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Comprehensive Environmental Impact Assessment of Nuclear Power Plant (Units 1 & 2), Kudankulam

Sponsor

Nuclear Power Corporation of India Ltd., Mumbai

National Environmental Engineering Research Institute
Nehru Marg, Nagpur 440 020

January, 2003

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FOREWORD

M/s Nuclear Power Corporation of India Ltd. (NPCIL) proposes to set up two units of 1000 MWe capacity each at Kudankulam in Radhapuram taluka of Tirunelvelli-Kottabomman District of Tamil Nadu.

In order to assess the potential impacts arising out of the proposed project activities M/s NPCIL retained National Environmental Engineering Research Institute (NEERI) to undertake Environmental Impact Assessment studies for various environmental components and to prepare a Comprehensive Environmental Management Plan for minimising the adverse impacts.

This report presents baseline data collected during summer, post-monsoon and winter seasons for air, noise, water, land, biological and socio-economic environmental components including radiological parameters with a view to identifying, predicting and evaluating the potential impacts due to proposed activities. An Environmental Management Plan has also been delineated in the report.

The cooperation and assistance rendered by the staff of NPCIL in preparation of this report is gratefully acknowledged.

(R.N. Singh)

Nagpur
January, 2003

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Introduction

1.1 Preamble

M/s Nuclear Power Corporation of India limited has proposed to establish 2 units of 1000 MWe capacity each with reactors of VVER - 1000 type, the reactor plant with a water cooled water moderated power reactor (VVER) comprising four coolant loops. The proposed NPP is to be established at a site which is near to the Kudankulam village in Radhapuram taluka of Tirunelveli Kottabomman district of Tamil Nadu State. The power plant is being constructed within the framework of Inter-Governmental Agreement (IGA) signed in November 1988 and its supplement signed in May 1998 between the Indian Republic and Russian Federation. As per the IGA and it's supplement, as a first step towards implementation of this project, the Russian Organizations have prepared a Detailed Project Report (DPR) based on the terms of reference mutually agreed upon. The Nuclear Power Corporation (I) ltd. has already sought necessary environmental clearance from the Ministry of Environment and Forests, (MoEF) GOI, New Delhi vide MoEF's letter No. J - 14011/1/88 - IA dated 9th May, 1989 and the same is valid now as has been informed by MOEF vide their letter No. J 14011/1/88. II (M) dated 6th September, 2001. However, the NPCIL has been directed by the MoEF to have strict compliance of the terms and conditions of their environmental clearance granted on 9-5-1989 till the completion of installation of power plant.

The Nuclear Power Corporation of India Limited retained National Environmental Engineering Research Institute, (NEERI) with a view to establish the baseline status with respect to various environmental components viz. air, noise, water, land, biological, and socio-economic including parameters of human interest. The data collected and analyzed for three seasons is presented in the form of Comprehensive Environmental Impact Assessment with a view to assess the present baseline environmental status, predict and evaluate the potential impacts due to the proposed activities. An Environmental Management plan incorporating control measures has also been delineated in this CEIA report.

1.2 Nuclear Power Programme : Present Scenario

The present total installed capacity in the country for generating electricity is about 51,000 MWe which includes 65% thermal, 32% hydro and 3 % nuclear power. Oil is used as an auxiliary fuel on a small scale. By the year 2020, the total nuclear power generating capacity is expected to reach 1,25,000 MWe out of which Nuclear Power is expected to contribute around 10% of the total power requirements.

The nuclear power programme in India for the next fifteen years is based on installation of a series of 220 MWe and 500 MWe capacity heavy water reactor units. The current nuclear capacity of 2770 MWe is expected to increase to over 6600 MWe as indicated in **Table 1.1**. The locations of various nuclear power plants in India are shown in **Figure 1.1.**

