleus	-	-	-	-	+	-	-	-	-	-		Scarce
Cobra												
Naja naja	-	-	-	-	+	+	-	-	-	-		Scarce
King Cobra												
Ophiophorus hanna	-	-	-	-	+	+	-	-	-	-		Scarce
Viperridae												
Russel's Viper												
Viper russeli	-	-	+	+	+	+	-	+	+	-		Scarce
Monsoon												
Chelonidae												
Green Sea Turtle												
Chelonia mydus	+	+	+	-		-	-	-	-	-	Sch.I	
Olive Ridley												
Lepidochelys olivacea	-	+	+	-		-	-	-	-	-	Sch.I	
Lissenudae												
Indian Softshell Turtle												
Lissenys punctata	-	-	-	-		-	+	-	-	-	Sch.I	

Common Name / Scientific Name	Intertidal Zone	Sea Coast	Tidal Mudflat	Marsh and aquaculture	Coastal Vegetation	Village Plantation	Inland Waterbodies	Nalaikonda R F	Narava R F	Vizag Township	Status in IBWL	Remarks
Greconidae												
Brook's Gecko												
Hemidactyius brooki	-	-	-	-		-	+	-	-	-	Sch.I	
Agamidae												
Garden Lizard												
Calcotes versicolor	-	-	-	-		+	-	+	+	-	Sch.I	
Post-monsoon												
Chelonidae												
Greeen Sea Turtle												
Chelonia mydus	+	+	-	-		-	-	-	-	-		Common
Lissenudae												
Indian Softshell Turtle												
Lissenys punctata	-	-	+	-		-	+	-	-	-	Sch.I	
Geckonidae												
Brook's Gecko												
Hemidactylus brooki	-	-	-	-	-	-	-	-	-	+		Common
Agamidae												
Southern Calotes												
Calotes dussumeri	-	-	-	-	+	-	+	+	+	+		Very Co
Ophidae												
Checker Kulback												
Natrix piscator	-	-	-	-	-	-	-	-	-	-		Scarce

Table F.9. Aves around HNPCL plant site

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaikonda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Winter												
Accipitridae												
Blackwinged Kite *Elanus caurulescens*	-	-	-	-	-	-	-	-	+	+	Sch IV	Sc
Honey Buzzard *Pernis ptiforhyncus*	-	-	-	-	-	-	-	+	-	+	Sch IV	Sc
Black Kite *Milvus migrans*	+	+	+	+	+	+	+	+	+	+	Sch IV	Sc
Pariah Kite *M m govinda*	-	-	-	+	+	+	-	+	+	+	Sch IV	VC
Brahminy Kite *Halistus indus*	+	+	+	-	-	-	-	-	-	-	Sch IV	Sc
Shikra *Accipiter badius*	-	-	-	-	+	-	-	-	-	+	Sch I	VC
Sparrow Hawk *Accipiter nissus*	-	-	-	-	+	-	-	-	+	+	Sch IV	C
White-eyed Buzzard *Butastur teesa*	-	-	-	-	-	-	-	-	+	+	Sch IV	Sc
Cristed Hawk Eagle *Spizaetus cirrhatus*	-	-	-	-	-	-	-	-	+	-	Sch I	Sc
Whitebellied Sea Eagle *Haliaetus leucogaster*	+	+	+	-	-	-	-	-	-	+	Sch IV	Sc
Longbilled Vulture *Gyps indicus*	-	-	-	-	-	-	-	-	+	+	Sch IV	C
Whitebacked Vulture *G benghalensis*	-	-	-	-	-	-	-	-	-	+	Sch IV	R
Whit Scavengeer *Neopron perenopterus*	-	-	-	-	-	-	-	-	-	+	Sch IV	R
Marsh Harrier *Circus aeruginosus*	-	-	-	-	-	-	+	-	-	+	Sch IV	C
Cresteed Serpent Eagle *Spilornis chula*	-	-	-	-	-	-	+	+	+	+	Sch IV	C
Falconidae												
Kestrel *Falco tinunculus*	-	+	+	+	-	-	-	-	-	+	Sch IV	C
Redheaded Marlin *F chicguera*	-	-	-	-	-	-	-	+	+	-	Sch IV	R
Phasianidae												
Black Partridge *Francolinus francolinus*	-	-	-	-	-	-	-	+	+	-	Sch IV	Sc

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaikonda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Grey Partridge												
F pondicerianus	-	-	-	+	-	-	-	+	+	+	Sch IV	C
Jungle Bush Quail												
Perdicula oniatica	-	-	-	+	-	-	-	+	-	-	Sch IV	C
Common Peafowl	-	-	-	+	-	-	-	-	+	-	Sch I	R
Pavo cristatus												
Columbidae												
Bengal Green Pigeon												
Treron phoenicopterus	-	-	-	-	-	+	-	-	-	+	Sch IV	Sc
Rufous Turtle Dove												
Steptopelia orientalis	+	+	+	+	+	+	+	+	+	+	Sch IV	C
Ring Dove												
S Dicaocto	-	+	+	+	+	+	+	+	+	+	Sch IV	C
Little Brown Dove												
S senegalonsis	-	-	-	-	-	-	-	+	+	-	Sch IV	C
Spotted Dove												
S chinensis	-	-	+	+	+	+	+	+	+	+	Sch IV	C
Psittacidae												
Alexandrine Parakeet												
Psittacula eupatria	-	-	-	-	+	-	-	-	-	+	Sch IV	C
Roseringed Parakeet												
P krameri	-	-	-	-	-	+	-	+	+	+	Sch IV	C
Blossomheaded Parakeet												
P cyanocephala	-	-	-	-	-	+	-	+	-	+	Sch IV	C
Cuculidae												
Hawk Cuckoo												
Cuculus varius	-	-	-	-	+	+	-	-	-	+	Sch IV	Sc
Koel												
Eudynamys scolopacea	-	-	-	-	-	+	-	-	-	+	Sch IV	C
Coucal												
Contropus sinensis	-	-	-	-	+	+	-	+	+	+	Sch IV	C
Charadridae												
Red Wattled Lapwing												
Vanellus indicus	-	-	+	+	+	+	+	+	+	+	Sch IV	C
Yellow Wattled Lapwing												
V malabaricus	-	-	+	+	+	+	-	-	-	-	Sch IV	C
Strigidae												
Barn Owl												
Tyto alba	-	-	-	-	-	-	-	-	-	+	Sch IV	R
Scops Owl												
Otus scops	-	-	-	-	-	+	+	-	+	-	Sch IV	Sc
Collared Scops Owl												
Otus bakkamoena	-	-	-	-	-	+	-	-	-	-		

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaikonda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Barred Jungle Owlet												
Glaucidium radiatum	-	-	-	-	+	-	-	-	+	-	Sch IV	Sc
Caprimulgidae												
Jungle Nightjar												
Caprimulgus indicus	+	+	+	+	+	+	+	+	+	+	Sch IV	C
Longtailed Nightjar												
C macrourus	-	-	-	-	-	+	-	-	-	-	Sch IV	Sc
Apodidae												
House Swift												
Apus affinis	+	+	+	+	+	+	+	+	+	+	Sch IV	C
Palm Swift												
Cypsiurus palvus	+	+	+	+	+	+	+	+	+	+	Sch IV	C
Alcedinidae												
Pied Kingfisher												
Càryle rudis	-	-	+	+	-	-	-	-	-	-	Sch IV	R
Common Kingfisher												
Alcedo athis	-	-	-	+	+	+	+	-	-	-	Sch IV	Sc
Whitebreasted Kingfisher												
H smyrnensis	-	-	+	+	+	+	+	+	+	+	Sch IV	Sc
Miropidae												
Chestnutheaded Bee-eater												
Merops leschenaulti	-	-	+	-	-	-	-	-	-	-	Sch IV	R
Green Bee-eater												
M Orientalis	-	-	+	+	+	+	+	+	+	+	Sch IV	C
Coracidae												
Indian Roller												
Coracias benghalensis	-	-	+	+	+	+	+	+	+	+	Sch IV	C
Upupidae												
Hoopoe												
Upupa epops	-	-	-	+	+	+	-	-	+	-	Sch IV	R
Bucerotidae												
Common Grey Hornbill												
Tockus griseus	-	-	-	-	-	-	-	+	-	+	Sch IV	Sc
Capitonidae												
Coppersmith												
Megalaima haemacephala	-	-	-	-	+	-	-	+	+	+	Sch IV	R
Bluethroated Barbet												
M Asiatica	-	-	-	+	+	-	-	+	+	+	Sch IV	R
Picidae												
Wryneck												
Jynx forquila	-	-	+	-	-	-	-	-	-	+	Sch IV	R
Goldenbacked Woodpecker												
Dinopium benghalensis	-	-	-	+	+	+	-	+	-	+	Sch IV	Sc

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Alaudidae												
Redwinged Bushlark												
Mirafra erythroptera	-	+	+	-	+	-	-	-	-	-	-	R
Blackcrowned Finchlark												
Erempoptern	+	+	+	+	+	+	+	+	+	+	Sch IV	Sc
Rufoustailed Finchlark												
Ammomanes phoenicurus	-	-	-	+	-	-	-	-	-	-		R
Eastern Skylark												
Alauda gulgula	-	-	-	+	+	+	-	-	-	-	-	R
Hirundinidae												
Swallow												
Hirundo rustica	+	+	+	+	+	+	+	+	+	+	Sch IV	R
Striated Swallow												
Hirundo daurica	+	+	+	+	+	+	+	+	+	+	Sch IV	Sc
Lanidae												
Baybacked Shrike												
Lanius vittatus	-	-	-	-	+	-	-	+	+	+	Sch IV	Sc
Rufousbacked Shrike												
L tephronotus	-	-	-	+	+	-	+	+	+	+	Sch IV	Sc
Oriolidae												
Golden Oriole												
Oriolus oriolus	-	-	-	-	+	+	-	+	-	-	Sch IV	Sc
Blackheaded Oriole												
O xanthornus	-	-	-	-	+	-	-	+	+	+	Sch IV	C
Dicruridae												
Black Drongo												
Dicrurus adsimilis	+	+	+	+	+	+	+	+	+	+	Sch IV	C
Bronze Drongo												
D aeraeus	-	-	-	-	+	-	-	+	-	-	Sch IV	Sc
Pre-monsoon												
Podicipetidae												
Little Grebe												
Podiceps ruficollis	-	-	-	+	-	-	-	+	-	-		
Phalacrocoracidae												
Shrag												
Phalacrocorax fuscicollis	-	-	-	-	-	-	+	-	-	-		
Dittle Cormorant												
P. Niger	-	-	-	+	-	-	+	-	-	-		
Darter												
Anhinga rufa	-	-	-	-	-	-	+	-	-	-		
Ardecidae												
Pond Heron												
Areola grayii	+	+	+	+	+	+	+	+	+	+		

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Cattle Egret												
Bubulcus ibis	-	-	-	+	+	+	+	+	+	-		
Large Egret												
Ardea alba	-	-	-	-	-	-	+	-	-	-		
Smaller Egret												
Egreeta intermedia	-	-	-	-	-	+	+	-	-	-		
Reef Heron												
*Ardea insularis**	-	+	-	-	-	-	+	-	+	+		
Night Heron												
Nycticerox nycticerox	-	-	-	-	-	-	+	-	-	-		
Chestnut Bittern												
Ixobrychus cinnamomeus	-	-	-	-	-	-	+	-	-	-		
Yellow Bittern												
I. sinensis	-	-	-	-	-	-	+	-	-	-		
<u>Anatidae</u>												
Lesser whistling Teal												
Dendrocygna javanica	-	-	-	-	-	-	+	-	-	+		
Cotton Teal												
Nettapus coromandelianus	-	-	-	-	+	+	+	-	-	-		
<u>Rallidae</u>												
Whitebreasted Waterhen												
Amaurornis phoenicurus	-	-	+	+	-	-	+	-	-	-		
<u>Jacanidae</u>												
Bronzewinged Jacana												
Metopidius indicus	-	-	-	-	-	-	+	-	-	-		
Pheasanttailed Jacana												
Hydrophasianus chirugus	-	-	+	+	-	-	+	-	-	-		
<u>Rustratudidae</u>												
Painted snipe												
Rostatula bengalensis	-	-	-	-	-	-	-	-	-	-		
<u>Recurvirostridae</u>												
Blackwinged Stlit												
Himantopus himantopus	-	-	-	-	-	-	-	-	-	-		
<u>Charadridae</u>												
Kedwattled Lapwing												
Vanellus indicus	-	-	-	-	-	-	-	-	-	+		
Yellowwattled Lapwing												
V. malabaricus	-	-	-	-	-	-	-	-	-	-		
Ringed Plover												
Charadrius hiaticula	-	+	-	-	-	-	-	-	-	-		
Eastern Curlew												
Numenibes arquata	-	+	-	-	-	-	-	-	-	-		

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Laridae												
Great Blackheaded Cull												
Larus ichthyaectus	+	+	-	-	-	-	-	-	-	-		
Brownheaded Gullus												
L. brunilcephalus	+	+	-	-	-	-	-	-	-	-		
Lesser Blackheaded Gull												
L. ridibundus	-	-	-	+	-	-	-	-	-	-		
Whiskered Tern												
Cnlidonias hybrida	+	+	-	-	-	-	-	-	-	-		
Gullbilled Tern												
Gelochelidon nilotica	-	+	-	-	-	-	-	-	-	-		
Indian River Tern												
Sterna aurantia	+	+	-	+	-	-	-	-	-	-		
Accipitridae												
Crested Serpent Eagle												
Haliaeetus leucogaster	-	-	-	-	-	-	-	-	+	+		
Alcedinidae												
Pled Kingfisher												
Caryle rudis	-	+	-	-	-	-	-	-	-	-		
Common Kingfisher												
Alcedo athis	-	-	+	-	+	+	-	-	-	-		
Whitbreasted Kingfisher												
H. smyrensis	-	-	+	-	+	+	-	-	-	-		
Acclpitridae												
Blackwinged Kite												
Elanus caurulescens	-	-	+	-	-	-	-	-	-	-		
Black Kite												
Milvus migrans	-	+	+	+	+	+	+	+	+	+	Sch.IV	
Pariah Kite												
M.M. migrans	-	+	+	+	+	+	+	+	+	+	Sch.IV	
Brahminy Kite												
Halistus indus	+	+	-	-	-	-	-	-	-	-	Sch.IV	
Snikra												
Accipter badius	-	-	-	-	-	-	-	-	+	+	Sch.IV	
Whiteeyed Buzzard												
Butastur teesa	-	-	-	-	-	+	-	-	-	-	Sch.IV	
Crested Hawk Eagle												
Spisaetus cirrhatus	-	-	-	-	-	-	-	-	+	-	Sch.IV	
Longbilled Vulture												
Gyps indicus	-	-	-	-	-	-	-	-	+	-	Sch.IV	
Whitebacked Vulture												
G. bengalensis	-	-	-	-	+	+	+	-	-	-	Sch.IV	
White Scavenger												

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Neopron perenopterus	-	-	-	-	-	-	-	+	+	-	Sch.IV	
Crested Serpent Eagle												
Spilornis cheeta	-	-	-	-	-	+	-	-	-	-	Sch.IV	
Miropidae												
Chestnutheaded bee-eater												
Merops leschenaulti	-	-	-	-	-	+	-	-	-	-	Sch.IV	
Green Bee-eater												
M. orientalis	-	-	-	+	-	+	+	-	-	-	Sch.IV	
Coracidae												
Indian Roller												
Coracias benghalensis	-	-	-	-	+	+	-	-	+	-	Sch.IV	
Upupidae												
Hoopoe												
Upupa epops	-	-	-	-	-	+	-	-	-	-	Sch.IV	
Bucerotidae												
Common Crey Mornbill												
Tockus griseus	-	-	-	-	-	-	-	+	-	-	Sch.IV	
Captionidae												
Coppersmith												
Megalama haemacephala	-	-	-	-	-	+	-	-	+	+	Sch.IV	
Bluethorated barbet												
M. asiatica	-	-	-	-	-	+	-	+	+	-	Sch.IV	
Cuculidae												
Nawk Cuckoo												
Cuculus varius	-	-	-	-	-	+	-	-	-	-	Sch.IV	
Koel												
Eudynamys scolopacea	-	-	-	-	-	+	-	-	-	+	Sch.IV	
Coucal												
Contropus sinensis	-	-	-	-	-	+	-	+	-	-	Sch.IV	
Cnaradridae												
Redvattled Lapwing												
Vanellus indicus	-	+	+	+	-	-	-	-	-	-	Sch.IV	
Yellowwattled Lapwing												
V.malabaricus	-	-	-	-	-	-	-	-	+	-	Sch.IV	
Strigidae												
Barn Owl												
Tyto alba	-	-	-	-	-	-	-	+	-	+	Sch.IV	
Sccops Owl												
Otus scops	-	-	-	-	-	-	-	+	-	-	Sch.IV	
Collared Scops Owl												
Otus bakkamoena	-	-	-	-	-	+	-	+	-	-	Sch.IV	
Barred Jungle Owlet												
Glaucidium radiatum	-	-	-	-	-	+	-	-	-	-	Sch.IV	
Caprimulgidae												

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Jungle Rightjar												
Caprimulgus indicus	-	-	-	-	+	-	-	+	-	-	Sch.IV	
Longtailed Rightjar												
C. macrourus	-	-	-	-	+	+	-	-	-	-	Sch.IV	
Apodidae												
House Swift												
Apus affinis	-	-	-	-	-	-	-	-	-	+	Sch.IV	
Palm Swift												
Cypsturus palvus	-	-	+	+	+	+	-	-	-	-	Sch.IV	
Phasianidae												
Black Partridge												
Francolinus francolinus	-	-	-	-	-	+	-	-	-	-	Sch.IV	
Grey Patridge												
F. Pondicerianus	-	-	-	-	-	-	-	-	+	+	Sch.IV	
Jungle Bush Quail												
Perdicula oniatica	-	-	-	-	-	-	-	-	+	-	Sch.IV	
Common Peafowl												
Pavo cristatus	-	-	-	-	-	+	-	-	-	-	Sch.IV	
Motacillidae												
Padyfied Pipit												
Anthus novaisulondias	-	-	-	+	-	+	-	-	-	-	Sch. IV	
Lanidae												
Blackheaded Shirke												
Lanias schach tricolor	-	-	-	-	-	+	-	-	-	-		
Sturnidae												
Common Myna												
Acridothires trintis	-	-	-	+	+	+	-	-	+	+	Sch.IV	
Pied myna												
Sturnus contra	-	-	-	-	+	+	-	-	+	+	Sch.IV	
Corvidae												
Indian Tree Pie												
Dehdrocitta vagabunda	-	-	-	-	-	+	-	-	-	-	Sch.IV	
House Crow												
Corvus splendens	-	+	+	+	+	+	+	+	+	+	Sch.IV	
Jungle Crow												
C. macrorhynchus	-	+	+	+	+	+	+	+	+	+	Sch.IV	
Monsoon												
Podicipettidae												
Little Grebe												
Podiceps ruficollis	-	-	-	-		+	+	-	-	-	Sch. IV	
Phalacrocoracidae												
Little Cormorant												
Phalacrocrorax niger	-	-	-	-		-	+	-	-	-	Sch. IV	
Indian Shaz												
Phalacrocorax fuscicollis	-	-	+	-		-	-	-	-	-	Sch. IV	

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Ardeidae												
Pond Heron												
Ardeola grayii	-	-	+	+		+	+	-	-	+	Sch. IV	
Cattle Egret												
Bubulcus ibis	-	-	+	+		+	-	-	-	-	Sch. IV	
Large Egret												
Ardea alba	-	+	-	-		-	-	-	-	-	Sch. IV	
Little Egret												
Egretta garzetta	-	-	-	-		+	-	-	-	-	Sch. IV	
Night Heron												
Nycticorax nycticorax	-	-	-	-		-	-	-	-	+	Sch. IV	
Ciccnidae												
Openbilled Stork												
Anastomas oscitans	-	-	-	-		-	+	-	-	-	Sch. IV	
Anatidae												
Lesser Whisling Teal												
Dendrocygna javanica	-	-	-	-		-	+	-	-	-	Sch. IV	
Spotbill Duck												
Anas poecilorhyncha	-	-	-	-		-	+	-	-	+	Sch. IV	(1)
Accipitridae												
Pariah Kite												
Milvus migrans	-	+	+	+		+	-	-	+	+	Sch. IV	
Shikra												
Accipeter badius	-	-	-	-		-	-	-	-	+	Sch.I	(2)
Whitebacked Vulture												
Gyps bengalensis	-	-	-	-		+	-	+	+	+	Sch.I	
Whiteeyed Buzzard Eagle												
Butaastur teesa	-	-	-	-		+	-	-	-	-	Sch. IV	(3)
Phasianidae												
Black Partridge												
Francolinus francolinus	-	-	-	-		+	-	-	-	-	Sch. IV	(3)
Rallidae												
Whitebreasted Waterhen												
Amaurornis phoenicrurus	-	-	-	-		-	+	-	-	+	Sch. IV	
Jacanidae												
Bronzewinged Jacana												
Metoipidius indicus	-	-	-	-		-	+	+	-	-	Sch. IV	
Chardridae												
Redwattled Lapwing												
Vanellus indicus	-	-	+	+		+	-	-	+	-	Sch. IV	
Yellowwatled Lapwing												
V. malabaricus	-	-	+	+		-	-	-	+	-	Sch. IV	
Little Ringed Plover												
Charadrius dubius	-	+	-	-		-	-	-	-	-	Sch. IV	
Easter curlew												

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Falco tinanculus	-	-	-	-		-	+	-	-	+		Sc
Phasianidae												
Grey Partridge												
Francdinus pondicereanus	-	-	-	-		-	-	-	-	+		C
Rallidae												
Whitebreasted Waterhen												
Amaurornis phoenicrurus	-	-	-	-		-	+	-	-	+		C
Recurvirostridae												
Avocet												
Recurvirostra avocetta	-	-	+	+		-	-	-	-	-		(1)
Burhinidae												
Stone Curlew												
Burhinus aedicnemus	-	-	-	-		-	-	-	-	+		Sc
Charadridae												
Yellowwattled Lapwing												
Vanellus malabaricus	-	-	+	+		+	+	+	-	-		C
Eastern Golden Plover												
Pulvialis dominica fulva	-	-	+	+		+	-	-	-	-		C
Large Sand Plover												
Charadrius leachenaulti	-	-	+	+		-	-	-	-	-		C
Ringed Plover												
Ch. hiaticula	-	-	+	+		-	-	-	-	-		C
Little Ringed Plover												
Ch. dubius	-	+	+	+		+	-	-	-	-		C
Curlew												
Numenius arquata	-	-	+	+		+	-	-	-	-		C
Redshank												
Tringa totanus	-	-	+	+		-	+	-	-	-		C
Green Shank												
T. nebularia	-	-	-	-		-	+	-	-	-		Sc
Green Sandpiper												
T. hypoleucos	-	+	+	+		-	+	-	-	+		C
Eastern Knot												
Callidris tenuirostris	-	+	-	-		-	-	-	-	-		Sc
Laridae												
Whiskered Tern												
Sterna hirundo	+	+	+	+		-	-	-	-	-		C
River Tern												

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Picidae												
Goldenback Woodpecker												
Dinopium benghalensis	+	+	-	-		+	-	-	-	+	Sch. IV	
Alandidae												
Redwing Bushlark												
Mirafra erythroptera	-	-	-	-		+	-	-	+	+	Sch. IV	
Blackbrested Finchlark												
Eremeopteryx	-	-	-	-		-	-	+	-	-	Sch. IV	
Rufoustailed Finch Lark												
Ammomanes phoenicrurus	+	+	+	+		+	+	+	+	+	Sch.IV	
Eastern Skylark												
Alauda gulgula												
Diomridae												
Black Drongo												
Dicrurus adsimilis	-	-	+	+		-	-	-	+	+	Sch.IV	
Hirudonidae												
Common Swallow												
Hirundo rustica	-	+	+									
Redrumped Swallow												
Hirundo daurica	-	+	+	-		+	-	-	-	-	Sch.IV	
Motacillidae												
Pied Wagtail												
Motacitta alba	-	-	-	-		+	-	-	-	-	Sch.IV	
Paddyfield Pipit												
Anthus novaseelandiae	-	-	-	-		+	-	-	-	-		
Lanidae												
Brown Shirke												
Lanias cristatus	-	-	-	-		+	+	+	-	-	Sch.IV	
Sturnidae												
Common Myna												
Acridotheres tristis	-	-	-	-		+	+	-	-	-	Sch.IV	
Pied Myna												
Sturnus contra	-	-	-	-		-	-	-	-	+	Sch.IV	
Greyheaded Myna												
Sturnus Pogadarum	-	-	-	-		-	-	-	+	+	Sch.IV	
Corvidae												
Indian Tree Pie												
Dendrocitta vagabunda	-	-	-	-		+	-	-	+	+	Sch.IV	
Jungle Crow												
Crovus macrorhynchos	-	-	+	+		+	-	-	+	-	Sch.IV	
House Crow												
Corvus splendens	-	-	-	-		+	-	-	+	-	Sch.IV	
Ploceidae												
House Sparrow												
Passer domesticus	-	-	-	-		+	-	-	-	+	Sch.IV	
Baya												
Ploceus phillippensis	-	-	-	-		-	-	-	-	+	Sch.IV	

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Numenius arguata	-	+	-	-		-	-	-	-	-	Sch. IV	
Redshank												
Tringa totanus	-	-	+	+		-	-	-	-	-	Sch. IV	
Grunshank												
T. mebularia	-	-	+	+		-	-	-	-	-	Sch. IV	
Common Sandpiper												
T. hypoleucos	-	-	-	+		-	+	-	-	-	Sch. IV	
Little Stint												
Callidris minuta	-	+	-	-		-	-	-	-	-	Sch. IV	
Laridae												
Indian River Tern												
Sterna aurantia	+	+	-	-		-	-	-	-	-	Sch. IV	
Whiskered Tern												
Chhidonias hybrida	+	+	-	-		-	-	-	-	-	Sch. IV	
Columbidae												
Indian Ring Dove												
Streptopelia dicaocto	-	-	-	-		+	-	+	+	+	Sch. IV	
Spotted Dove												
S. chinensis	-	-	-	-		+	+	+	+	+	Sch. IV	
Psittacidae												
Roseringed Parakeet												
Psittacula kramerii	-	-	-	-		-	-	-	+	+	Sch. IV	
Cuculidae												
Koel												
Eudynanys scolopacea	-	-	-	-		+	-	-	+	+	Sch. IV	
Strigidae												
Spotted Owlet												
Athehene brama	-	-	-	-		+	-	+	+	+	Sch. IV	
Caprimulgidae												
Jungle Nightjar												
Caprimulgus indicus	-	-	-	+		-	-	-	+	-	Sch. IV	
Apodidae												
Palm Swift												
Cypsiurus parvas	-	-	+	+		+	-	-	+	-	Sch. IV	
Alcedinidae												
Whitebreasted Kingfisher												
Halcyonsmyrnensis	-	-	+	+		+	+	-	-	+	Sch. IV	
Meropidae												
Chestnutheaded Bee-eater												
Merops leschenaulti	-	-	-	-		-	-	-	+	+	Sch. IV	
Coracidae												
Indian Roller												
Coracias bengalensis	-	-	-	+		-	-	-	+	+	Sch. IV	
Capitonidae												
Bluethrroated Barbet												
Megalaima asiatica	-	-	-	-		-	-	-	-	+	Sch. IV	
Coppersmith												
Megalaima haemacephala	-	-	-	-		+	-	-	-	+	Sch. IV	

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaikonda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Whitebacked Munia												
Londhura punctulata	-	-	-	-		-	-	-	-	+	Sch.IV	
Post-monsoon												
Podicipetidae												
Little Grebe												
Podiceps ruficollis	-	-	-	-		-	-	-	-	+		Sc
Phalacrocoracidae												
Shag												
Phalacrocorax fusicollis	-	-	-	+		-	+	-	-	+		C
Little Cormorant												
P. niger	-	-	-	-		-	+	-	-	+		R
Ardeidae												
Pond Heron												
Ardeola grayii	+	+	+	+		+	+	+	+	+		VC
Cattle Egret												
Bubulcus ibis	-	-	+	+		+	+	-	+	+		VC
Small Egret												
Egretta intermedia	-	-	+	-		-	-	-	-	-		R
Large Egret												
E. modesta	-	-	+	-		-	-	-	-	-		R
Little Egret												
E. garzetta	-	-	+	+		+	+	-	-	+		C
Night Heron												
Nycticorax nycticorax	-	-	-	-		-	-	-	-	+		Sc
Accipitridae												
Blackwinged Kite												
Elanus caeruleus	-	-	-	-		+	-	-	-	-		Sc
Pariah Kite												
Milvus migrans	+	+	+	+		+	+	+	-	+		VC
Brahminy Kite												
Haliastus indus	-	+	-	+		-	+	-	-	-		C
Shikra												
Accipiter badius	-	-	-	-		-	-	-	+	-		Sc
Whitebacked Vulture												
Gyps bengalensis	-	-	-	-		-	-	-	+	-		R
Whitebellied Sea-Eagle												
Hilaetus leucogaster	+	+	-	-		-	-	-	-	-		Sc
Falconidae												
Kestrel												

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaikonda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Denddroctta vagabunda	-	-	-	-		-	-	-	-	-		C
House Crow												
Corvus splendence	-	+	+	-		+	-	-	-	+		C
Jungle Crow												
C. macrorhynchos	-	-	+	+		+	-	+	-	+		C
Pycnonotidae												
Redvented Bulbul												
Pycnonotus cafer	-	-	-	-		-	+	-	+	+		C
Muscicapidae												
Jungle Babbler												
Turdoides caudatus	-	-	-	-		+	-	+	+	+		C
Redbreasted Flycatcher												
Muscicapa parva	-	-	-	-		+	-	+	+	+		C
Streaked Fantail Warbler												
Cisticla juncidis	-	-	-	-		+	-	+	-	+		Sc
Ashy Wren Warbler												
Prinia socialis	-	-	-	-		+	-	+	+	+		C
Tailor Warbler												
*Orthotomus sutorius***	-	-	-	+		-	-	-	-	-		C
Indian Great Pied Warbler												
Acrocephalus stentorius	-	-	-	+		-	-	-	-	-		
Blyth's Reed Warbler												
A dumetorum	-	-	-	+		+	+	-	+	+		C
Chiffchaff												
Phylloscopus collibita	-	-	-	-		+	-	-	-	+		C
Dusky Warbler												
P. fuscatus	-	-	-	-		+	-	+	-	+		C
Indian Robin												
Saxicoloidis fluicata	-	-	-	-		-	-	+	+	+		C
Blue Rock Thrush												
Monticola solitaria	-	+	-	-		-	-	-	-	-		R
Motacillidae												
Tree Pipit												
Anthus hodgsoni	-	-	+	-		-	-	-	-	-		C
Paddyfield Pipit												
Anthus novaeseelandiae	+	+	+	+		+	+	+	+	+		C
Brown Rock Pipit												
A similis	-	-	-	-		-	-	+	+	-		C

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaikonda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Coracidae												
Indian Roller												
Coracias bengalensis	-	-	-	-		+	-	+	+	+		C
Upupidae												
Hoopoe												
Upupa epos	-	-	-	-		+	-	-	-	-		
Capitonidae												
Crimsonbreasted Barbet												
Megalaima haemocephala	-	-	-	-		-	-	+	-	+		Sc
Alaudidae												
Singing Bush Lark												
Mirafra javanica	-	-	-	+		+	-	-	+	+		Sc
Rufoustailed Finchlark												
Eremeopteryx grisea	-	-	-	-		+	-	+	+	+		C
Eastern Skylark												
Alauda gulgula	-	-	-	-		+	-	-	-	-		Sc
Hirundinidae												
Dusky craggmartin												
Hirundo concolor	-	-	-	+		-	-	-	-	-		C
Swallow												
Hirundo rustica	-	-	+	+		+	+	+	-	+		C
Striated Swallow												
H.daurica	-	-	-	+		+	-	+	-	-		Sc
Lanidae												
Baybacked Shrike												
Lanias vittatus	-	-	-	-		+	-	-	+	-		Sc
Oriolidae												
Blackheaded Oriole	-	-	-	-		-	-	-	-	+		C
Dicruridae												
Black Drongo												
Dicrurus adsimilis	-	-	-	+		+	+	+	+	+		C
Sturnidae												
Pied Myna												
Sternus contra	-	-	-	-		-	+	-	-	+		C
C Myna												
Acridotherus trintis	-	-	-	-		-	+	+	-	+		C
Corvidae												
Indian Tree Pie												

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaikonda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
S. aurantia	-	-	+	+		-	+	-	-	-		R
Large Crested Tern												
	+	-	-	-		-	-	-	-	-		R
Great Blackheaded Gull												
larus icthyaetus	+	+	-	-		-	-	-	-	-		R
Brown-headed Gull												
L. brunnicephalus	+	+	-	-		-	-	-	-	-		C
Columbidae												
Rinage Dove												
Steptopelia decaocto	-	-	-	-		+	+	+	+	+		C
Spotted Dove												
S. chinensis	-	-	-	-		+	+	+	+	+		C
Rufous Turtle Dove												
S. orientalis	-	-	-	-		-	-	+	+	-		C
Psittacidae												
Roseringed Parakeet												
Psittacula kramerii	-	-	-	-		+	-	+	+	+		C
Alexandrine Parakeet												
P. eupatria	-	-	-	-		+	-	-	+	+		R
Brainfeaver Bird												
Cuculus varius	-	-	-	-		-	-	-	-	+		Sc
Koel												
Eudynamys scolopacca	-	-	-	-		-	-	-	+	+		C
Coucal												
Centropus sinensis	-	-	-	-		-	-	-	+	+		Sc
House Swift												
Apus affinis	-	-	-	-		+	+	+	+	+		C
Palm Swift												
Cypsiurus parvus	-	+	-	-		+	-	-	+	+		C
Alcedinidae												
C Kingfisher												
Alcedo athis	-	-	-	-		-	+	-	-	-		Sc
Whitebreasted Kingfisher												
Halcyon smyrnensis	-	-	-	-		+	-	+	+	+		C
Meropidae												
Green bee-eater												
Merops orientalis	-	-	+	-		+	-	+	-	+		C

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaikonda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Yellowwheaded Wagtail												
Motacilla citreola	-	-	-	+		-	+	-	-	-		C
Grey Wagtail												
M. cinerea	-	-	-	+		-	+	-	-	-		C
Nectarinidae												
Purplerumped Sunbird												
Necterinia zeylonica	-	-	+	+		-	-	-	-	-		C
Ploceidae												
Houser Sparrow												
Passer domesticus	-	-	-	-		+	-	+	+	+		VC
Baya												
Ploceus philippinus	-	-	-	-		-	+	-	-	+		C

VC=Very Common C=Common Sc=Scrce R=Rare

(1) A group of 16 birds was encountered during the present survey

(1) Recorded for the first time during 3 surveys

(2) Recorded near Simhachalam

(3) Recorded near plant site

*The print record is northward extension of the range of Reef Heron in the East Coast where it is known to be extremely r

** Recorded from project site

Table F.10. Mammals around HNPCL plant site

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaiconda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Winter												
Soricidae												
Suncus murinus	-	-	-	-	-	+	-	-	-	+	Sch V	
Tupiidae												
Anthana ellioti	-	-	-	-	-	-	-	-	+	-	Sch IV	
Petoropodididae												
Rousettus leschenaulti	-	-	-	+	-	-	-	+	-	-	Sch IV	
Pteropus giganteus	-	-	-	+	-	-	-	+	-	-	Sch IV	
Cynopterus sphinx	-	-	-	+	-	-	-	+	-	-	Sch IV	
Emballonuridae												
Taphozous longimanus	-	-	-	-	+	-	-	-	-	-	Sch IV	
Megadermatidae												
Megaderma lyra	-	-	-	-	-	-	+	-	-	-	Sch IV	
Vespertilionidae												
Pipistrellus coromandra	-	+	+	+	+	+	+	+	+	+	Sch IV	
P mimus	-	-	-	-	+	-	+	+	+	+	Sch IV	
Scotophilus kuhli	-	-	-	-	+	-	-	+	-	-	Sch IV	
S heathi	-	-	-	-	+	-	-	+	-	+	Sch IV	
Canidae												
Canis aureus	+	+	+	+	+	+	+	+	+	+	Sch I	
Vulpus benghalensis	+	+	+	+	-	-	-	+	-	-	Sch II	
Cuon alpinus	-	-	-	-	-	-	-	-	+	-	Sch I	
Ursidae												
Melursus ursinus	-	-	-	-	-	-	-	-	+	-	Sch II	
Mustellidae												
Lutra perspiciliata	-	-	+	+	-	-	+	-	-	-	Sch I	
Viverridae												
Vivera eibetha	-	-	-	-	+	-	-	-	-	-	Sch II Pt II	
Viverricula indica	-	-	+	+	+	+	-	-	+	-	Sch II Pt II	
Paradoxurus hermaphroditus	-	-	+	-	+	+	-	-	-	-	Sch II Pt II	
Herpestes edwardsi	-	-	-	-	+	+	+	-	-	-	Sch IV	
Hyaenidae												
Hyaena hyaena	-	-	-	-	+	-	-	-	-	-	Sch I	
Felidae												
Felis chaus	-	-	-	-	+	-	-	-	+	+	Sch I	
Suidae												
Sus scrofa	-	-	-	-	+	-	-	-	+	+	Sch III	
Cervidae												
Murtiacus muntjack	-	-	-	-	-	-	-	-	+	-	Sch III	