The first nuclear power station in India, that was set up in late 60's at Tarapur, consists of two boiling water reactors of 160 MWe capacity. The subsequent stations which form the mainstay of the first stage of nuclear power programme in the country are of the Pressurized Heavy Water Reactor (PHWR) type. The first PHWR station was constructed at Rajasthan (RAPS) with 1 x 150 & 1 x 200 MWe reactor units. In addition to RAPS, two more units of 170 MWe each are in operation in Madras (MAPS). Construction of two stations having two units each 220 MWe each at Narora (NAPP) and Kakrapar (KAPP) was completed and the units were commissioned. Construction work for two units of 220 MWe each at Kaiga and additional two units of 220 MWe each at Rawatbhata in Rajasthan was completed and these were also commissioned. At Rawatbhata and Kaiga, construction of expansion units (2 nos of 220 MWe each) is in progress and at Tarapur, 2 units of 500 MWe capacity are under construction. NAPP design is a standardised design for all future 220 MWe stations and a number of such stations are proposed to be constructed. A number of significant changes in the design have been made progressively from Rajasthan to Madras to Narora and finally to the 500 MWe units. These design changes have been made from the consideration of currently prevailing safety criteria, improved availability of technology, in-service inspection, ease of maintenance etc. as appropriate to the conditions in India. Construction of the nuclear power plant comprising 2 units of 1000 MWe capacity each has been initiated at Kudankulam in Tamil Nadu.

1.3 Economics of Nuclear Power Generation

In India, all the operating nuclear power units supply electricity at the rates cheaper than those for coal based electricity in the region.

A committee consisting of representatives from the planning commission, central electricity authority, outside energy experts and the Department of Atomic Energy has observed that for units to be commissioned in the early 90's, nuclear power would be cheaper than thermal power even from a Pithead station. If the thermal unit is located away from the coal mine, the economic advantage of nuclear power is much stronger.

A detailed study was made by a committee on pricing of nuclear power in Department of Atomic Energy. Three studies were conducted as follows:

Study 1 - Comparison based on actual costs of stations commissioned in 1983

Study 2 - Comparison of expected costs for stations to be commissioned in early 1990

Study 3 - Comparison of total thermal and nuclear fuel cycle costs in the year 1990

The studies show that nuclear power is likely to be cheaper at locations increasingly away from the coalfields and in due course at pitheads themselves. The key to this is to achieve gestation periods for nuclear power plants in 8 to 9 years and it is progressively being reduced to 6-7 years.

Comparison of fuel cycle costs indicate that contrary to common belief, nuclear power is not more capital intensive. The total fuel cycle costs for nuclear power are 35% higher while the corresponding costs for thermal power are 75% higher. Comparison of nuclear and thermal power costs is presented in **Table 1.2**.

As regards the comparison of nuclear power plant with that of coal based thermal power plant with respect to fuel use and the environmental pollutants generated, the nuclear power plants do not generate conventional pollutants as can be seen from **Figure 1.2**.

However the radionuclides generated from nuclear power plants are required to be handled and disposed of carefully and are subjected to more stricter regulations enforced by International agencies and National Regulatory Boards

1.4 Project Setting

The site (Latitude 8°9'52" N & Longitude 77°42'41"E) of the proposed Nuclear Power Plant project is a coastal site which is 4 km south of Kudankulam village. The site is on the shore of Gulf of Mannar and is located near the South-Eastern tip of India. The town of Kanyakumari is about 27 kms away from the project site. It is located in Radhapuram taluka of Tirunelveli-Kottabomman district of Tamilnadu state. There are two nearby railway stations, one at Kanyakumari which is at a distance of 27 kms to the west from the site and another at Vadakku Valliyur at a distance of 27 kms to the north from the site. A major district road runs along the coast and passes through Kudankulam village at a distance of 3 kms from the proposed power plant. The nearest National Highway (No. 7) passes through Vadakku Valliyur and is at a radial distance of 20 kms from the site. Location plan for Kudankulam NPP site is shown in **Figure 1.3**

There are no industrial establishments near the site. The nearest chemical plant is at Tuticorin. There is a stone quarry at Erukkanthurai which is at a distance of around 6 kms from the site. Only controlled blasting is used for quarrying. There is also a stone quarry at a distance of 5 kms from the site near Vijayapati. Here, only open soft excavation is used up to 2 meters depth. The other stone quarries are at distances of more than 18 kms from the site.

The NPP site is situated in the coastal track at an elevation of +3 to +45 m above MSL forming the southern fringe of soil covered plains. This vast plain has to the east of the western ghats rising upto heights of 1679.8 m above MSL. The Hanuman Nadi and the Nambiar river rise in the eastern slopes of the western ghat range and flow in E, SE and SSE direction in the coastal areas both entering the Gulf of Mannar at about 5 km west and 9 km NE of the site respectively. Most of the rivers in the area are seasonal.

There are no major lakes, dams or ponds existing within 20 km radius around project site except some local rain fed tanks which serve the local needs. The land within the exclusion zone of 2 km from the plant site is mostly barren with no agricultural produce. Being the coastal site, fishing is the main source of livelihood in the area.

The topography of the area is flat with small undulations. Thekkumalai is an isolated hill with an altitude of about +800 m located in north west direction of the site.

The climate of the area is arid and is similar to other coastal regions. As per IMD station at Kanyakumari, the wind speed is in the range of 6 to 30 km/hr. The ambient temperature varies in the range of 21°C-34°C while the relative humidity ranges from 68%-80%. The average annual rainfall is around 800 mm with maximum rainfall occurring during the period from October to December every year.

1.4.1 Geological & Hydrological Characteristics

1.4.1.1 Geology

Geologically the site is made up of the Archean super group of crystalline rocks, sedimentary rocks of Precambrian origin and recent quarternery deposits. The geological profiles studied upto 80 m depth indicates that the site comprises of highly metamorphised rocks with granulated and amphibolites facies of charnokites belonging to the archean super group.

The major mineral ingredients of the rock are quartz, potassium, feldspar, sodium and garnet etc. Amphibolized granulated rock is a medium grained grey-green rock comprising mainly quartz and hornblende and occurs sporadically in the form of thin interlayers. The shallower depths are built of grey weathered fissured rocks still holding the textural features of parent materials.

The recent quaternary deposits of the site are characterized by alluvial medium to coarse grained semi-gravel loamy sand and clay sand. The upper levels of these deposits have thin soil layer.

The NPP site is situated at the south of Pandian movable belt, the metamorphic rocks of which are the foundations of ancient platform. Various site investigations carried out earlier at project site indicate no major rock discontinuities.

1.4.1.2 Hydrogeological Characteristics

The level of the underground water observed through the boreholes is inclined towards the sea. The depth of underground water increases with the distance from the seashore. The depth varies from 4.2 m to 18.9 m at west of the site and from 1.25 m to 13.6 m at east of the site. Seasonal variation of underground water level is around 4.5 m. At the site the water is held in fissured granitic rocks. The permeability coefficient varies from 1.10^{-4} cm/sec to $4.7.10^{-3}$ cm/sec.

1.5 Seismic Setting of Plant Site

The NPP site is situated in an area with expected earthquake intensity of upto V. The site area falls within the seismic zone II which is a moderately stable area as per seismic zoning map of India. The strongest earthquake near this area and within the Indian peninsula is Coimbatore earthquake of Feb. 1900. The epicentre of this earthquake was situated at a radial distance of 300 km from the proposed NPP site.

The nearest epicentre of a recorded earthquake was located near Trivandrum which is situated at a distance of 88 km NNW of NPP site.

The estimated intensities of earthquake and peak ground acceleration at the site for the design-basis earthquake and ultimate design-basis earthquake are as follows:

Sr. No.	Design Basis	Peak Ground Acceleration		Earthquake Intensity at Site
		Horizontal	Vertical	
1	Ultimate design basis earthquake	0.15	0.11	VII
2	Design basis earthquake	0.05	0.036	V

The site of proposed nuclear power plant lies in zone II of the seismic zoning map of India (IS 1893 - 1975) where shocks of intensity VI or magnitude 5 can occur. In the region, no shock of magnitude 5 is known to have occurred at less than 100 km distance from the plant site. Within a distance of about 300 kms, some 27 earth quakes of intensity IV to VIII or a magnitude ranging between 4 and 5.7 are known to have occurred from 1341 to 1972 as given in different catalogues. From the available Gauribadanur Array data, another 27 possible tremors of magnitude within a range of 2.2 - 4.8 have occurred during 1968 - 1985.