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaiconda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Viverridae												
Large Civet												
Vivera zibetha	-	-	-	-	-	-	+	-	-	-		
Small Indian Civet												
Viverricula indica	-	-	-	-	-	-	+	+	-	-		
Palm Civet												
P. nermaphroditus	-	-	-	-	+	-	+	-	+	+		
Small Mongoose												
Herpestes edwardii	-	-	-	-	+	+	-	+	+	+		
Felidae												
Jungle Cat												
Felis chaus	-	-	-	-	+	-	-	-	-	-		
Suidae												
Wild Boar												
Sus scrofa	-	-	-	-	+	-	-	-	-	-		
Cervidae												
Barking Deer												
Murtiacus muntjack	-	-	-	-	-	-	-	+	+	-		
Sciuridae												
Thrustriped Squirrel												
funumbulus palmarum	-	-	-	-	+	+	-	+	+	+		
Muridae												
Tree Rat												
Rattus rattus arboreus	-	-	-	-	-	-	-	+	-	-		
Mouse												
Mus musculus	-	-	-	-	-	-	-	+	-	-		
Field Mouse												
Mus booduga	-	-	-	-	-	+	-	+	+	+		
B. Marine forms												
C Dolphin												
Delphinus delphis												
Monsoon												(1)
Sciuridae												
Three striped Squirrel												
Funumbulus palmarum	-	-	-	-	+	-	+	+	+		Sch.IV	
Field Mouse												
Mus booduga	-	-	-	-	+	-	-	-	-		Sch.IV	
Bushrat												
Gollunda ellicti	-	-	-	-	+	-	-	-	-		Sch.IV	

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaiconda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Leporidae												
Lepus nigricollis	-	-	+	+	+	+	-	+	+	-	Sch IV	
Sciuridae												
Funumbulus palmarum	-	-	+	+	+	+	+	+	+	+	Sch IV	
Muridae												
Rattus rattus arboreus	-	-	-	-	-	-	-	+	-	-	Sch V	
Mus musculus	-	-	-	-	-	+	-	-	-		Sch V	
Mus booduga	-	-	-	-	-	+	-	-	-	+	Sch V	
Pre-monsoon												
Terrestrial forms												
Soricideae												
House Shrew												
Suncus murinus	-	-	-	-	-	-	-	-	-	+		
Tuplidae												
Tree Shrew												
Anthana ellioti	-	-	-	-	-	-	-	+	+	-		
Petorpodidae												
Giant Fruit Bat												
Pteropus giganteus	-	-	-	-	+	+		+	+	+		
Lesser Fruit Bat												
Cynopterus sphinx	-	-	-	-	+	+		+	+	+		
Megadermatidae												
Plase Vampirebat												
Megaderma lyra	-	-	-	-	-	-	-	+	-	-		
Vespertilionidae												
Pipistrellus coromandra	-	-	-	+	+	+	+	+	+	+		
P. mimus	-	-	-	-	-	+	+	+	+	+		
Yellow Bat												
Scotophillus kuhli	-	-	-	-	-	-	-	+	+	-		
S. neathi	-	-	-	-	-	+	-	-	-	-		
Canidae												
Jackal												
Canis aureus	-	-	-	-	-	-	-	+	+	-		
Bengal Fox												
Vulpus bengalensis	-	-	-	-	-	-	-	+	+	-		

Table F.11. Livestock in *Mandals* around HNPCL plant site

	Subdivision/Mandal	Cattle	Buffaloes	Sheep	Goats	Pigs	Poultry birds
A	Visakhapatnam						
1	Visakhapatnam (rural + urban)	2256	18345	4103	3196	1270	145184
2	Pendurthi	3808	9912	4234	3010	444	112138
3	Sabbavaram	6097	14669	4337	4358	500	247073
4	Paravada	4290	9340	4247	2563	369	62108
B	Bheemunipatnam						
5	Peddagantyada	1756	1068	59	1174	2	9809
C	Anakapalli						
6	Anakapalli	6214	19907	8598	7354	3123	141603
7	Kasimkota	3724	18066	5559	5089	1526	31615
8	Munagapaka	3133	11234	1880	1302	794	46962
9	Gajuwaka	1295	3905	2119	976	907	25002
D	Yelamanchili						
10	Achuthapuram	6720	13161	4393	3509	582	85377
11	Rambilli	7359	9936	3338	3785	324	31137
12	Rayavaram	3227	18404	4622	2747	405	N.A.

Source: Handbook of Statistics :Visakhapatnam, Chief of Planning, A.P.

Common Name / Scientific Name	Intertidal zone	Sea Coast	Tidal mudflat	Marsh & aquaculture	Coastal vegetation	Village plantation	Inland waterbodies	Nalaiconda R.F.	Narava R.F.	Vizag township	Status in IBWL	Remarks
Vespertelionidae												
Lesser Fruit Bat												
Scotophilus heathi	-	-	-	-		+	-	+	+	+	Sch.IV	
Yellow Bat												
Scotophilus heathi	-	-	-	-		+	-	-	-	-	Sch.IV	
Floying Fox												
Pteropus giganteus	-	-	-	-		+	-	-	-	-	Sch.IV	
Pipistrelle												
Pipistrellus mimus	-	-	+	+		+	+	+	+	+	Sch IV	
Laporeadae												
Blacknaped Hare												
Lkepas nigricollis	-	-	-	+		+	-	-	-	-	Sch.IV	
Suidae												
Wild Boar												
Sus scrofa	-	-	-	+		+	-	-	-	-	Sch.IV	
C Mongoose												
Herpestes edwardsii	-	-	-	+		+	-	-	-	-	Sch.IV	
C Dolphin												
Delphinus delphis	-	+	-	-		-	-	-	-	-	Sch.IV	
Post-monsoon												
Sciuridae												
Threestriped Squirrel												
Funumbulus palmaum	-	-	-	-		+		+	+	+	Sch VI	VC
Muridae												
Indian Metad												
Tatera indica	-	-	-	-		+	+	-	-	+		C
Molerat												
Bandicoota indica	-	-	-	-		[illegible]	+	-	-	+		C
C Mongoose												
Herpestes edwardsii	-	-	-	-		+	-	-	-	-	Sch V	Sc
Canidae												
Jackal												
Canis aureus	-	+	+	+		-	-	[illegible]	-	-	Sch II	VC
Delphinidae												
C Dolphin												
Delphinus delphis	+	-	-	-		-	-	-	-	-		C

VC – Very Common C – Common Sc – Scarce

(1) This particular form was noted to abound in and around the Visakhapatnam harbour especially in south along the shore to it. Altogether 19 sightings were recorded during two days cruise, mostly in pairs. Some very pale and boldly blotched forms were also noted at the mouth of the harbour.

Table F.12. Plankton load (no/lit) in aquatic habitats around HNPCL plant site

	Species	Yeleru canal	Aquaculture farm (Dalaipalem)	Backwater tidal creek	Sea coast near Appikonda	Pond near Palavlasa
Winter						
Phytoplankton	*Merismopedia sp*	10	-	10	-	-
	Microcystis sp	-	-	-	-	50
	Oscillatoria sp	10	30	40	-	30
	Spirogyra sp	50	50	30	-	30
	Mougeotia sp	100	60	20	-	-
	Cosmerium sp	20	50	10	-	10
	Peridinium sp	-	-	-	10	-
	Thallasiothrix sp	-	-	-	10	-
	Coscinodisous sp	-	-	20	100	-
	Bacteriastrum sp	-	-	20	30	-
	Skeletonema sp	-	30	10	100	-
	Asterionella sp	-	-	20	50	-
Zooplankton	*Acantharia sp*	-	20	-	-	-
	Tintinids sp	-	10	-	-	-
	Calanoid sp	-	10	10	-	-
	Cyclopoid sp	-	-	20	-	10
	Naupli sp	-	-	20	10	10
	Keratella sp	-	-	10	-	10
	Cladocera sp	-	-	-	-	10
Gross Total		190	260	240	310	160

Table F.12. Plankton load (no/lit) in different aquatic habitats around HNPCL plant site (contd...)

	Species	Yeleru canal	Aquaculture farm (Dalaipalem)	Backwater tidal creek	Sea coast near Appikonda	Pond near Palavlasa	Offshore water near harbour	Offshore water near Gangavaram	Offshore water near Pudimadaka
Pre-monsoon									
Phytoplankton	*Merismuopedia sp*	100							
	Microcystis sp.	50							
	Oscillatoria sp.	50	20	20		30			
	Spirogyra sp.	20				20			
	Navicula sp.	10				20			
	Fragilaria sp.	20							
	Chaeteceros sp.				20				
	Coscinodiscus sp.			10	30		40	50	50
	Skeletonema sp.				20		60	50	60
	Biddulphia sp.				20		30	40	40
	Surirella sp.		50	30					
	Ceratium sp.				10		10	20	20
	Skeletonema sp.				20		20	20	20
	Peridinium sp.				10		10	20	20
Zooplankton	*Tintinids sp.*				10				
	Copepods	10	20	10					
	Naupli sp.				10		10	10	20
	Brachionus sp.			10					
Gross Total		260	90	80	150	80	180	230	230

Table F.12. Plankton load (no/lit) in different aquatic habitats around HNPCL plant site (contd...)

	Species	Yeleru canal	Aquaculture farm (Dalaipalem)	Backwater tidal creek	Sea coast near Appikonda	Pond near Palavlasa	Offshore water near harbour	Offshore water near Gangavaram	Offshore water near Pudimadaka
Monsoon									
Phytoplankton	*Merismopedia sp.*	50							
	Microcystis sp.	40	20			200			
	Oscillatoria sp.	40	30			20			
	Spirogyra sp.	20							
	Mongeotia sp.								
	Cosmerium sp.	30							
	Peridinium sp.					10			
	Thallasiothrix sp.		20	20	20		20	30	20
	Coscinodiscus sp.		20	60	40		50	40	40
	Bacteriastrun sp.						20	30	30
	Skeletonema sp.				20		20	30	30
	Asterionella sp.								
	Ceratium sp.						10	20	10
	Gyrosigma sp.			20	40		20	20	30
	Cyclotella sp.						10	20	20
Zooplankton	*Acantharia sp.*				10				
	Tintinids sp.						10		
	Calarioid sp.				10				
	Cyclopoid sp.	10				20			
	Naupli sp.		40	40			20	10	10
	Keratella sp.				20		10		10
	Cladocera sp.	10			10		20	20	20
Gross Total		200	130	140	170	250	210	220	220

Table F.12. Plankton load (no/lit) in different aquatic habitats around HNPCL plant site (contd...)

	Species	Yeleru canal	Aquaculture farm (Dalaipalem)	Backwater tidal creek Tikkavanipalem	(Littoral sea water) Pond near Palavlasa	Offshore water near harbour	Offshore water near Gangavaram	Offshore water near Pudimadaka
Post-monsoon								
Phytoplanktons	*Merismopedia sp.*	30			20			
	Cosdmerium sp.	20			30			
	Coscinodiscus sp.			20	40			60
	Thalassionema sp.		10	10	20	*	*	10
	Thalassionema sp.			20	10			20
	Chaetoceros sp.				20			20
	Pleurosigma sp.		30	40	20			20
	Biddulphia sp.				30			40
	Amphiphora sp.		10		10			10
	Hemidiscus sp.			10				10
	Bacteriastrum sp.		20	20	10			
	Ceratium sp.				10			10
	Peridinium sp.							10
Zooplanktons	*Filinia sp.*			10		*	*	
	Nauplius sp.				10			10
	Harpacticoid Copepod sp.		10		30			40
	Calaroid copepod sp.				30	10		60
	Tintinids	10			10			20
Gross Total		60	80	130	240	70	*	*	340

* Sampling could not be made due to bad weather.

F.2.6 Freshwater Fish

A checklist of freshwater fish using data collected from local fish markets and examination of catches during field visits is given in Table F.17. The list contains 24 species. None of the species belongs to to rare or endangered categories as per Indian Board of Wild Life (IBWL).

F.2.7 Aquatic Birds

Various marine and coastal avi fauna were recorded during the TCS team's visit. Flocks of migratory ducks such as the common teal, garganey, shoveller, tufted pochard, and other waders were regularly seen along the coast (100-300 m off the coast). Forty seven species of aquatic birds were recorded in the study area, of which 12 species were commonly recorded at 3 or more stations (Table F.18).

F.2.8 Marine Fauna

Several species of invertebrates, which include micro-, meio-, and macro forms were recorded off the Visakhapatnam coast. The interstitial sands harbour a rich variety of protozoans, nematodes, annelids, gastrotrichs, kinorhynchs, crustaceans, and molluscus. The tidal fauna also include micro-, meio-, and macrofaunal species of invertebrates. Some of the major important marine faunal species observed during the survey are given in Table F.19.

a. Littoral and Benthic Macrofauna

Benthic fauna plays a crucial role in the trophic relationships of continental shelf. Demersal fish mainly depend for their food on benthic fauna. The littoral macrobenthos off the Visakhapatnam coast mainly comprises *Cnidarians*, *Annelida*, *Crustacea*, *Mollusca*, *Echinodermata*, *Sipunculids*, *Brachiopod*, and fish; estimated numbers of species are given in Table F.20. It can be seen from the table that polychaetes (9), crustaceans (12), bivalves (15), and gastropod molluscs (30) have good species diversity. A single species of *Holothuroid* seems to be most common among all the littoral macrobenthos.

A detailed checklist of all macrobenthos reported off the Visakhapatnam coast is given in Table F.21. Macrobenthic fauna off Visakhapatnam, collected from various depths during the TCS survey (both dredge- and grab collections) are listed in Table F.22. About 68% of benthic biomass was found to occur within a

F.2.3 Marine Benthic Algae

The Bay of Bengal coast near Visakhapatnam is one of the important habitats for marine algae, with rocky outcrops scattered along the coastline on which benthic algae grow. The TCS flora-fauna team extensively surveyed the rocky outcrops near the HNPCL site, near Appikonda and Thikkavanipalem. The team also surveyed outcrops near Pudimadaka, Dolphin's Nose, and Lawson's Bay area (near Visakhapatnam outer harbour). A detailed checklist of the species found at these locations is given in Table F.14.

Benthic algal communities in intertidal zones showed higher variation in Lawson's Bay and Pudimadaka regions. Certain taxa were very common at all the study locations. Detailed comparative data for each station are given in Table F.15.

F.2.4 Aquatic Macrophytes

Both freshwater and brackish water bodies in the area around the HNPCL site were found to harbour a number of macrophytic plants. In addition, a number of marsh plants were also noticed in this area. A detailed checklist is given in Table F.16.

F.2.5 Life Cycle of Sea Algae

Among the benthic algae on rocky outcrops, the species of *Sargassum*, *Ulva*, *Porphyra*, and *Padina* were found to be very common. Life cycle of the three dominant taxa - *Sargassum*, *Padina*, and *Ulva* were examined through periodic field visits. All *Sargassum* spp were observed to have sporophytic plant body (2n) with sex organ borne on sporophytic thallus in clusters. In the species of *Ulva*, the plant body itself was germetophytic where any cell of the thallus could be transformed into gametangia as required for maintaining the sexual cycle. The details of phenological behaviour as observed during the field surveys is tabulated below:

Species	Winter	Pre-monsoon	Monsoon	Post-monsoon
Sargassum illicifolium	R	V	V	R
Ulva fasciata	R	V	V	R
Caulerpa sertularioides	V	V	R	V
Porphyra vietnamensis	R	V	V	V
Padina tetrastromatica	V	V	R	V
Gracilaria corticata	V	V	R	R

V=Vegetative phase, R=Reproductive phase

Table F.13. Periphytons around HNPCL plant site

Species	Yeleru Canal	Aquaculture farm	Backwater Tidal Creek	Coastal water at Kuttukonda	Pond water at Palavalasa
Winter					
Lyngbya spp	+	+	+	-	+
Spirogyra spp	++	++	-	+	+
Oscillatoria spp	+	+	-	+	+
Spirulina spp	-	+	+	-	-
Cladophora spp	-	-	-	+	-
Oedogonium spp	+	+	-	-	+
Premonsoon					
Lyngbya sp.	++	-	-	-	+
Spirogyra sp.	++	-	-	-	+
Oscillatoria sp.	+	+	-	-	-
Spirulina sp.	-	++	-	-	-
Cladophora sp.	-	-	-	-	+
Oedogonium sp.	+	-	-	-	++
Zygnema sp.	+	-	-	-	+
Monsoon					
Lyngbya sp.	-	+	+	-	-
Spirogyra sp.	++	-	-	-	++
Oscillatoria sp.	-	-	-	-	+
Spirulina sp.	-	+	-	-	-
Cladophora sp.	+	-	-	-	-
Oedogonium sp.	+	-	-	-	+
Postmonsoon					
Lingbya sp.	-	-	-	-	-
Spirogyra sp.	++	-	-	-	++
Oscillatoria sp.	+	+	-	-	+
Spirulina sp.	-	+	+	-	-
Cladophora sp	-	+	+	-	-
Oedogonium sp.	+	-	-	-	+

+ Present
++ Abundant
- Absent

Table F.14. Marine benthic algae around HNPCL plant site

Species	Pudimadaka	Thikkavanipalem	Appikonda	Visakhapatnam	Lawson's Bay
Winter					
Enteromorpha compressa	+	+	+	+	+
Ulva fasciata	+	+	+	+	+
Chaetomorpha anterinia	+	+	'	+	+
Cladophora colabense	+	+	'	'	+
Bryopsis pennata	'	'	'	+	+
Caulerpa fastigiata	+	+	'	'	+
Caulerpa sertularioides	+	+	'	+	+
Codium iyengarii	+	+	+	+	+
Dictyota dichotoma	+	'	'	+	+
Padina tetrastromatica	+	+	'	+	+
Sargassum illicifolium	+	+	'	+	+
Sargassum vulgare	+	'	'	+	+
Porphyra vietnamensis	'	'	'	+	+
Acrochaetium iyengarii	+	+	+	+	+
Gelidiella myriocladia	+	+	'	+	+
Gelidium heteroplatos	'	'	'	+	+
Grateloupia filicina	+	+	+	+	+
Grateloupia lithophida	'	'	'	+	+
Gracilaria corticata	+	+	'	+	+
Gracilaria textorii	+	+	'	+	+
Hypnea musciformis	+	+	+	+	+
Gagastina acicularis	+	+	+	+	+
Ceratium finbriatum	'	'	'	+	+
Polysiphonia ferulacea	+	+	'	+	+
Polysiphonia platycarpa	+	'	'	+	+
Herposiaphonia tencila	'	'	+	+	+
Herposiphonia secunda	'	'	'	+	+
Chondria cornuta	'	+	+	+	+
Pre-monsoon					
Enteromorpha compressa	+	+	+	+	+
Ulva fasciata	+	+	+	+	+
Chaetomorpha autennia	+	-	-	-	-
Chaetomorpha brachygona	+	-	+	-	-
Cladophora colabense	+	-	-	-	-
Sryopsis pennata	-	-	-	-	+
Caulerpa satigita	+	+	+	+	+
Caulerpa sertularioides	+	+	+	+	+
Codium iyengarii	+	-	-	-	+
Dictyota dichotoma	+	-	-	-	+
Podina tetrastrometica	+	+	+	+	+
Sargassum illicifolium	+	+	+	+	+
S. vulgure	+	+	+	+	+
Porphyra vietnamensis	-	-	-	-	+
Acrochaetium iyengarii	+	-	-	+	+
Gelidiella myrioeladia	-	-	-	+	+
Grateloupia filicina	+	+	+	+	+