Microsesmic data was recorded at eight seismic stations for a period of 8 years from 1990 to 1998. During this period, 29 local earthquakes of magnitude 0.4 to 3.5 have been recorded (Ref:- NPC - KK 0.0.00. PSAR. PR)

1.6 Nuclear Power Reactors at Kudankulam

1.6.1 Reactor

The VVER-1000 water-cooled and water-moderated power reactor (No.V- 412) is the pressure vessel type, heterogeneous reactor on thermal neutrons. Water is used as coolant and moderator, and reactivity variations as required is done by control rods and concentration of boron in coolant. Uranium dioxide with an average enrichment of 3.92% is used as a nuclear fuel.

The reactor vessel is a cylindrical high pressure vessel manufactured of high-strength heat-resistant alloyed steel. The vessel internal surface is clad with corrosion-resistant austenitic steel. Schematic diagram of the reactor plant is presented in **Figure 1.4**.

The coolant is supplied by the reactor coolant pumps through four inlet nozzles, flows down in annular space between the vessel and reactor core shroud and enters the fuel assemblies (FA), through perforation in the bottom and support tubes of the shroud. When passing through FA the coolant is heated due to nuclear fuel fission reaction. The coolant enters annular space between the vessel and shroud and passes through perforations in the bottom plate and protecting tube unit shell and leaves the reactor through four outlet nozzles of the vessel. Simplified diagram of VVER-1000 reactor coolant system is presented in **Figure 1.5.**

The V-412 reactor is the modernized version of the V-320 reactor widely used at various nuclear power plants. The main improvements are as given below:

- Increased number of control rods from 61 to 121;
- Increased efficiency of the reactor shut-down system by bringing the reactor into subcritical state (including in accidents) and its keeping in this state while cooling down approximately to 100°C without boron injection;
- The system of in-core instrumentation is improved;
- The features to decrease consequences of the core barrel in case of break of core barrel;
- The design of top unit nozzles is changed in order to improve its in-service maintenance;
- Duration of fuel staying in the core is 3-4 years as compared to 3 years period in V-320 type reactor;
    * Average fuel burn up in the removed fuel assembly (FA) is more
    * Average enrichment of the make up fuel with isotopes- U^{235}, is more
    * There is less temperature differential (heating-up) in the reactor

* Coolent flow rate in the loop cold leg is more as compared to flow rate in V-320 reactor

* More number of pumps are provided for emergency boron injection system and high pressure emergency injection system

* There is a provision of 2 Gate valve with electrical drive (4 Nos) which is absent in Balakovo 4 plant

* Provision of more flow rate in secondary circuit overpressure protection system has been made

In addition to the above, the Kudankulam project uses some safety systems which are absent in Balakovo nuclear power plant. Some of the features to be implemented in these safety systems are as follows :

- Additional system for core passive flooding
- Passive heat removal system
- System for emergency discharge and purification of release from containment
- Hydrogen monitoring and suppression system inside the containment
- Core catcher outside the reactor
- Quick boron injection system
- Steam generators emergency cooldown and blowdown system

Reactor core is designed for heat generation and transferring heat from the surface of fuel elements (FE) to the coolant for the design lifetime without fuel elements damaging beyond allowable limits.

Neutronic characteristics of the reactor core and reactivity control system are selected in accordance with the initial design requirements, and they satisfy the safety requirements.

The reactor core consists of 163 hexagonal fuel assemblies (FA), some of which include control and emergency protection elements.

Control and protection elements (absorber rods) are designed for fast termination of nuclear reaction in the reactor core, maintaining power at desired level and its change from one level to another, power density axial distribution flattening over the reactor core, precluding and suppression of xenon oscillations.

The V-412 reactor plant is the modernized version of the V-320 reactor plant and possesses inherent self-protection properties in respect of nuclear safety.

Reactor core inherent nuclear feedback is directed towards compensation of fast reactivity changes and restriction of power rise.

Reactivity coefficients characterizing the reactor core reactivity change in response to variations in parameters of the fuel, coolant, and boron concentration are negative under normal operation, anticipated operational occurrence and design-basis accidents.

Reactivity control is carried out by two independent methods, viz by absorber rods and by liquid boron system. As an absorber rod material $B_4C+(Dy_2O_3TiO_2)$ is used.