Species	Pudimadaka	Thikkavanipalem	Appikonda	Visakhapatnam	Lawson's Bay
G. lithophila	-	-	+	-	-
Gelidium heteroplatos	-	-	-	-	+
Gracilaria corticata	+	+	+	+	+
G. textorii	-	-	+	-	-
Hypnea musciformis	+	+	+	+	+
Gagartina acicularis	+	+	+	+	+
Ceratium cruciatum	-	-	+	-	+
Ceratium fimbriatum	-	+	-	-	-
Polysiphomia ferulacea	+	+	-	-	-
P. platycopa	-	-	-	+	-
Herposiphonia tenella	-	-	-	-	+
H. secunda	-	-	-	+	+
Chondria cornuta	+	-	+	+	+
Monsoon					
Enteromorpha compress	+	+	+	+	+
Ulva fasciata	+	+	+	+	+
Chaetomorpha antennia	+	+	-	+	+
Chaetomorpha brachygona	+	-	-	-	+
Cladophora colabense	-	-	+	+	+
Bryopsis pennata	+	-	-	-	-
Caulerpa fastigiata	+	+	+	-	+
Caulerpa sertularioides	+	+	-	-	+
Codium iyengarii	+	+	+	+	+
Dictyota dichotoma	+	-	-	-	-
Padina tetrastromatica	+	+	+	+	+
Sargassum illicifolium	+	+	+	+	+
Sargassum vulgare	+	+	+	+	+
Porphyra vietnamensis	+	+	+	-	+
Acrochaetium iyengarii	-	+	-	-	-
Gelidiella myrioclada	+	-	-	-	+
Gelidium heteroplatos	+	-	-	-	+
Grateloupia filicina	+	+	+	-	-
Grateloupia lithophiloa	+	-	-	-	+
Gracilaria corticata	+	+	+	-	+
Gracilaria textorii	+	+	+	+	+
Hypnea musciformis	+	+	+	-	+
Gagartina acicularis	+	-	-	-	-
Ceratium cruciatum	+	-	-	+	-
Ceratium fimbriatum	-	-	-	-	+
Polysiphonia ferulacea	+	+	-	-	+
Polysiphonia platycarpa	+	+	-	-	+
Herposiphonia tenella	-	-	-	-	-
Herposiphonia secunda	-	-	-	-	-

Species	Pudimadaka	Thikkavanipalem	Appikonda	Visakhapatnam	Lawson's Bay
Chondria cornuta	+	-	-	-	+
Post-monsoon					
Enteromorpha compressa	-	-	-	+	+
Ulva fasciata	+	+	+	+	+
Chaetomorpha autennia	+	-	-	+	+
Chaetomorpha brachygona	-	-	-	-	+
Cladophora colabense	-	-	-	+	-
Bryopsis pennata	-	-	-	-	-
Caulerpa fastigita	+	-	+	+	+
Caulerpa sertularioides	+	+	+	-	+
Codium iyengarii	-	-	-	-	-
Dictyota dichotoma	+	-	-	-	-
Podina tetrastrometica	+	+	+	+	+
Sargassum illicifolium	+	+	+	+	+
Saragassum vulgure	+	+	-	-	-
Porphyra vietnamensis	-	-	-	-	-
Acrochaetium iyengarii	-	-	-	-	-
Gelidium heteroplatos	-	-	-	-	-
Gelidiella myriolada	-	-	-	-	-
Grateloupia filicina	+	-	-	+	+
G. lithophila	-	-	-	-	-
Gracilaria corticata	+	+	+	+	+
G. textorii	+	+	-	-	+
Hypnea musciformis	+	-	-	-	-
Gagartina acicularis	-	-	-	-	-
Ceratium cruciatum	+	-	-	-	-
Ceratium fimbriatum	-	-	-	-	-
Polysiphomia ferulacea	+	-	-	-	+
P. platycarpa	-	+	+	-	-
Herposiphonia tenella	-	-	-	-	-
H. secunda	-	-	-	-	-
Chondria cornata	-	-	-	-	-

Table F.15. Seasonl variation of Marine benthic algae around HNPCL plant site

	Pudimadaka				Thikkavanipalem				Kuttukonda				Visakhapatnam harbour				Lawson's Bay			
	Winter	Premonsoon	Monsoon	Postmonsoon	Winter	Premonsoon	Monsoon	Postmonsoon	Winter	Premonsoon	Monsoon	Postmonsoon	Winter	Premonsoon	Monsoon	Postmonsoon	Winter	Premonsoon	Monsoon	Postmonsoon
Total number of algal taxa occure	23	19	25	14	20	13	17	8	9	16	13	7	28	16	10	9	30	22	22	12
Most dominant taxa (all seasons)	*Sargassum illicifolium*				*Gracillaris corticata*				*Gracillaria corticat*				*Ulva fasciata*				*Ulva fasciata*			
Most common taxa (all seasons)	*Chatomorpha autennia*				*Ulva fasciata*				*Ulva fasciata*				*Ulva fasciata*				*Ulva fasciata*			
					Chatomorpha autenni				*Gracillaris corticat*				*Chatomorpha autennia*				*Chatomorpha autennia*			
	Caulerpa serhilarioides				*Caulerpa sersuleriodes*				*Padina tetrastromatica*								*Padina tetrastromatica*			
	Sargassum illicifolium				*Sargassum illicifolium*				*Sargassum illicifolium*								*Sargassum illicifolium*			
	Gracillaris corticata				*Gracillaris corticata*															
	Padina tetrastromatica																			

Table F.16. Macrophytes around HNPCL plant site

Species	Growth form type
Eichhornea crassipes	Floating
Pistia stratiotes	- do -
Lemma purpurila	- do -
Salvinea natans	- do -
Azolla pinnata	- do -
Smithia spinolusa	- do -
Jussia repens	- do -
Nymphoides speltata	- do -
Alternanthera phylliseorides	- do -
Vallisneria spiralis	Submerged
Potamogeton spp	- do -
Hydrilla verticillata	- do -
Scirpus articulatus	Amphibio
Typha angustifolia	- do -
Ipomoea fistulosa	- do -
Cyperus tagetiformis	- do -
Sagitaria sagttifolia	- do -
Enhydra fluctuans	- do -
Nymphea naucheli	- do -

Table F.17. Freshwater fish around HNPCL plant site

Latin name	1	2	3	4	5	6	7	8	9	10
Notopterus notopterus				+			+			+
Chela Lauluca				+			+			+
Sccuricula gora							+			
Barilius bendelisis			+	+			+			+
Barilius vagra				+			+			+
Danio acquipinnatus				+			+			
Danio dangula							+			+
Danio devario			+							
Danio rerio			+				+			+
Aspidoparia morar				+			+			+
Catla catla							+			
Cirrhinus reba							+			
Cyprinus carpiro							+			
Garra gotyla gotyla							+			
Taleo bata							+			
Taleo boga							+			
Taleo cabbasu							+			
Taleo rohita							+			
Puntius amphibius							+			
Puntius chala				+			+			
Puntius conchonius				+			+			+
Puntius sophore			+	+			+			+
Puntius ticto ticto			+	+			+			+
Mystus cavasius							+			

Note : None of the above species belong to rare or endangered category as per IBWL

(1) Intertidal zone at Pudimadaka (18km)
(2) Sea coast near Appikonda (5km)
(3) Tidal mudflat (4km)
(4) Marsh and aquaculture farm near Thikkavanipalem (3km)
(5) Coastal front (southern end of HNPCL site)
(6) Village plantations at Palavalasa (3km)
(7) Inland water of Yeleru canal (12km)
(8) Nalaikonda Reserve forest (15km)
(9) Narava Reserve forest (18km)
(10) Vizag Township (22km)

Table F.18. Aquatic birds around HNPCL plant site

	Intertidal	Sea Coast	Tidal mudflat	Marsh and aquaculture	Coastal foant	Village plantation	Inland water	Nalaikonda R. F.	Narava R. F.	Vizag Township	Status in IBWL	Remarks
Podicipetidae												
Podiceps ruficollis Little Grebe	-	-	-	+	-	-	+	-	-	-	Sch. I	C
Phalacrocoracidae												
Phalacrocorax fuscicollis Shag	-	-	+	+	-	-	+	-	-	-	Sch. I	C
P. niger Little Cormorant	-	-	-	+	-	-	+	-	-	-	Sch. I	SC
Anhinga rufa Darter	-	-	-	-	-	-	+	-	-	-	Sch. I	R
Ardeidae												
Ardea purpurea Purple Heron	-	+	+	-	-	-	-	-	-	+	Sch. I	R
Areola grayii Pond Heron	-	+		-	-	-	-	-	-	-	Sch. I	VC
Bubulcus ibis Cattle Egret	-	-	+	-	-	-	-	+	+	-	Sch. I	SC
Ardea alba Large Egret	-	-	+	-	-	-	-	-	-	-	Sch. I	R
Egretta intermedia Smaller Egret	-	-	+	-	-	-	-	-	-	-	Sch. IV	
E. garzetta Little Egret	-	-	+	-	-	-	-	-	-	-	Sch. I	R
Nycticerox nycticerox Night Heron	-	-	+	-	+	+	-	-	-	-	Sch. I	SC
Ixobrychus cinnamomeus Chestnut Bittern	-	-	-	-	-	-	+	-	-	-	Sch. I	C
I. sinensis Yellow Bittern	-	-	-	+	-	-	-	-	-	-	Sch. I	SC
Anatidae												
Dendrocygna javanica Lesser Whisttling Teal	-	-	-	+	-	-	+	-	-	-	Sch. IV	
Nettapus coromandelianus Cotton Teal	-	-	-	-	-	-	+	-	-	-		
Rallidae												
Poszana pusilla Bailons Crake	-	-	-	+	-	-	-	-	-	-	Sch. I	R
Amauronis poenicurus Whitebreased Waterhen	+	+	-	-	-	-	+	-	+	-	Sch. I	C
Fulica atra Coot	-	-	-	-	-	-	-	-	-	-		
Jacanidae												
Netopidius indicus Bronzewinged Jacana	-	-	+	+	-	-	+	-	-	+	Sch.IV	C
Hydrophasianus chirugus Pheasanttailed Jacana	-	-	-	-	-	-	+	-	-	-	Sch. I	C

	Intertidal	Sea Coast	Tidal mudflat	Marsh and aquaculture	Coastal foant	Village plantation	Inland water	Nalaikonda R. F.	Narava R. F.	Vizag Township	Status in IBWL	Remarks
Rostatula bengalensis	-	-	-	+	-	-	-	-	-	-	Sch. I	R
Painted Snipe												
Recurvirostridae												
Himantopus nimantopus	-	+	+	-	-	-	-	-	-	-	Sch. I	R
Blackwinged Stilt												
Recurvirostra avocetta	-	+	-	-	-	-	-	-	-	-	Sch. I	C
Avocet												
Charadridae												
Vanellus indicus	+	+	+	+	+	+	+	+	-	-	Sch. I	C
Redwattled Lapwing												
V. malabaricus	-	-	-	-	-	-	+	+	-	-	Sch. I	C
Yellowwattled Lapwing												
Pluvialis domica fulva	+	-	-	-	-	+	-	-	-	-	Sch. I	C
Eastern Golden Plover												
Charadrius hiaticula	+	-	+	-	-	-	-	-	-	-	Sch. I	C
Ringed Plover												
C. dubius	+	+	+	-	-	-	-	-	-	-	Sch. I	C
Little Ringed Plover												
C. alexandrianus	-	+	-	-	-	-	-	-	-	-	Sch. I	R
Kentish Plover												
Numenibes phaeopus	+	+	-	-	-	-	-	-	-	-	Sch. I	R
Whimbrel												
N. arguata	+	+	+	+	-	-	-	-	-	-	Sch. I	C
Eastern Curlew												
Limosa limosa	-	-	+	+	-	-	-	-	-	-	Sch. I	C
Blacktailed Godwit												
Tringa erythropus	-	-	-	-	-	-	+	-	-	-	Sch. I	SC
Spotted or Dusky Redshank												
T. totanus	-	-	-	+	-	-	+	-	-	-	Sch. I	C
Redshank												
T. stagnatitis	-	-	+	-	-	-	+	-	-	+	Sch. I	C
Marsh Sandpiper												
T. nebularia							+			+	Sch. I	C
Green Sandpiper												
T. glareola	-	-	+	+	-	-	+	-	-	-	Sch. I	C
Wood Sandpiper												
T. hypolurcos	-	-	+	+	-	-	+	-	-	-	Sch. I	C
Common Sandpiper												
Arnenaria interprus	+	+	-	-	-	-	-	-	-	-	Sch. I	C
Turnstone												
Gallinago sternura	-	-	-	+	-	-	+	-	-	-	Sch. I	C
Paintail Snipe												
Callidris minuta	-	-	-	+	-	-	-	-	-	-	Sch. I	SC
Little Stint												
Loridae												
Larus ichthyacctus	+	+	-	-	-	-	-	-	-	-	Sch. I	R
Great Blackheaded Gull												

	Intertidal	Sea Coast	Tidal mudflat	Marsh and aquaculture	Coastal foant	Village plantation	Inland water	Nalaikonda R. F.	Narava R. F.	Vizag Township	Status in IBWL	Remarks
L. brusicephalus Brownheaded Gull	+	+	-	-	-	-	-	-	-	-	Sch. I	C
L. ridibundus Lesser Blackheaded Gull	-	-	-	+	-	-	-	-	-	-	Sch. I	SC
Chliodonias hybrida Whiskered Tern	-	-	+	+	-	-	+	-	-	-	Sch. I	C
Gelochelidon nilotica Gullbilled Tern	-	-	-	-	-	-	-	-	-	-	Sch. IV	
Sterna aurantia Indian River Tern	-	-	+	+	-	-	-	-	-	-	Sch. I	C

VC - Very Common

C - Common

SC - Scarce

R - Rare

* Only one true marine avian forms, the Masked Booby, *Sula dactyla* was recorded from Palavalasa at open sea.

Table F.19. Marine fauna around HNPCL plant site

Scientific Name	Occurrence
A. Phylum Bryozoa	
Electra pilosa	On the algae *Gracilaria*
E bellula	On *Gracilaria*, *Spongomorpha*, etc
E angulata	On algae
E benghalensis	On algae
Membranipora tuberculata	On rocks, algae and molluscan shells
M Savartii	Attached to drift wood
B. Phylum Mollusca	
Family Patellidae	
Cellana radiata radiata (Born)	Common limpet on rocky outcrops
Family Trochidae	
Euchelus asper (Gmelin)	Common on shirgles
Family Turbidinae	
Turbo brunneus Roding	Common on shirgles
Family Neritidae	
Nerita albicilla Linnaeus	Common on rocks
Nerita chamaeleon Linnaeus	Common on rocks
Nerita costata Linnaeus	Uncommon
Family Littorinidae	
Littorina undulata Gray	Common on rocks at high tide line
Noolilittorina pyramidalis pyramidalis (Quay and Gaimard)	
Noolilittorina millegrana (Philippi)	
Family Muricidae	
Mancinella bufo (Lamarck)	Common
Thais hyppocastanum Linnaeus	
Thais tissoti (Petit)	
Purpura panama (Roeding)	
Morula granulata (Duclos)	Common
Family Nassariidae	
Bullia vittata	Common mollusc of sandy beaches
Family Olividae	
Oliva oliva (Linnaeus)	
Anachis terpsichore	Common
Family Conidae	
Conus biliozus (Roeding)	
Family Terebridae	
Terebra aciculina Lamarck	Common
Class Bivalvia	
Family Donacidae	
Donax pulchella	
C. Offshore Molluscs	
Order Mesogastropoda	
Family Turritellidae	
Turritella columnaris Kiener	
Family Strombidae	
Strombus listeri Gray	Rare mollusc of Visakhaptnam coast
Family Ficidae	
Ficus ariegata (Roeding)	
Family Muricidae	
Murex tribulus (Linnaeus)	
Family Buccinidae	
Babylonia spirata (Linnaeus)	
Class Bivalvia	

Scientific Name	Occurrence
Mactra mera Delhayes	
Class Cephalopoda	
Sub-class Coleoidea	
Order Sepioidea	
Family Sepiidae	
Sepia pharaonis Ehrenberg	
Sepia aculeata Ferussac & d'Orbigny	
Sepiella inermis Ferussac & d'Orbigny	
Order Teuthoidea	
Sub-order Myopsida	
Family Loliginidae	
Loligo duvauceli d'Oribigny	
D. Offshore Echinoderms	
Phylum Echinodermata	
Class Echinoidea	
Order Clypeastroidea	
Family Clypeastridea	
Clypeaster rarispinus de Meijere	
Tropiometra encrinus Clark	
Class Echinoidea	
Stomopneustes variolaris (Lamarck)	
Class Holothuroidea	
Holothhuria atru Jaeger	

Table F.20. Estimated numbers of species of littoral macrobenthos

Name of the group	No.of species	No.of examples
Cnidaria	4	15
Annelida		
Polychaeta	9	350
Crustacea	12	100
Mollusca		
Gastropoda	30	100
Bivalvia	15	100
Scaphopoda	1	1
Echinodermata		
Asteroidea	1	2
Echinoidea	2	2
Opniuroidea	1	3
Holothuroidea	1	300
Sipuncula	1	1
Branchiopoda	1	1
Fishes	2	4
Total	80	679