The reactor, as well as the instrumentation and control systems are designed in such a way that possible variations in power density distribution connected with xenon instability are timely revealed and suppressed without exceeding the design limits for the fuel and allowable power level.

Steam generator

The steam generator is a horizontal single-vessel with submerged heat exchanging surface formed by horizontally arranged tubes, the system for the main and emergency feed water distribution, submerged perforated sheet and steam header.

The reactor coolant pump

The pump is vertical, single stage type, consisting of the casing and removable part. The vertical asynchronous electric motor is used as a drive. The motor lubrication is independent using incombustible oil. The pump is provided with independent circuit of cooling water for mechanical seals.

Pressurizer

The pressurizer is the vertical vessel with electric heaters located in the vessel bottom part, it is designed for building up of pressure in the primary circuit during the reactor plant heatup and restriction of pressure deviations during the reactor power operation.

The pressurizer casing is made of carbon steel with corrosion-resistant coating of internal surfaces by the fused austenitic layer.

The pressurizer total volume amounts to 79 m^3, water volume under rated conditions is 55 m^3. Pressurizer is fitted with three pulse safety devices to protect the primary system from overpressure. Cold water and emergency boron water spray are provided for pressure control and depressurization respectively.

1.6.2 Containment System

To ensure the plant safety and prevent release of radioactivity to the environment and also to prevent any damage to the equipment by man made events like the falling of an aircraft engine on the dome, the entire primary circuit like reactor, main circulating pumps, steam generators, pressuriser etc. are housed in a double containment building.

The inner shell is cylindrical shell made to prestressed reinforced concrete with a spherical dome with inner surface of the cylindrical and spherical surface lined with 8 mm steal to prevent leakage of any radioactivity to the environment.

The outer shell is made of reinforced concrete with a spherical dome which is for withstanding external impacts, such as external air shock waves etc. Both the shells are designed to withstand seismic events.

On the outer surface of outer dome, passive heat removal systems are installed which utilize the natural convection of air to remove heat from the systems when there is a total failure of electricity to the systems.

The reactor containment and process safety systems are shown in **Figure 1.6** and **Figure 1.7** respectively.

1.6.3 Turbine Plant

The turbine plant is a constituent part of the power generating unit; it is connected to the NSSS with a VVER-1000 reactor.

The power unit is installed with a K-1000-60/3000-2 high-speed condensating turbine operating on saturated steam, with non-controlled steam bleeds, with moisture separation and single-stage steam reheating, with a rotational speed of 3000 rpm. The turbine serves as a prime mover for a TVV-1000/2/24 alternator; it is mounted on a vibration-proof foundation common with the generator.

The turbine set includes :

- A complete steam turbine with parts, systems and units, including systems for automatic control, protection, steam distribution, lubrication oil supply, and monitoring of thermal and mechanical parameters of the turbine;
- Basement-design condensers equipped with steam dump devices, with spring supports, pre-treatment devices, and a ball-cleaning system;
- Ejector system of the condenser;
- A system for intermediate separation and reheating consisting of, moisture-separator-reheater (MSR) separate pumps, separate collectors, condensate collectors, piping and valves;
- A high-pressure regeneration system consisting of two high pressure heaters, piping and valves;
- A low-pressure regeneration system consisting of 4 low pressure heaters, pipeline, valves and one deaerator;
- A main condensate system consisting of 1st and 2nd stage pumps, piping and valves;
- Pipelines for steam, condensate, water and oil designed for connecting pumps, heaters, oil coolers and other auxiliary equipment;
- Vibration-proof insulation of the turbine set;
- Fast-acting steam dump valve with discharge into turbine condenser and fast acting discharge valve which discharges steam in to the atmosphere;
- Instrumentation.

The turbine is a single-shaft four-cylinder set consisting of one symmetrical double-flow high pressure cylinder and three double-flow low pressure cylinders. The turbine has a throttle-type steam distribution system.

The turbine is equipped with a turning gear.

The steam from the steam generators is supplied to four stop-control valve units; then it passes to the high pressure cylinders of the turbine.