Table F.21. Littoral macrobenthos off Visakhapatnam

Phylum	Class/ Order	Family	Species
Annelida	Polychaeta	Aphroditidae	*Aphrodita sp.*
		Pilarrgidae	*Ancistrasyllis parua*
		Nereidae	*Nereis sp.*
		Glyceridae	*Glycera sp.*
		Eunicidae	*Diopatra neapolitana*
			Eunice indica
		Spionidae	*Polydora ciliata*
			Prionospid pinnata
		Terebellidae	*Terebellides stroemi*
Arthropoda	Crustacea		
	Stomatopoda	Squillidae	*Oratosquilla perpensa*
		Harplosquillidae	*Harpiosquilla anandalei*
	Decapoda	Penaeidae	*Penaeus indicus*
		Leucosiae	*Leucosia longifrons*
		Parthenopicae	*Lambrus presor*
		Albunidae	*Albunea sycinista*
Mollusca	Gastropoda	Trochidae	*Calliostoma tranquebarica*
			Minolia casta
			Euchelus circulatus
		Architectonicidae	*Architectonica perdix*
		Strombidae	*Strombus labiosus*
		Turritellidae	*Turritella columnaris*
		Ficidae	*Ficus variegata*
		Cassididae	*Phalium areola*
		Bursidae	*Bursa crumena*
		Naticidae	*Natica vitellus*
			Natica Lineata
			Sinum deleserti
		Cymatidae	*Distorsio reticulata*
		Muricidae	*Murex tribulus*
		Succinidae	*Babylonia spirata*
			Cantharus tranquebaricus
		Nassariidae	*Nassarius variegata*
			Nassarius kieneri
			Nassarius globosus
			Nassarius pullus
		Olividae	*Oliva oliva*
			Oliva vidua
			Agaronia nebulosa
		Cancellariidae	*Scalptia scalariformes*
		Turridae	*Branchytoma crenularis*
		Conidae	*Conus eburneus*

Phylum	Class/ Order	Family	Species
			Conus aculeiformes
			Conus figulinus
			Conus inscriptus
		Philinidae	*Pniline aperta*
	Bivalva	Nuculidae	*Nucula convexa*
		Arcidae	*Scapharea pilula*
			Trisidos fortuosa
		Family Tellinidae	*Macoma bruguieri*
		Cordiicae	*Trachycardium asiaticum*
		Mactridae	*Mactra mera*
		Veneridae	*Bassina calophylla*
			Paphia undulata
			Sunetta effosa
			Timoclea arakana
Brachipoda			*Lingula sp.*
Echinodermata	Asteroidea	Astropectinidae	*Astropecten velitaris*
	Opniuroidea	Amphiuridae	*Amphioplus cepressus*
	Ecninoidea	Clypeasteridae	*Clypeaster rarispinus*
		Astroclypeidae	*Ecninociscus auritus*
	Holotnuroidea	Phyllopnoridae	*Actinocumis typicus*

Table F.22. Macrobenthic fauna off Visakhapatnam (Dredge and Grab Collections)

Name of the species	Depth								
	10 m		20 m		30 m		50 m		Total
	G	P	G	P	G	P	G	P	
Phylum Cnidaria									
Heterocyathus acquicostatus			10	20	32	-	1	63	
Phylum Annelida									
Ancistrosyllis parava		2	5					7	
Nereis sp.			10	15	5	2			32
Nephthys dibranchis		10	5	25	10	10	8	68	
Diopatra neapolitana		20	15	30	10	40	30	145	
Sternaspis scutata									
Other polychaetes			10	12	10	15	5	2	54
Phylum Arthropoda									
Metapenacopsis			2	5	6	8	5	10	36
Other prawns			8	10	15	5	6	8	52
Diogenos custos			2	5	1	2			10
Dardanus hessii			1	2	1	1			5
Calappa lophos			2	1	1	1			5
Mafuta miessi			1	1					2
Charybdis bimaculata						3		3	
Chasmocarcinops gelasimoides						2		2	
Gomezo distincta						1			1
Albunea symnista							1		1
Oratosquilla penpensa			1						1
Harpiosquilla annandalei									
Phylum Mollusca									
Calliostoma tranquebarica			1						1
Minolia casta					1			1	
Turritella columnaris			2	5	10				17
Natica tigrina			2		10	5			17
Polinices melanostomus			1						1
Polinices tumidus					2				2
Sinum haliotoideum						1		1	
Ficus subintermedia				4	5				9
Distorsio reticulata	5		2					7	
Bursa crumena			6	4	2	1			13
Bursa clegans						1			1
Babylonia spirata			1						1
Nassaria nivea			30	15	10	5			60
Nassarius suturalis				2	3			5	10
Nassarius variegatus	10		5					15	
Amalda ampla						10	1		11
Agaronia nebulosa	2		2	6	3				13
Scalptia scalariformes				5	4				9

G=Gangavaram P=Pudimadaka

Name of the species	Depth								
	10 m		20 m		30 m		50 m		Total
	G	P	G	P	G	P	G	P	
Marginella angusta		2	10						12
Marginella ventricosa			2	1					3
Lophiotoma indica						1			1
Daphnella lymneiformes						1			1
Gemmula speciosa			5	15		5			25
Brachytoma crenularis					4	5			9
Conus eburneus			1	2					3
Conus aculeiformes		2						2	
Vexillum sp.						1			1
Neocanicilla sp.			10	15					25
Hastula strigilata			15	3				18	
Terebra nebulosa			2			1			3
Architectonica perdix					1			1	2
Nucula convexa				2	2				4
Scapharca pilula			2		1	2			5
Trachycardium asiaticus					1	2			3
Tellina iridescens					10	15			25
Azorinus emarginatus				2	5				7
Bassina calophylla				15	10	2			27
Callista erycina					2	1			3
Paphi undulata			3	2					5
Timoclea arakana				1	2				3
Corbula rotalis			15	20	10	30	5	10	90
hylum Echinodermata									
Astropecten velitaria		1		2					3
Amphioplus depressus				5	3				8
Ophiura Kinbergi		1	5		2	1			9
Clypeaster rarispinus				5	6	4	10		25
Crinoid	1								1
Fishes					2	5			7

G = Gangavaram
P = Pudimadaka

depth range of 0-200 m. The zone between 20 m and 30 m depth appeared to be the most productive zone. The mean faunal density was found to be maximum at 40-50 m depth. The benthic fauna at 10 m depth was almost negligible.

The faunal diversity in the area around the HNPCL plant site includes *Cnidaria* (*Arthrozoa*), *Annelida* (polychaetes), and *Crustacea* in abundance, *Mollusca* (large populations of bivalves and gastropods) and *Echinodermata* (starfish, brittle stars, echinoids, and a few hollothurians). The rare species and living fossil "Lingula" was collected only once in the dredge sample. The benthic fauna comprises predominantly *Polychaets* (about 68%) followed by *Crustacea* (22%), and *Mollusca* (3%).

A summary of the offshore fauna near Gangavaram and Pudimadaka is presented in Table F.23. The overall density varied from a single individual to as many as 150 per litre at these locations.

c. Intertidal Fauna

Visakhapatnam coast is mostly rocky with sandy beaches in certain stretches. The intertidal region is narrow and does not exceed 100 m. The rocky outcrops at Appikonda/Kuttukonda and Pudimadaka offer ideal habitats for invertebrates such as molluscs, crustaceans, sea anemonas, echinoderms, sponges, etc. The sandy beaches support only sand-burrowing forms such as crustaceans (crabs) and molluscs (gastropods and bivalves).

Although no sea turtle nesting was located in the area during the survey, local residents reported steady catch of Olive Ridley turtle during the turtle breeding season. A fresh carcass of a turtle was seen near the coast at Palavalasa.

A specimen of the whale shark *Rhineodon typhus* was stranded on the coast near the HNPCL site during the TCS survey in winter. According to the local fishermen, whale sharks are common in the area during winter, which also indicates abundance of plankton in the coastal zones of this region.

Among marine mammals, only the plumbeus dolphin, *Sousa plumbea*, was seen in the area. Another common species along the east coast, the finless black porpoise, *Neameris phocaenoides*, was also reported in the area.

F.2.9 Fisheries and Prawns

Andhra Pradesh has a coastline of 974 km and continental shelf area of 33,247 sq km, and ranks fifth in marine fish landings among all coastal states in India. Visakhapatnam district is an important marine fishing centre in the state, with 59 coastal villages and a population of 75,000 fishermen. Most of the fishing is carried out north of Visakhapatnam. The fish catches off the shore near the HNPCL site have been reported to be poor by the local fishermen.

Five fishing villages, including Pudimadaka and Mutyalammapalem, are located within a 20 km radius of the HNPCL plant site. Pudimadaka has 260 fishing vessels; Mutyalammapalem has 247 vessels. In addition to these, more than 200 small commercial trawlers are engaged in fishing. Fishing nets are operated at depths ranging between 10 m and 80 m.

There are two main seasons of fishing: July-November and February-April. Depending on the season, the species composition of the marine catch also varies. The catches during July-November consist of sciaenids; during February-April, carangids, perches, lizard fish, and *Psenes indicus* are the important constituents of the catch.

The major commercial marine fisheries are composed of:

- Sharks
- Seerfish
- Pomfrets
- Thread fish
- Ribbon fish
- Prawns

These contribute nearly 50% of the total marine catches from the area. Table F.24. provides common names and estimated catches off Visakhapatnam district in 1994-95. The data indicate that ribbon fish is the largest contributor to the total catch, followed by elasmobranch, thread fish, sardines, seer fish, and pomfrets. Other group of fish, such as lizard fish, flying fish, cat fish, and anchovies contribute less than 300 metric tonnes per year to the total catch. Prawns total about 392.64 tonnes per annum.

A detailed checklist of fish off Visakhapatnam coast is given in Table F.25.

Table F.23. Offshore fauna near Gangavaram and Pudimadaka

Taxa	Number of species	Number of examples
Phylum Cnidaria		
Order Sclerectinia	1	63
Phylum Annelida		
Class Polychaeta	10	307
Phylum Arthropoda		
Class Crustacea		
Order Stomatopoda	2	4
Order Decapoda	10 + 1*	107 + 5*
Phylum Mollusca		
Class Gastropoda	31 + 15*	288 + 50*
Class Bivalva	15	174
Class Scaphopoda	1	5
Phylum Echinodermata		
Class Asteroidea	1	3
Class Ophiuroidea	2	17
Class Echinoidea	1 + 1*	25 + 5 *
Classs Crinoidea		
Phylum Chordata	5	10
Total	80 + 17*	1002 + 55*

* Intertidal collection

Table F.24. Marine fish landing of Visakhapatnam district during 1994-95

Name of the species	Estimated Weight (tonne)
Sharks	634.72
Skates	290.73
Rays	321.00
Eels	80.00
Cat Fish	206.00
Wolf Barr	190.00
Sardins	960.00
Anchovics	200.00
Lizard Fish	290.00
Perches	178.00
Goat Fish	101.62
Ribbon Fish	1263.00
Silver Bellies	120.00
Carangids	123.74
Seer Fish	612.12
Pomfrets	418.86
Makeral	124.32
Tunnies	100.00
Prawn	392.64
Thread Fish	978.76
Miscellaneous	874.37

Table F.25. Fish off Visakhapatnam coast

Class/Order	Family	Scientific Name	Common Name
Chondrichthyes			
Orectolobiformes	Rhiniodontidae	*Rhinidon typus*	Whale Shark
	Hemiscyllidae	*Chiloscyllium indicum*	Ridge-back Cat Shark
	Stegostomatidae	*Stegostoma fasciatum*	Zebra Shark
Carcharhiniformes	Carcharhinidae	*Carcharhinus dussumieri*	White-checked Shark
		Carcharhinus limbattus	Grey Shark
		Carchahinus melanopterus	Black Shark
		Galaecerdo cuvieri	Tiger Shark
		Scoliodon laticaudus	Yellow Dog-Shark
	Sphyrnidae	*Sphyrna mokarran*	Squat-headed harmmer-head Shar
		Eusphyrna blochii	Arrow-head hammer-head Shark
Pristiformes	Pristidae	*Anoxypristis cuspidatus*	Pointed Saw Fish
		Pristis microdon	Small-toothed Saw Fish
Rajiformes	Rhinobatidae	*Rhinobatos granulatus*	Granulated Shovel-nose Ray
Myliobatiformes	Dasyatidae	*Dasyatis Zugei*	Pale-edged Sting Ray
		Gymnura poecilura	Long-tailed Butterfly Ray
		Himantura uarnak	Banded Whip-tail Sting Ray
	Myliobatidae	*Aetobatus narinar*	Spot-edged Ray
		Mobula diabolus	Lesser Devil-Ray
Torpediniformes	Narcinidae	*Narcine brunnea*	Brown Electric Ray
		N. timlei	Spotted Electric Ray
Osteichthyes			
Clupeiformes	Clupeidae	*Sardinella fimbriata*	Fringe-scale Sardine
		Dussumieria acuta	Rainbow Sardine
		Anodontostoma chacunda	Chacunda Gizzard-Shad
		Nematolosa nasus	Block's Gizzard-Shad
		Hilsa ilisha	Indian Shad
		H. toli	Chinese Herring
	Pristigasteridae	*Ilisha elongata*	Elongate Ilisha
		Opisthopterus tardoors	Tardoors
		Pellona ditchela	Indian Pellona
		Raconda russeliana	Russel's Smooth-back Herring
	Chirocentridae	*Chirocenrus dorab*	Dorab Wolf-Herring
		C. nudus	Whitefin Wolf-Herring
	Engraulidae	*Coilia dussumieri*	Gold-Spotted Grandaier Anchovy
		Sitipinna taty	Hair-fin Anchovy
		Stolephorus commersoni	Commerson's Anchovy
		S. devisi	Devisi Anchovy
		S. indicus	Indian Anchovy
		Thryssa mystax	Moustached Anchovy
Aulopiformes	Synodontidae	*Saurida fumbil*	Greater Lizard-fish
		S. undosquamis	Brushtooth Lizard-fish
		Trachinocephalus myops	Blunt-nose Lizard-fish
	Harpodontidae	*Harpodon nehereus*	Bombay Duck
Siluriformes	Ariidae	*Arius tenuispinis*	Slender-spined Cat Fish
		A. thalassinus	Giant Cat Fish
		Osteogeniosus milifaris	Soldier Cat Fish
		Plotosus canius	Canine Cat Fish

Class/Order	Family	Scientific Name	Common Name
Anguilliformes	Anguillidae	*Anguilla bicolor bicolor*	Level-finned Eel
	Muraenesocidae	*Congresox talabanoides*	Indian Pike-Conger
		Muraenesox cinereus	Dagger-tooth Pike-Conger
	Ophichthidae (Snake Eels)	*Neenchelys buitendijki*	Spotted Worm-Eel
Cyprinodontiforme	Exocoetidae	*Exocoetus volitans*	Two-winged Flying Fish
Perciformes	Centropomidae	*Lates calcarifer*	Giant Sea Perch
	Sillaginidae	*Sillago maculatus*	Trumpeter Whiting
		Sillago sihama	Silver Whiting
	Carangidae	*Alectis indicus*	Indiana Thread-fin Trevelly
		Alepes djedaba	Dijeddaba Trevally
		Carangoides armatus	Armed Trevally/ Long-fin Cavall
		Caranx malabaricus	
		Decapterus dayi	
		Decapterus macrosoma	Layang Scad
		D. russellii	Round Scad
		Megalaspis cordyla	Hardtail Scad
		Scomberoides commersonianus	Teland Queen Fish
		Scomberoides tala	Deep Queen Fish
	Apolectidae	*Apolectus niger*	Black Pomfret
	Menidae	*Mene maculata*	Moon Fish
	Leiognathidae (Silver bellies)	*Gazza minuta*	Toothed Pony Fish
		Leiognathus bindus	Orange Fin Pony Fish
		L.daura	Gold-striped Pony Fish
		L.splendens	Common Pony Finish
		Secutor insidiator	Pugnose Pony Fish
		S. ruconius	Deep Pungnose Pony Fish
	Lutjanidae	*Lutjanus johni*	John's Snapper
	Nemipteridae	*Nemipterus japonicus*	Japanese Threadfin Bream
		N. mesoprion	Red filament Threadfin Bream
	Gerreidae	*Gerres filamentosus*	Whipfin Mojarra
	Pomadasyidae	*Pomadasys hasta*	Lined Silver-grunt
		Pomadasys maculatus	Biotched Grunt
	Sciaenidae	*Johnius carutta*	Karut Croaker
		J. dussumieri	Dussumieris' Croacker
		J. vogleri	Sharp-toothed Hammer Croaker
		Nibea maculata	Blotched Croker
		N. soldado	Soldier Croaker
		Protonibea diacanthus	Spotted Croaker
	Mullidae	*Parupeneus indicus*	Indian Goat Fish
		Upeneus sulphureus	Yellow Goat Fish
		Upeneus vittatus	Yellow-striped Goat Fish
	Ephippidae	*Drepane punctata*	Spotted Sickle Fish
		Platax pinnatus	Round Batfish
	Scatophagidae	*Scatophagus argus*	Spotted Butterfish
	Mugilidae	*Liza parsia*	Goldspot Mullet
		Mugil cephalus	Flathead Grey Mullet
	Sphyraenidae	*Sphyraena flavicauda*	Shortjawed Barracuda
		S. jello	Banded Barracuda
	Polynemidae (Thread fin)	*Eleutheronema tetradactylum*	Fourfinger Thread-fin
		Polydactylus heptadactrylus	Sevenfinger Threadfin
		Plynemus indicus	Indian Threadfin

Class/Order	Family	Scientific Name	Common Name
		P. paradiseus	Paradise Threadfin
		P. sexfilis	Golden six-thread Threadfin
		P. sextarius	Black-spot Threadfin
	Trichiuridae (Ribbon fishes)	*Eupleurogrammus glossodon*	
		Lepturacanthus gangeticus	Gangetic Ribbonfish
		L. savala	Small-headed Ribbonfish
		Trichiurus lepturus	Large-head Ribbonfish
		T. ruselli	
	Scombridae (Mackerels and Tunas)	*Rastrelliger kangurta*	Indian Mackerel
		Sarda orientalis	Oriental bonito
		Scomberomorus commerson	Narrow-barred Spanish Mackerel
		S. guttatus	Indo-Pacific Spanish Mackerel
		S. linedatus	Straked Spanish Mackerel
	Xipiidae (Sword Fishes)	Xiphias gladius	Sword Fish
	Stromateidae (pomfrets)	*Pampus argenteus*	Silver Pomfret
		P. chinensis	Chinese Pomfret
	Ariommidae	*Ariomma indica*	Indian Drift Fish
Pleuronectiformes (Flat fishes)	Psettodidae	*Psettodes crumei*	Indian Halibut
		Pseudorhombus arsius	Large-toothed Flounder
	Soleidae	*Aesopia cornuta*	Horned Sole
	Cynoglossidae	*Paraplagusia bilineata*	Doublelined Tongue Sole
Tetraodontiformes	Tetraodontidae	*Tetraodon hispidus*	White-spotted Blowfish
		T. immaculatus	Immaculate Blowfish
		Metapenaeus monceros	Prawns
		M. dobsoni	Prawns
		Penaeus indicus	Prawns
		P. mondon	Prawns
		Parapenaeus longipes	Prawns
		Trachypenaeus curvirostris	Prawns

Recent data on yearly catches of prawns and allies are tabulated below.

Year	Quantity (kg)	
	Fish	Prawn
1989-90	4084905	77570
1990-91	3545935	1008512
1991-92	6916884	1576928
1992-93	6138283	925015

It can be seen from the above table that catches have increased by an order of magnitude from 1989-90 to 1992-93.

b. Prawn Farming in Tidal Flat and Salt Marsh Area

The potential of coastal aquaculture and the advantages of converting the vast derelict swamps and intertidal belts in the coastal zone into productive fish farms has been recognised only recently. Culture activities have expanded to such an extent that large number of private farmers, mostly salt producers, are diversifying into shrimp farming as a profitable profession along the coastline.

The low saline reservoirs in the adjacent salt farm form the potential ground for the collection of prawn seed. The number of farmers and area under prawn culture are given in the following table:

Number of farmers	Extent (ha)	Water spread (ha)
Private Sector (79)	492.46	426.47
Public Sector (314)	178.80	138.16

(Source : Andhra Pradesh Fisheries Department)

A few prawn farms exist near the salt farms towards the north-western side of the HNPCL plant site.

APPENDIX G

CORRESPONDENCE WITH ANDHRA PRADESH POLLUTION CONTROL BOARD (APPCB)

HINDUJA NATIONAL POWER CORPORATION LIMITED
(Plot 974, Road No. 50, Jubilee Hills, Hyderabad 500 003)
(Phone 216191,217174, Fax 040 217172)

HNPCL/Clear
Dated March 14 , 1997

To,

Member Secretary
Andhra Pradesh Pollution Control Board
Maitrivanam Complex
SR Reddy Nagar
Hyderabad

Dear Sir,

Ref : Visakhapatam 1040 MW Thermal Power Plant
Number 19/PCB/C Estt/RO/VSP/AEE-N/96-6259 dated 25.2.97

Sub : Clarifications on comments raised during Technical Committee meeting held on 18.2.97

This is in continuation of our letter of even number dated 6.3.97 and also refers to your above letter. A note on the points raised during the meeting is enclosed. The air quality modelling has been done using various scenarios and also by the procedure indicated by APPCB. Even with most conservative assumptions the air quality around the area, even after construction of our as well as NTPC's project, will still be within the limits specified in the Air Quality Standards. This is brought out in the table on page '3' of the enclosed note.

Trust the information provided will enable APPCB to clear the EIA.

We will be happy to provide any other information as desired by APPCB.

We also regret 2/3 days' delay in responding as some documents were misplaced by the courier company.

Thanking you,

Yours faithfully,

for Deepak Arora
Project Director

(Registered Office: III Floor, 94 Minerva House, Sarojini Devi Road, Secunderabad 500 003)

NOTE ON AIR QUALITY AROUND THE PROPOSED 1040 MW THERMAL POWER PLANT (NEAR VISAKHAPATNAM)

1.0 Air Quality

A brief on the Incremental loadings due to HNPCL and NTPC-Simhadri (as submitted to MOEF in August 1996) was handed over during the meeting.

1.1 Further details (HNPCL + NTPC) have been worked out for SO_2. For the other parameters namely SPM, CO and NO_x the incremental loading on GLC due to HNPCL plant + NTPC plant is very very insignificant. The existing air quality is also very good and the resultant anticipated air quality w.r.t these parameters is expected to be much better than the air quality standards. A brief picture is given in Annexure-I.

2. Modelling

The methodology used for modelling by our Consultants M/S TCS is an internationally accepted practice. The formula used is for multiple flue stacks.

One of the reasons for constructing multiflue chimneys is the fact that dispersion and resultant increase in GLC is more optimum than from two adjacent chimneys (one for each unit). Regarding plume heights the following table clarifies the issue.

Case	Plume height	Pollution/ Emission Load	Remarks Computation of incremental GLC
As in EIA	Single chimney	Sum of two flues	Computed using $X_{total}=X_1 \times N^{0.8}$
Suggested by APPCB	Same as above	Same as above	Computed using $X_{total}=X_1 \times 2$

Following documents are enclosed:

a) Relevant Extracts (Annexure II (i)) from 'Air Pollution' Volume I, Published by Academic Press, New York (and London) and edited by AC Stern.

The formula used by M/S TCS namely $X_{total}= X_1 \times N^{0.8}$ is explicitly mentioned.

As desired by APPCB the GLC's have now been calculated for $X_{total}= X_1 \times 2$

b) Extracts from 'HER MAJESTY's INSPECTOR OF POLLUTION - Technical Guidance Note (Dispersion) - D1 - Guidelines on Discharge Stack Heights for Polluting Emissions.

It clearly mentions the procedure to take into account the discharges from the Multiple Stacks and also mentions that discharge momentum should use "Sum Values".

Modelling using 'effective diameter' concept (British) was also done. The incremental GLC's were found to be much lesser (in magnitude and area affected) as compared to the case using the formula as in 'a' and hence not used.

In view of the above, we feel that the formula used by TCS represents a pessimistic, hence a conservative scenario. **Nevertheless as desired by APPCB, the incremental GLC's have also been calculated treating the two flues as independent emission sources and presented as Annexure VI.**

2.1 Our Consultants had done the modelling (as in EIA) assuming the worst conditions (Worst coal/worst ash (lowest calorific value/no sulphur passing thru to ash, worst meteorology data as observed at site for 52 weeks etc) and mentioned that the GLC's are expected to be less than these values. However as desired during the interaction in the meeting, modelling has been done assuming various scenarios.

The SO_2 emission from the stack would be dependent on following factors:

Parameter	Assumed for modelling in EIA	Actual Range	Likely impact on SO_2 as compared to the emissions presented in EIA
Sulphur Content	0.8 %	0.6 to 0.8 %. As per the supply agreement initialled with Mahanadi Coal Fields. Coal with Sulphur content > 0.8 % will be rejected by HNPCL (Please refer page 2-2 of EIA - Copy of relevant section of initialled Coal Supply Agreement is enclosed as Annexure III).	- 25 % (at 0.6% Sulphur content) Modelling has been done for both 0.8 % and 0.6% Sulphur options.
Sulphur Content in ash	Nil	Ash is likely to retain substantial sulphur. At Vijayawada which uses coal from Talcher (from where coal for HNPCL will be supplied as per linkage of GOI) emissions of SO_2 thru the stack is about 40 % of theoretical value. Refer Annexure IV.	The modelling has been done for various combinations i.e assuming that 100/90/80% Sulphur passes thru the stack.
Coal Consumption	Based on worst coal	Range between best and worst coal. Consumption per hour (2 units) Worst 670 T/Hr (Cal Value 3819 Kcal/kg) Best 570 T/hr(Cal value 4505 Kcal/kg) Typical 588 T/hr (Calorific Value 4158 Kcal/KG)	-15 % at worst coal/-14 % at typical coal and -7.5 % at mid range. The agreement provides for bonus/penalty on quality of coal and hence the supplier will endeavor to supply good quality coal. However no adjustment made for this while modelling or computing GLC's.

The modelling was carried out using various combinations of Sulphur Content in Coal and the percentage of sulphur being converted to SO_2/(or retained in ash). The modelling also included the impact of NTPC plant in addition to HNPCL plant. The results were also used to anticipate the maximum GLC's that were likely to occur at the 6 Air Quality Stations used during EIA study. As mentioned in EIA, Air Quality was monitored all thru the 52 weeks (48 hours each week), we anticipate that the picture that emerges would be quite accurate. **The results from the modelling are enclosed as Annexure V (For the formula used by TCS) and Annexure VI (Formula suggested by APPCB). Max./Min/Average/95 and 98 percentile of existing GLC's are mentioned in Annexures. From the tables it can be observed that different conditions result in a range of GLC's. This is represented in the following table:**

Air Quality Station Direction/Distance w.r.t Stack	Season[1] - when maximum GLC (existing + Incremental) likely to occur	Background GLC (24 Hrs) 98 percentile	Formula Used	Power Station H-HNPCL H+N =HNPCL + NTPC	Incremental GLC impact range		Total anticipated GLC (Existing + Incremental)	
					*Maximum	**Minimun	*Maximum	**Minimum
Palavalsa 3 km NE	Pre-Monsoon	25	$X_{total}=X_1 \times N^{0.8}$	H	47(30)	31	72	56
				H+N	52	32	**77**	**57**
			$X_{total}=X_1 \times 2$	H	54	36	79	61
				H+N	63	40	**88**	**65**
Peddapalem 6 km N	Winter	27	$X_{total}=X_1 \times N^{0.8}$	H	41(25)	22	68	49
				H+N	44	26	**71**	**53**
			$X_{total}=X_1 \times 2$	H	47	28	74	55
				H+N	52	31	**79**	**58**
Chipurapalle 6 km WSW	Post Monsoon	19	$X_{total}=X_1 \times N^{0.8}$	H	24(15)	15	43	34
				H+N	50	30	**69**	**49**
			$X_{total}=X_1 \times 2$	H	28	15	47	34
				H+N	55	34	**74**	**53**
Thikkavanapalem 3 km SW	Post Monsoon	17	$X_{total}=X_1 \times N^{0.8}$	H	45(32)	32	62	49
				H+N	48	34	**65**	**51**
			$X_{total}=X_1 \times 2$	H	60	36	77	53
				H+N	63	37	**80**	**54**
Deshapatrunipalem 9.5 km N	Pre-Monsoon	22	$X_{total}=X_1 \times N^{0.8}$	H	15(10)	09	37	31
				H+N	48	28	**70**	**50**
			$X_{total}=X_1 \times 2$	H	16	10	38	32
				H+N	56	35	**78**	**57**
Peddagantayada 14 km NE (Nearest to Vizag, takes care of emission from VSP, HNPCL + NTPC)	Pre-Monsoon	25	$X_{total}=X_1 \times N^{0.8}$	H	23(8)	16	48	41
				H+N	28	17	**53**	**42**
			$X_{total}=X_1 \times 2$	H	26	16	51	41
				H+N	30	22	**55**	**47**

* Maximum - With 0.8 % Sulphur and no Sulphur retention in ash
** Minimum _ With 0.6% Sulphur and 20 % retention in ash
All figures in $\mu g/m^3$
Figures in () the values as obtained using effective Diameter concept (UK practice), since they were very less not computed for other options

Note- Effect of rain not considered

It can be observed that the GLC's even with the most conservative assumptions are expected to be within the limits specified in the ambient air quality standards.

The iso-pleths for the above scenarios are also enclosed in Annexure V & VI respectively.

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1 Winter (December-February), Pre Monsoon (March-May), Monsoon (June-August), Post Monsoon (September-November)

3. The information as at Sr No 2 is given air quality station wise.

4. Infrastructure

As already explained during our presentation, HNPCL has made best efforts to minimise any loading on the existing local infrastructure to the extent practical. A separate road is being built from NH_5 to site for catering to traffic for the power station. Although HNPCL will construct this road, it will be open for use by other traffic as well. In addition some roads may have to be strengthened for catering to some heavy traffic during construction and till the time the permanent road is ready. The strengthened portion will also be available for use by other traffic. A desalination plant is being provided to meet needs of sweet water required for operating the plant (including drinking water). The project is being implemented based on a Capital Cost and scope approved by Govt. Of Andhra Pradesh and a Power Purchase Agreement with Govt. of Andhra Pradesh/APSEB. The cost and scope approved includes the above infrastructure development.

Annexure I

The existing air quality and the incremental GLC of SPM, CO and NO_2 is as under (as in our EIA):

Parameters	Existing background GLC 98 percentile (in $\mu g/m^3$)	Worst Case incremental (Due HNPCL plant)	Total GLC	Standard
NO_x	39*	10	49	120
SPM	127*	2 (with 115 mg/nm^3, it will be still less with 90 mg/nm^3 the plant design)	129	500
CO (in mg/m^3 8 hourly value)	2.8*	.004	2.804	5.0

* Maximum 98 percentile value (in any season) out of 6 air quality stations. The figure is based on 52 weeks field study and hence represents the worst case for all practical purposes.

Even assuming another 100% addition to Incremental GLC due to NTPC plant the final GLCs are much below the limits specified in the Air Quality Standard. Hence more analysis was not done.

Existing Air quality (SPM) around the proposed HNPCL power plant
(All units are in ug/m^3)

Station	Distance*	Direction*	Season	Max	Min	Max	Min	Ave	95 **	98 **
				8 hourly		24 hourly				
Palavalasa	3 km	NE	Winter	213	13	132	37	77	120	127
			Pre-monsoon	105	34	97	57	76	89	94
			Monsoon	94	24	77	34	51	70	73
			Post-monsoon	98	25	81	39	61	79	81
			Annual	213	13	132	34	66	98	112
Peddapalem	6 km	N	Winter	111	29	102	33	64	99	101
			Pre-monsoon	118	39	94	48	71	89	92
			Monsoon	101	25	83	39	55	77	80
			Post-monsoon	112	33	84	40	62	79	82
			Annual	118	25	102	33	63	89	98
Chipurupalli	6 km	WNW	Winter	227	22	124	30	70	107	117
			Pre-monsoon	106	50	90	64	78	90	90
			Monsoon	108	34	93	43	62	89	92
			Post-monsoon	93	43	76	51	65	72	74
			Annual	227	22	124	30	69	91	102
Thikkavanipalem	3 km	SW	Winter	216	19	121	46	67	94	110
			Pre-monsoon	137	28	99	47	76	95	97
			Monsoon	66	27	55	38	45	51	53
			Post-monsoon	65	32	59	41	50	57	58
			Annual	216	19	121	38	60	89	96
Deshapatrunipalem	9.5 km	N	Winter	253	17	128	35	67	103	118
			Pre-monsoon	98	46	87	51	73	86	87
			Monsoon	73	21	52	31	42	49	51
			Post-monsoon	80	21	65	34	49	63	65
			Annual	253	17	128	31	58	81	87
Peddagantyada	14 km	NE	Winter	166	18	120	36	84	117	119
			Pre-monsoon	106	39	93	46	68	84	89
			Monsoon	82	25	68	32	50	66	68
			Post-monsoon	81	26	69	33	54	68	69
			Annual	166	18	120	32	64	97	110

* With respect to stack
** Percentile

Existing Air quality (NOx) around the proposed HNPCL power plant
(All units are in ug/m^3)

Station	Distance*	Direction*	Season	Max	Min	Max	Min	Ave	95 **	98 **
				8 hourly		24 hourly				
Palavalasa	3 km	NE	Winter	57	11	39	15	26	38	39
			Pre-monsoon	23	10	19	14	17	19	19
			Monsoon	29	9	23	13	17	22	22
			Post-monsoon	31	9	23	12	18	22	22
			Annual	57	9	39	12	19	30	36
Peddapalem	6 km	N	Winter	47	10	36	12	23	35	36
			Pre-monsoon	32	9	25	16	20	22	24
			Monsoon	22	7	18	12	14	16	17
			Post-monsoon	28	7	25	12	19	25	25
			Annual	47	7	36	12	19	24	32
Chipurupalli	6 km	WNW	Winter	30	11	18	13	15	18	18
			Pre-monsoon	22	8	18	12	15	17	17
			Monsoon	23	5	19	10	13	17	18
			Post-monsoon	24	9	19	12	16	18	18
			Annual	30	5	19	10	15	18	18
Thikkavanipalem	3 km	SW	Winter	22	11	20	13	15	19	20
			Pre-monsoon	23	5	17	13	15	17	17
			Monsoon	17	5	12	9	11	12	12
			Post-monsoon	22	5	15	9	12	15	15
			Annual	23	5	20	9	13	17	17
Deshapatrunipalem	9.5 km	N	Winter	34	9	24	15	17	21	23
			Pre-monsoon	22	7	18	11	15	17	17
			Monsoon	19	7	15	11	13	14	15
			Post-monsoon	25	7	20	12	15	17	19
			Annual	34	7	24	11	15	19	21
Peddagantyada	14 km	NE	Winter	34	9	24	14	18	22	24
			Pre-monsoon	28	10	23	17	21	23	23
			Monsoon	27	7	22	12	16	19	20
			Post-monsoon	37	7	27	11	21	26	26
			Annual	37	7	27	11	19	24	26

* With respect to stack
** Percentile

Carbon Monoxide (8 hourly) concentrations in mg/m^3 around HNPCL plant site

Station	Distance	Direction	Season	Max	Ave	Min	95th percentile	98th percentile
Palavalasa	3 km	NE	Winter	3.4	1.1	0.3	2.5	2.8
			Pre-moonsoon	2.3	0.7	0.0	2.2	2.8
			Monsoon	2.0	0.7	0.0	1.6	2.2
			Post-monsoon	1.4	0.7	0.0	1.3	1.9
Peddapalem	6 km	N	Winter	2.0	0.6	0.0	1.4	1.3
			Pre-monsoon	1.7	0.7	0.0	1.4	1.6
			Monsoon	2.0	0.7	0.0	1.4	1.5
			Post-monsoon	1.7	0.7	0.2	1.3	1.7
Chipurupalli	6 km	WNW	Winter	0.9	0.5	0.0	0.8	1.4
			Pre-monsoon	2.3	0.7	0.0	1.7	0.9
			Monsoon	2.0	0.8	0.0	1.4	2.1
			Post-monsoon	1.7	0.7	0.0	1.3	1.6
Thikkavanipalem	3 km	SW	Winter	1.4	0.5	0.0	1.1	1.4
			Pre-monsoon	2.7	0.8	0.0	1.9	1.3
			Monsoon	2.0	0.8	0.0	1.6	2.0
			Post-monsoon	1.6	0.8	0.0	1.3	1.7
Deshapatrunipalem	9.5 km	NE	Winter	1.7	0.5	0.0	1.4	1.7
			Pre-monsoon	2.5	1.0	0.2	2.0	2.4
			Monsoon	2.2	0.8	0.0	1.7	2.1
			Post-monsoon	1.6	0.9	0.0	1.4	1.4
Peddagantyada	14 km	N	Winter	1.4	0.5	0.0	0.9	1.3
			Pre-monsoon	2.5	1.0	0.0	2.2	1.1
			Monsoon	2.0	0.9	0.0	1.6	2.3
			Post-monsoon	1.9	0.9	0.0	1.4	1.9

Standards (mg/m^3)	
Industrial Area	5.0
Resedential Area	2.0

ANNEXURE II(1)

AIR POLLUTION

THIRD EDITION

VOLUME I

Air Pollutants, Their Transformation and Transport

Edited by

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ACADEMIC PRESS New York San Francisco London 1976
A Subsidiary of Harcourt Brace Jovanovich, Publishers

ANNEXURE II(i)

Part C

THE TRANSPORT OF AIR POLLUTANTS

[illegible] there is some [illegible] in plume diffusion. Vertical diffusion [illegible] should be [illegible] topography. Horizontal diffusion [illegible] overall fall between that of level country and of urban regions. The [illegible] data (see above text) is less definitive. Hinds (*64*) includes other forms of diffusion data.

While the above mountainous data may be the basis for obtaining crude estimates of plume concentrations, they do not locate plume centerline. It cannot be assumed that the plume will continue moving in a fixed direction. The plume centerline will be distorted depending on specific topographical features.

2. Multiple Stacks

While multiple stack arrangements are common for industrial installations, the effect of such stack configurations on plume behavior has had only limited exploration. Available means for evaluating multiple stacks are based on field studies of existing stack installations, generally power plants. Since such plumes are usually of the buoyant type, applicability of multiple stack corrections to jets is an open question.

Two stacks at sufficient separation distance will obviously have no mutual interaction. Concentration at a given downwind location will be a simple addition of the concentrations caused by the individual stacks. If two identical stacks were brought close together with negligible separation distance, and if there were no mutual interaction, plume concentration at a given location would be twice that from one stack. In terms of the various diffusion equations in Section III,C,1,a all terms including h_e would be the same except Q, which would be doubled. Concentration χ at a given location would, therefore, be twice as large. If the two adjacent stacks were viewed as one combined source, having heat emission Q_h twice that of one stack, then by the various plume rise equations of Section III,B, Δh and thereby h_e in the diffusion equations would increase. For maximum ground-level concentration by Equation (70), an increase in h_e will reduce concentration. The net result of doubling Q and increasing h_e will depend on relative magnitudes of the various quantities involved. Experience has shown that proximity of stacks tends to reduce ground-level concentrations compared with those obtained with simple superposition of individual stacks. At some elevated locations, concentrations could increase due to change in plume centerline location.

Montgomery *et al.* (*41*) include a correction factor for multiple stacks of approximately same height based on TVA power plant experience. It is expressed by the following equation applicable to ground-level concentrations:

$$\chi_N = \chi_1 N^{4/5} \tag{87}$$

where W_1 is the number of stacks upwind to the left, W_2 is the number to the right, C_1 is the concentration due to one stack alone without the influence of the other stacks, C_N is the ground-level concentration from the N stacks, and S is the spacing factor. For example, with three stacks, $N = 3$, $W_1 = 1$, $W_2 = 1$, $S = 0.5$, $C_N/C_1 = 1.4$ if multiple stacks were omitted.

Briggs (*56*) has developed an "enhancement factor" E_N for multiple stack buoyant plume rise on the basis of TVA power plant data. This factor includes the effects of stack spacing as well as number of stacks. It is applied to plume rise Δh Equations (22) and (47). Enhancement of plume rise is obtained by the equation:

$$\Delta h_N = E_N \Delta h_1 \tag{88}$$

where Δh_1 is plume rise of a single stack without any effect of nearby stacks; Δh_N is rise of the same stack as one of a group of N enhanced by the presence of other stacks; and E_N is given in terms of a spacing factor S, and number of stacks N, as follows:

$$E_N = [(N + S)/(1 + S)]^{1/3} \tag{89}$$

For a line of N stacks with center spacing d_c of adjacent stacks:

$$S = 6[(N - 1)d_c/N^{1/3}\,\Delta h_1]^{3/2} \tag{90}$$

Briggs suggests that for a group of stacks not in a line, a conservative result is obtained by replacing $(N - 1)d_c$ with the maximum width of the group.

Briggs' (*56*) analysis includes the effect of multiple sources on plume rise in calm conditions and various other characteristics of multiple source plumes.

3. Nonuniform Atmospheric Conditions

Nonuniformities in atmospheric characteristics and surface features produce plume configurations and concentration distributions markedly different from those of the uniform type given by the equations of Section III,C,1. They may cause local concentrations higher than otherwise occur. Analytical methods are not as accurate as for uniform atmospheres over flat regions, but concentration estimates can be made with various procedures given below.

a. Restricted Diffusion Caused by Inversion Layers. A neutral or unstable surface layer capped with a stable or inversion layer creates a situation in which plume diffusion is largely confined within the surface

ANNEXURE II (ii)

HER MAJESTY'S
INSPECTORATE OF POLLUTION

Environmental Protection Act 1990

Technical Guidance Note
(Dispersion)

D1

Guidelines on Discharge Stack Heights for Polluting Emissions

HMSO

the stack discharge conditions. In these cases part load conditions may produce the more severe pollution problems. This can occur where reduced loading is associated with a substantial reduction in [illegible] discharge momentum. It may then be advisable to calculate discharge stack heights at low load as well as at maximum capacity. The highest calculated discharge stack should be used.

6.4 Multiple sources, nearby sources and combining discharges

6.4.1 General

It is common to find a number of different pollutant sources discharged either together from a multiple stack discharge or from discharge stacks in close proximity. This section provides guidance in dealing with these multiple emissions. It is assumed in what follows that the discharge stacks are of similar heights, which is good practice for stacks in close proximity. Discharge stacks close together of markedly dissimilar heights are only acceptable in restricted circumstances. These are considered in section 6.4.5.

For convenience, a summary of the rules for combining discharges is given in Table 4.

6.4.2 Multiple-stack discharges

Dealing with these is quite straightforward, the combined emissions being treated as a single discharge. The pollutant discharge is treated in the same way as with combinations of pollutants, described in section 4.5. Values of the Pollution Index for the individual discharges are added together as appropriate. The heat release, Q, and discharge momentum, M, of the combined emission is also found by summing the respective values for the individual discharges. The discharge stack height is calculated using these combined values of Pollution Index, heat release and discharge momentum.

6.4.3 Discharge stacks in close proximity

This is defined approximately as stacks within a distance $U_m/2$ of one another. If the discharge stacks are within a distance of three stack diameters of one another, they can be treated as a single discharge, as in the case of multiple discharge stacks, above. For discharge stacks further apart, but within a distance of $U_m/2$, the pollutant discharges should be considered as a single discharge, values of the Pollution Indices for the discharges being added together as appropriate. In the same way heat release, Q, may be considered as a single discharge and values for the individual stacks summed. The discharge momentum, M, however, should not be summed, the individual values of U_m should be calculated and the largest value of U_m used in the final stack height calculation.

6.4.4 Nearby sources

For discharge stacks at distances between $U_m/2$ and $5U_m$ apart, the pollutant discharges should be considered as a single discharge, values of the Pollution Index for the stacks being added together as appropriate. The heat release and the discharge momentum should be taken individually and stack heights calculated on this basis. The tallest height calculated should be applied to all the discharge stacks unless the conditions in 6.4.5, below, are satisfied.

Discharge stacks at distances beyond $5U_m$ apart should be treated individually.

6.4.5 Discharge stacks of dissimilar heights close together

This is not good practice unless the Pollution Index of the lower discharge is small compared with that of the higher discharge. As far as the lower discharge is concerned, the taller nearby discharge stack has the same effect as a tall building and should be treated as such. Thus low discharge stacks should be at a greater distance than $5U_m$ (calculated from the Pollution Index of the lower discharge) from taller stacks. Even at this distance, there may be localised pollution problems due to plume downwash when the plume from the lower discharge runs into the taller stack.

6.5 Difficult siting

6.5.1 General

Discharge stack heights on some sites may need further consideration, despite satisfying the building height correction in section 5.4. This applies particularly if there are tall buildings in the vicinity but beyond the range of $5U_m$.

6.5.2 Courtyard wells and nearly enclosed spaces

Low discharge stacks should not be situated in

courtyard wells [illegible] where ventilation [illegible] be poor, unless the pollutant discharge [illegible] As a rough guide, discharges in each [illegible] across and where the [illegible] heights are more than 20% of the spacing between them should be [illegible] may be better if the discharge is set above the surrounding buildings using the building height correction in section 5.4.

6.5.3 Nearby tall buildings

Buildings taller than the discharge stack but at distances beyond 5[illegible] meandering. As a rough gu[illegible] building taller than the discharge stack [illegible] within a distance of five building heights [illegible] these circumstances consideration should be given to any problems that might result from [illegible] also be problems due to the plume running into the taller building.

Particular attention should be given to the possibility of contaminating nearby ventilation inlets.

Table 4: Summary of Rules for Combining Discharges from Nearby Stacks. (Section 6.4)

Spacing Between Stacks	Pollution Index P	Heat Release Q	Discharge Momentum M
Spacing < 3d	Sum Values	Sum Values	Sum Values
3d < Spacing < $U_m/2$	Sum Values	Sum Values	Use Individual Values
$U_m/2$ < Spacing < $5U_m$	Sum Values	Use Individual Values	Use Individual Values
$5U_m$ < Spacing	Use Individual Values	Use Individual Values	Use Individual Values

6.6 Highly abated emissions

Some plant operates with high levels of emission abatement and, as a result, quite low discharge stack heights may be calculated for the residual pollutant discharge during normal operation. In such circumstances consideration should be given to three matters.

1) Whether serious local pollution problems might result from occasional malfunction or deterioration of the abatement equipment, during which period a much larger pollutant emission may occur.

2) Whether some secondary aspect of the emission, for example a visible plume due to a relatively high water content or a low level of residual odour, may in fact be the major pollutant rather than the small abated residue of what would normally have been the major pollutants.

3) Whether, particularly in the case of some types of incineration plant, any sort of emergency stack is fitted to the plant, which will bypass the abatement equipment in the event of some sort of plant failure. This would result in an unabated emission being discharged.

In these circumstances an increased discharge stack height may be desirable. There is a good case for ensuring that stack heights for highly abated discharges are sufficient for the discharge to pass well clear of its immediate surroundings. This would be sufficient to avoid the most severe local pollution problems likely to arise. To achieve this for wide buildings, the minimum required discharge stack height is 1.5 times the tallest of the adjacent buildings. Otherwise the minimum height should be T+1.5K, as noted in section 5.4.4.

CHAPTER 5

ANNEX III

Quality of Beneficiated Coal

5.1 (a) QUALITY: The Beneficiated Coal delivered by the Seller to Buyer hereunder shall have quality as set forth in Annex F and as set forth below:

(i) The Ash percentage will be 34% but may vary between 32 per cent. with tolerance limit up to 36%.

(ii) The total moisture should vary up to 12% with tolerance limit up to 15%.

(iii) [redacted]

(iv) The size of Beneficiated Coal should not exceed 75mm.

(v) Free from tramp iron.

(b) Seller shall ensure that the fines will be of a level that ensures that the Buyer has no difficulties in handling the Beneficiated Coal or discharging the same from the Trains.

5.1 (c) [redacted]

(i) In the event Ash per cent. of actual supplies in any Train (expressed on an equilibrated basis) goes beyond the contracted value, i.e. 34 per cent, the Seller shall be liable to pay a penalty at 0.2% of the Price per Tonne (which for the avoidance of doubt shall exclude any adjustment to the Price made pursuant to this Section 5.1(c)) for every increase of Ash by 0.1 per cent. beyond 34.0 per cent. Ash up to cut-off Ash level of 36 per cent. Likewise, the Buyer shall be liable [redacted] of the Price per Tonne (which for the avoidance of doubt shall exclude any adjustment to the Price made pursuant to this Section 5.1(c)) for every decrease of Ash per cent. by 0.1 per cent. from the contracted value of 34 per cent. for the concerned shipment.

(ii) If the average total moisture content of any Train measured as a percentage of the Beneficiated Coal delivered to Buyer hereunder, as measured at Delivery Point, exceeds 12 per cent. then the actual deliveries (in Tonnes) for such Train shall be deemed to be the value determined in accordance with the the following formula:-

$$\text{Deemed weight} = \text{weight as per RR} \times \frac{(100 - X)}{(100 - 12)}$$

where 'X' is the determined percentage total moisture content of the Beneficiated Coal in that Train.

EXTRACT FROM COAL SUPPLY AGREEMENT.

Annexure IV

Station - Vijayawada (6 x 210 MW) Coal source: Talcher 98 % and 2 % from Singreni

Stack Flows

Date	SPM*	SO_2*	Load on set MW
Unit V			
11.10.96	77	788	213
19.11.96	70	753	212
18.12.96	98	648	213
6.1.97	87	759	215
Unit VI			
11.10.96	106	900	215
19.11.96	60	743	212
18.12.96	66	670	212
6.1.97	87	781	208

* All figures in mg/nm3

Sulphur Content in Coal Average 0.6 %

Theoretical Value of SO_2 is about 2000 mg/nm^3. Actual about 40 % of theoretical value

The readings also suggest a very strong co-relation between ash precipitated in ESP's and SO_2 emission thru the stack. More ash precipitation (less SPM reading in the stack) less is the SO_2 thru the stack. ESP's at HNPCL plant are designed for achieving 90 mg/nm^3 and hence the probability of retention of Sulphur is high.

Source: APSEB

Air quality (SO_2) (ug/m^3) predictions around the proposed HNPCL power plant (Intrerfering plumes)

	Station	Distance	Direction	Season	Existing air quality $$							0.8% Sulphur in coal $						0.6% Sulphur in coal $						
					Max	Min	Max	Min	Ave	95 **	98 **	100%		90%		80%		100%		90%		80%		
					8 hourly		24 hourly					H	H+N	H	H+N	H	H+N	H	H+N	H	H+N	H	H+N	
71	Palavalasa	3 km	NE	Winter	36	14	33	19	25	29	31	21	22	20	21	19	19	19	19	16	18	15	15	40 +31 = 71
				Pre-monsoon	32	8	26	17	21	24	25	47	52	46	50	42	44	38	41	32	33	31	32	~~55~~
				Monsoon	32	9	24	14	18	24	24	40	42	34	35	33	33	31	31	24	25	22	23	
				Post-monsoon	43	9	26	13	19	25	26	45	50	43	48	38	42	34	39	32	33	28	30	60
				Annual	43	8	33	13	21	27	29													
69	Peddapalem	6 km	N	Winter	37	9	28	14	23	26	27	41	44	35	40	32	34	31	33	25	30	22	26	52 + 27 = 69
				Pre-monsoon	33	9	24	17	20	23	24	40	45	36	43	33	35	33	35	29	32	23	26	
				Monsoon	25	7	19	13	16	18	19	35	40	33	37	28	33	23	29	23	28	22	26	
				Post-monsoon	35	6	30	13	20	26	28	25	28	20	25	18	22	17	21	17	18	16	17	80
				Annual	37	6	30	13	20	26	27													
83	Chipurupalli	6 km	WNW	Winter	42	9	27	16	20	27	31	35	37	31	32	28	29	26	27	23	26	20	23	52 +31 = 83
				Pre-monsoon	32	10	26	19	22	23	24	21	26	19	24	17	20	16	18	14	16	13	15	
				Monsoon	22	6	27	14	20	19	20	13	15	12	13	12	12	11	11	9	10	8	10	
				Post-monsoon	26	11	28	14	21	19	19	24	50	22	45	19	40	17	39	16	34	15	30	60
				Annual	42	6	28	14	21	25	27													
56	Thikkavanipalem	3 km	SW	Winter	42	5	33	14	22	24	28	20	21	18	19	17	18	16	17	15	16	13	15	28 + 28 = 56
				Pre-monsoon	26	7	24	16	20	20	20	16	18	13	16	11	13	11	12	11	11	9	9	
				Monsoon	19	5	20	12	15	13	14	11	13	9	12	9	11	9	10	7	10	6	8	
				Post-monsoon	21	6	19	14	17	17	17	45	48	42	44	38	42	36	40	34	37	32	34	~~70~~
				Annual	42	5	33	12	18	20	23													
79	Deshapatrunipalem	9.5 km	N	Winter	42	9	31	10	18	28	29	13	40	13	35	11	32	10	30	9	26	9	22	50 = 79
				Pre-monsoon	31	7	20	14	17	21	22	15	48	12	45	10	38	10	37	9	34	9	28	
				Monsoon	32	7	14	9	12	19	20	13	39	10	35	10	31	9	29	8	26	8	23	
				Post-monsoon	35	8	17	9	14	19	20	23	40	18	36	16	32	15	30	14	25	12	22	40
				Annual	42	7	31	9	15	24	27													
66	Peddagantyada	14 km	NE	Winter	37	5	29	16	21	25	26	18	22	18	20	18	19	17	18	15	18	13	17	40 = 66
				Pre-monsoon	37	11	23	13	19	24	25	23	28	19	26	18	20	18	20	17	18	16	17	
				Monsoon	36	8	21	11	16	25	26	18	28	17	14	15	23	12	22	11	19	10	18	
				Post-monsoon	37	10	21	12	16	27	27	17	18	16	17	14	16	12	14	11	13	10	12	~~28~~
				Annual	37	5	29	11	18	26	27													

ANNEXURE V

USING FORMULA $X_{total} = X_{1hr} \times N^{0.8}$)

* With respect to stack

** Percentile

$ - Incremental GLC

$$ - Adjusted to nearest number

H - Incremental GLC due to HNPCL plant alone

H+N - Incremental GLC due to HNPCL & Simhadri plants

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI (C0.8)

Season : Winter : December - February
Case : Sulphur Content 0.8 %, No retention in ash

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI (C0.8)

Season : Winter : December - February
Case : Sulphur Content 0.6 %, 20% retention in ash

Winter, HNPCL+NTPC with 0.6'S coal converts to 80'SO2

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI (C0.8)

Season : Summer : March - May
Case : Sulphur Content 0.8 %, No retention in ash

Summer,HNPCL+NTPC with 0.8'S coal converts to 100' SO2

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI (C0.8)

Season : Summer : March - May
Case : Sulphur Content 0.6 %, 20 % retention in ash

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI (C0.8)

Season : Monsoon : June - August
Case : Sulphur Content 0.8 %, No retention in ash

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI (C0.8)

Season : Monsoon : June - August
Case : Sulphur Content 0.6 %, 20 % retention in ash

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI (C0.8)

Season : Post Monsoon : September - November
Case : Sulphur Content 0.8 %, No retention in ash

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI (C0.8)

Season : Post Monsoon : September - November
Case : Sulphur Content 0.6 %, 20 % retention in ash

Air quality (SO_2) (ug/m^3) predictions around the proposed HNPCL power plant (Two independent plumes)

Station	Distance*	Direction*	Season	Existing air quality $$							0.8% Sulphur in coal $						0.6% Sulphur in coal $					
				Max	Min	Max	Min	Ave	95 *	98 *	100%		90%		80%		100%		90%		80%	
				8 hourly		24 hourly					H	H+N	H	H+N	H	H+N	H	H+N	H	H+N	H	H+N
Palavalasa	3 km	NE	Winter	36	14	33	19	25	29	31	27	28	25	28	20	21	20	20	18	20	17	18
			Pre-monsoon	32	8	26	17	21	24	25	60	63	52	58	45	50	42	50	40	42	36	40
			Monsoon	32	9	24	14	18	24	24	44	45	42	43	36	42	34	35	32	32	25	26
			Post-monsoon	43	9	26	13	19	25	26	55	60	50	54	42	49	37	45	32	40	31	37
				43	8	33	13	21	27	29												
Peddapalem	6 km	N	Winter	37	9	28	14	23	26	27	47	52	42	46	40	44	32	35	31	34	28	31
			Pre-monsoon	33	9	24	17	20	23	24	48	55	42	48	38	48	35	40	32	35	31	35
			Monsoon	25	7	19	13	16	18	19	42	48	42	48	32	40	32	38	24	30	22	28
			Post-monsoon	35	6	30	13	20	26	28	28	30	24	28	20	26	18	25	17	20	16	20
				37	6	30	13	20	26	27												
Chipurupalli	6 km	WNW	Winter	42	9	27	16	20	27	31	40	42	38	39	31	32	30	31	22	28	21	25
			Pre-monsoon	32	10	26	19	22	23	24	23	25	23	25	20	25	18	25	15	18	15	16
			Monsoon	22	6	27	14	20	19	20	15	18	14	18	13	16	13	11	12	10	9	10
			Post-monsoon	26	11	28	14	21	19	19	28	55	26	50	22	44	17	44	16	40	15	34
				42	6	28	14	21	25	27												
Thikkavanipalem	3 km	SW	Winter	42	5	33	14	22	24	28	24	25	21	25	20	20	18	18	18	18	18	18
			Pre-monsoon	26	7	24	16	20	20	20	20	20	17	18	12	18	12	18	12	12	10	12
			Monsoon	19	5	20	12	15	13	14	14	15	12	15	11	14	12	14	9	11	8	9
			Post-monsoon	21	6	19	14	17	17	17	60	63	56	58	47	50	42	48	38	42	36	37
				42	5	33	12	18	20	23												
Deshapatrunipalem	9.5 km	N	Winter	42	9	31	10	18	28	29	20	48	20	29	18	26	18	25	18	22	12	20
			Pre-monsoon	31	7	20	14	17	21	22	16	56	15	50	14	48	12	42	10	38	10	35
			Monsoon	32	7	14	9	12	19	20	14	48	12	48	10	40	10	30	9	30	8	28
			Post-monsoon	35	8	17	9	14	19	20	16	48	22	42	19	39	17	35	15	31	13	28
				42	7	31	9	15	24	27												
Peddagantyada	14 km	NE	Winter	37	5	29	16	21	25	26	20	28	20	22	18	20	18	19	18	18	16	18
			Pre-monsoon	37	11	23	13	19	24	25	26	30	24	20	18	26	18	29	18	30	16	22
			Monsoon	36	8	21	11	16	25	26	20	36	19	33	18	32	18	23	15	21	14	21
			Post-monsoon	37	10	21	12	16	27	27	18	26	18	24	16	19	15	18	12	17	11	15
				37	5	29	11	18	26	27												

* With respect to stack
** Percentile

$ - Incremental GLC
$$ - Adjusted to nearest number

H - Incremental GLC due to HNPCL plant alone
H+N - Incremental GLC due to HNPCL & Simhadri plants

ANNEXURE VI
(USING FORMULA $X_{total} = X_1 \times 2$)

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI

Season : Winter : December - February
Case : Sulphur Content 0.8 %, No retention in ash

hnnpwin(.8)

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI

Season : Winter : December - February
Case : Sulphur Content 0.6 %, 20% retention in ash

h68win(...)

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI

Season : Summer : March - May
Case : Sulphur Content 0.8 %, No retention in ash

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI

Season : Summer : March - May
Case : Sulphur Content 0.6 %, 20 % retention in ash

h68psum

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI

Season : Monsoon : June - August
Case : Sulphur Content 0.8 %, No retention in ash

hnnpmon(.8)

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI

Season : Monsoon : June - August
Case : Sulphur Content 0.6 %, 20 % retention in ash

h68pmon

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI

Season : Post Monsoon : September - November
Case : Sulphur Content 0.8 %, No retention in ash

AIR QUALITY INCREMENTAL GROUND LEVEL CONCENTRATION WITH HNPCL AND SIMHADRI

Season : Post Monsoon : September - November
Case : Sulphur Content 0.6 %, 20 % retention in ash

ANDHRA PRADESH POLLUTION CONTROL BOARD

2nd Floor, HUDA Complex, Maitrivanam, S.R. Nagar, HYDERABAD - 500 038.

Phones : 291120
294043
293278
292132
Fax : 040-293261
Grams : Kalushya Nivarana

BY REGISTERED POST WITH ACK. DUE

Lr.No.19/PCB/C.Estt/RO/VSP/AEE-N/96 **Dated:25-2-97**

To

M/s.Hinduja National Power Corporation Ltd.,
Plot No.974, Road No.50,
Jubilihills,
Hyderabad - 500 033.

Sir,

Sub: PCB - NOC CELL-II - Submission of comprehensive EIA - Discussion with the Technical Committee - Clarification Sought - Regarding.

Ref: Your letter No.HNPC/CLEAR dt.22-1-97.

Your attention is invited to the reference cited, wherein you have submitted Comprehensive EIA of your coal based power project proposed at Wadachepurupally (V), Visakhapatnam District to produce electric energy of 1040 MW.

The Technical Committee in the meeting held on 18-2-97 discussed with you regarding various aspects of the Comprehensive EIA submitted.

The Committee scrutinised the Comprehensive EIA submitted by you and offered the following comments:

1. It appears that the data presented is not comprehensive enough to understand the exact impact of air quality changes predicted by the proponent and the consultant. This is so because the information supplied with regard to the concentration levels at each station likely to be contributed by other up-coming units was not included in the report.

2. It was also observed that the emission data and the formula used for calculating the twin flue stacks needs to be revised to incorporate the rational approach. This means they will have to be recalculated and the ground level concentration using single flume raised height and twin flue mass emission rates for arrival at more realistic picture.

3. The industry shall furnish minimum and maximum concentrations for the monitored value of the air quality sampling stations. As regards the water pollution problem the present system as proposed for intake of the cooling water and its characteristics and method of redischarge into the sea appears to be acceptable and appear to be not harmful to the ecology of the Coastal region.

4. The developmental activities in this city will be creating excessive (short term as well as long term) demand on the traffic and transporatation requirements. This cannot be met unless the concerned authorities of the State as well as all the industries join and develop the necessary road network/strengthening of the existing roads and related infrastructure on a priority basis.

The issue will be placed before the Technical Committee again after receipt of the above mentioned information.

Yours faithfully,

for MEMBER SECRETARY

3.1.2 Ambient Air Quality

Air quality was measured nearest to and surrounding the proposed plant site at six locations (Exhibit 1.2). As discussed in Chapter 1, the locations were decided based on preliminary estimates (using Gaussian air dispersion modelling) of the distance from the plant where maximum ground level concentrations (GLCs) of pollutants emitted by HNPCL would occur under the prevalent meteorological conditions, including coastal fumigation effects. Apart from the various pollutants, dust fall rates were also measured at the six locations.

Monthly maximum, minimum, and average concentrations of SO_2, NO_x, RPM and residual dust at each monitoring location are plotted in Exhibits 3.17 through 3.22. It must be noted that the maximum concentrations of the pollutants were observed on only few occasions, persisting for a small fraction of time. The average concentrations in the area surrounding the HNPCL site (average of all six locations) are tabulated below.

Pollutant	Background concentration				Standard
	Winter	Pre-monsoon	Monsoon	Post-monsoon	for industrial area
SO_2 ($\mu g/m^3$)	21.5	19.8	16.2	17.4	120
NO_x ($\mu g/m^3$)	19.1	17.0	14.0	16.6	120
SPM ($\mu g/m^3$)	76.0	73.7	50.7	55.8	500
CO ($\mu g/m^3$)	1550	2110	1870	1640	3333

Average monthly SO_2 concentrations (24-hourly) around the HNPCL site varied between 10 $\mu g/Nm^3$ at Thikkavanipalem to 29 $\mu g/Nm^3$ at Palavalasa. The range for NO_x during the monitoring period was 11 $\mu g/Nm^3$ at Thikkavanipalem and Chipurapalli to 34 $\mu g/Nm^3$ at Peddapalem. In general, higher concentrations were observed during winter. During monsoon, pollutant concentration were comparatively lower. This is likely due to the washout of pollutants by precipitation. The SPM (comprising RPM and residual dust) concentrations were relatively higher during winter and pre-monsoon. The monthly average concentration of RPM varied from 24 $\mu g/m^3$ at Peddapalem to 70 $\mu g/m^3$ at Palavalasa. Residual dust concentrations were highest at Thikkavanipalem (55 $\mu g/m^3$), but at most of the other locations they were generally less than 10 $\mu g/m^3$.

As expected in a rural area, the average concentrations of SO_2, NO_x, SPM, and RPM were observed to be low and well within the CPCB limits for residential, rural, and other areas. Average CO concentrations were also found to be well within CPCB limits.

There is no ambient HC standard; nevertheless, average concentration (eight hourly) of HC was also found to be relatively low. The area around the HNPCL site has been declared as an industrial zone. Compared with the CPCB ambient air quality standards for industrial/mixed use areas, the air quality was excellent.

Presence of CO and HC in the ambient air surrounding the proposed project site could be attributed to the traditional shell-burning for lime preparation, brick-making, and preparation of molasses in village *chulhas* (country stoves) using firewood.

The dust fall rates observed in the project area are given in the following table.

Location	Dust fall rate ($g/m^2/month$)
Palavalasa	1.14
Peddapalem	1.06
Vadachipurapalli	1.03
Thikkavanipalem	0.99
Deshapatrunipalem	1.16
Peddagantyada	0.54

The dust fall rates during 1995-96 varied between 0.54 and 1.16 $g/m^2/month$. The highest dust fall rate was observed at Deshapatrunipalem, which could be attributed to the proximity of this monitoring location to the Gajuwaka-Yelamanchili road.

3.2 Noise Environment

Equivalent noise levels (L_{eq}) for day and night at and around the HNPCL plant site during 1995-96 are given in Exhibit 3.23. The following salient observations can be made from the exhibit:

- L_{eq} at and around the project site varied between 49 dBA and 70 dBA during day time and between 40 dBA and 59 dBA during night time, which were well within the standards specified for industrial areas.
- Noise levels were found to be highest at Desapatrunipalem and lowest at the plant site throughout the year during both day and night. This could be attributed to the traffic plying on the busy Gajuwaka-Yelamanchili Road which passes very close to this location.
- At most of the locations where monitoring was undertaken, the highest L_{eq} values were found to have occurred during

Exhibit 3.17. Ambient air quality characteristics at Palavalasa

Exhibit 3.18. Ambient air quality characteristics at Peddapalem

Exhibit 3.19. Ambient air quality characteristics at Chipurapalli

Exhibit 3.20. Ambient air quality characteristics at Thikkavanipalem

Exhibit 3.21. Ambient air quality characteristics at Deshapatrunipalem

Exhibit 3. 22. Ambient air quality characteristics at Peddagantyada

Methodology

Hourly data on wind speed and direction, and temperature collected at the HNPCL site during December 1995 - November 1996 were used for the model. The mixing height for the area for this period was assumed to be 1500 m (maximum).

To estimate the GLC due to N number of identical sources at the same location, the GLC obtained considering emission from one source can be multiplied by a factor of $N^{0.8}$ as follows:

$$\chi_{total} = \chi_1 \times N^{0.8}$$

Since HNPCL will have two identical flues in the stack, in the present case, N = 2.

The source data and model options used for the air quality simulation are given in the following table. Modelling was carried out for SPM, SO_2, NO_x, and CO since the emissions of these pollutants are expected to have some impact on the surrounding air quality. Maximum anticipated emissions were considered for assessing the worst case impact.

Model	: ISCST v.2
Simulation area	: 60 km × 60 km
Averaging time*	: 24 h
Source data	
Pollutant strength	
SO_2	: 2935 g/s
NO_x	: 614 g/s
SPM	: 115 g/s
CO	: 128 g/s
Stack height	: 275 m
Exit gas temperature	: 419 K
Exit gas velocity	: 30 m/s
Flue diameter (exit point)	: 6 m
Stack location	: centre of simulation area
Receptors: 500 m intervals	
elevation range (w r t stack base)	: 0 - 375 m
Meteorological data	
Hourly wind speed	: HNPCL site
Hourly wind direction	: HNPCL site
Hourly temperature	: HNPCL site
Mixing height (assumed)	: Maximum 1500 m
Stability	
Pasquill's classification, using	: Radiation index : On site cloud cover : Wind speed
Decay/deposition	: Not opted
Chemical transformation	: Not opted

* Averaging time = 8 h for CO

Uniform (steady state) horizontal wind was assumed for each hour. Straight line transport was assumed to all distances. Separate wind profile exponents applicable for rural cases were used. Vertical wind speed was assumed to be zero.

For both horizontal and vertical dispersion, buoyancy-induced dispersion coefficients were used. Standard Pasquill stability classes were used. Mixing height was accounted for with multiple reflections until the vertical plume standard deviation equalled 1.6 times the mixing height. Uniform vertical mixing was assumed beyond that point. Perfect reflection was assumed at the ground.

Results and Conclusions

The increases in the pollutant concentrations due to HNPCL's stack emissions predicted by the ISCST model are shown in Exhibits 4.1 through 4.16. The maximum increases in GLCs at different distances are given in Table 4.1.

The results in Table 4.1 indicate that the increases in the ambient levels of SO_2 would be higher that those of other pollutants. The values in the table indicate the maximum GLC increments in the plains; the GLC increments on hillocks would be relatively higher. The hillocks harbour mainly thorny bushes with isolated trees; they are not inhabited. The impact of SO_2 on these hillocks is therefore not expected to be significant.

The maximum increments in GLCs are expected to vary more or less in the same range in all four seasons. Ambient SO_2 concentrations are exepcted to rise by 35-45 $\mu g/m^3$, with maximum during pre-monsoon season. Ambient NO_x concentrations are expected to rise by 8-10 $\mu g/m^3$. SPM levels may go up by 1-2 $\mu g/m^3$ and CO by 2-3 $\mu g/m^3$.

The predicted maximum concentrations of pollutants with observed background levels are compared with national air quality standards in the following table.

Season and Pollutant	Predicted maximum increase in GLC	Direction with respect to stack	Back-ground GLC	Total GLC	Standard for industrial areas
	All values are in $\mu g/m^3$				
Winter (December-February)					
SO_2	40	N, W, NE, SW	21.5	61.5	120
NO_x	10	W	19.1	29.1	120
SPM	2	W, SW	76.0	78.0	500
CO	3	W, SW, N, NE	1550	1553	3333

Table 4.1. Predicted increase in GLCs of various pollutants due to HNPCL's stack emissions

	Distance from stack (km)	Winter		Pre-monsoon		Monsoon		Post-monsoon	
		Maximum 24 h GLC (μg/m³)	Direction with respect to stack	Maximum 24 h GLC (μg/m³)	Direction with respect to stack	Maximum 24 h GLC (μg/m³)	Direction with respect to stack	Maximum 24 h GLC (μg/m³)	Direction with respect to stack
SO_2									
	00-05	40	N, W	50	NE	40	NE	40	NE, SW
	05-10	40	N, NE, W, SW	30	NE	40	NE	30	SW
	10-15	30	NE, SW, W	20	NE	30	N, NE	20	N, SW, SE
	15-20	20	NE, SW, W	20	NE	20	N, NE	10	NE, NW, SE, SW
	20-30	20	NE, W, SW	10	NE, SW, NW, E	20	NE	10	NE, NW, SE, SW
NO_x									
	00-05	08	N, NE, W	10	NE	08	NE	08	NE, SW
	05-10	10	W	06	NE	08	NE	06	NE, SW
	10-15	08	SW, NE	06	NE	06	N, NE	04	NE, SW, SE
	15-20	06	NE	04	NE	04	N, NE	02	NE, NW, SE, SW
	20-30	04	N, NE, SW, W	02	NE, SW, NW, E	04	NE	02	NE, NW, SE, SW
SPM									
	00-05	01	N, NE, W	02	NE	02	NE	02	NE, SW
	05-10	02	W, SW	01	NE	1.5	NE	01	NE, SW
	10-15	01	NE, W, SW	01	NE	01	NE	0.5	NE, NW, SE, SW
	15-20	01	NE, W, SW	0.5	NE, SW	01	NE	0.5	NE, NW, SE, SW
	20-30	01	NE	0.5	NE, SW, N, E	0.5	NE, S, N	0.5	NE, NW, SE, SW
CO									
	00-05	03	W	02	NE	2.5	NE	02	NE, SW
	05-10	04	W, SW, N, NE	1.5	N, NE	1.5	NE	01	NE, SW
	10-15	03	SW, NE	01	NE, N	01	NE, N	0.5	NE, NW, SE, SW
	15-20	03	NE	0.5	NE, N, E, SW	01	NE, N	0.5	NE, NW, SE, SW
	20-30	02	NE, W	0.5	NE, N, E, SW	0.5	NE, N, S	0.5	NE, NW, SE, SW

Season and Pollutant	Predicted maximum increase in GLC	Direction with respect to stack	Back-ground GLC	Total GLC	Standard for indus-trial areas
	All values are in $\mu g/m^3$				
Pre-monsoon (March-May)					
SO_2	45	NE	19.8	64.8	120
NO_x	10	NE	17.0	27.0	120
SPM	2	NE	73.7	75.7	500
CO	2	NE	2110	2112	3333
Monsoon (June-August)					
SO_2	35	NE	16.2	51.2	120
NO_x	8	NE	14.0	22.0	120
SPM	2	NE	50.7	52.7	500
CO	3	NE	1870	1873	3333
Post-monsoon (September-November)					
SO_2	40	NE, SW	17.4	57.4	120
NO_x	8	NE, SW	16.6	24.6	120
SPM	2	NE, SW	55.8	57.8	500
CO	2	NE, SW	1640	1642	3333

*8-h standards were converted to 24-h by dividing the 8-h value by 1.5

It can be seen from the above table that the estimated 24 h concentrations of all pollutants would be well within limits for industrial areas. Hence the impact of HNPCL's plant on the air environment would be well within acceptable limits. The highest GLCs of pollutants due to HNPCL's stack emissions would generally be in the NE direction from the stack throughout the year. Thus, even if the proposed 1000 MW Simhadri Power Station comes up towards the NW of the HNPCL site, the ambient air quality standards in the area are unlikely to be violated.

The impacts given here are based on conservative assumptions and represent the worst-case scenario (*coal having the highest ash and sulphur at the same time, no sulphur going into ash, and worst-case meteorological data collected at the HNPCL site*). On most occasions, the plume from HNPCL's stack is likely to rise much higher than predicted here. Consequently, *the average GLCs are likely to be about half of the concentrations predicted for the worst-case scenario.*

Coastal Fumigation

Patterns of dispersion at coastal sites differ from those at inland sites primarily because dispersion is affected by differences between temperature and roughness of land and water surface. The temperature difference between land and water can affect dispersion through two mechanisms: (i) it tends to cause a difference in the air pressure above land and water surfaces, leading to the existence of land-sea breeze, and (ii) it tends to produce a different at-