After the HPC, the steam goes through four steam lines (two lines per each exhaust from the HPC) to the two steam separator-reheater for separation and intermediate reheating, both are single-staged. On passing separation and reheating, the steam goes through the LP valve units, to the LPCs. From the low pressure cylinders, the steam is discharged into three condensers. The condensers are basement-type, transverse, with titanium tubes. Steam dump valves are installed in the immediate vicinity of the condensers.

Steam is dumped into the condenser via a steam receiver built into the condenser. Condensate is supplied from the pressure header of stage 2 condensate pumps to cool the steam in the steam receiver.

Main Cooling Water System (Sea Water System)

The main cooling water system is provided for condensation of steam and removal of heat from the condensers of the turbine.

The components to ensure performance of the system include main cooling water pump units, system of channels of pipelines as well as valves.

The main cooling water system functions in normal operation modes and ensures continuous heat removal from the condensers of the turbine.

The system functions in all modes of normal operation.

During Anticipated Operational Occurrence (AOO) (without loss of electric power) the system continues to operate.

The system is designed as a once-through circuit with single-pass heat-exchanger – condensers of the main turbines, units of auxiliary turbine equipment (condensers of turbine feed pumps, ejectors).

Turbine Condensate Demineralizing System

Turbine condensate demineralizing system is a system, provided for maintaining secondary circuit water-chemistry regime (WCR) in accordance with regulations requirements to VVER-1000 NPP secondary circuit WCR, from the point of view of providing minimal deposits on steam generators (SG) heat exchanging surface, in turbines flow part and in condensate-feeding line; preventing SG, secondary circuit equipment and pipelines structure materials corrosion and corrosion-erosion damage; providing minimum discharges with impurities concentration, not exceeding maximum-permissible concentration for discharge into the sea.

Secondary circuit design envisages hydrazine-ammonia water-chemistry regime with increased dose of ammonia in feedwater.

LDF system's main function is 100% cleaning of generated turbine condensate.

LDF system functions in all normal operation modes, including unit start-up and shutdown.

In normal operating conditions disruption modes and in emergency modes, not connected with power loss, system performs its functions, depending on disruption type.

- LDF system consists of :
- Electromagnetic filter;
- Five groups of mixed and trap filters.

Main Condensate System

The purpose of the main condensate system is as follows :

- To transfer condensate to the deaerator through unit demineralizing plant and low pressure heaters system
- To control condensate flow pumped by main condensate pumps in order to maintain the level in the deaerator and in LP heaters within the preset limits
- To provide condensate flow in recirculation line needed for normal operation of the condensate pumps of both stages when the turbine is running at no load and at low load

The main condensate system is designed to operate under all operating conditions : from Unit start-up to it's shutdown, beginning from the moment of filling piping with water, to the stop of steam supply from the steam generator to the condenser.

The system has following components:

- I-st stage condensate pumps;
- II-nd stage condensate pumps;
- Pipeline;
- Valves.

Feed Water System

The feed water system is designed for :

- Initial filling and providing the steam generators with feed water;
- Maintaining level in the steam generators;
- Preventing feed water supply in case of a steam generator overfilling;
- Preventing feed water supply to a damaged steam generator in case of the SG steam line rupture in the non disconnectable section, feed line rupture or leakage from the primary circuit to the secondary circuit;
- Deaeration and regenerative heating of turbine condensate in the deaerator to provide the design rates of oxygen content in feed water (10 μg/kg at most), and also accumulation of "hot" water in the deaerator;
- Cooling down of power unit in case of failure of auxiliary feed water pump, as well as for quick cooling of the steam generators by standby electric pump;
- Averaging of feed water parameters downstream of the high-pressure reheater (HPH) groups

Under normal operating conditions, the system performs the functions of level maintaining in the steam generators and feed water supply to them. Under abnormal operating conditions accompanied by level increase in the steam generators above the limits set for normal operating conditions or in case of a leak in the feeding line, the system performs the functions of supply disconnection.

The LAB system incorporates two basic turbine feed pumps (2 x 50%), two stand-by electric feed pumps (2 x 25%), valves and pipelines.

Steam Generators Blowdown System

The system for steam generators (SG) blowdown is designed for the SG blowdown and supply of blowdown water for purification with the aim to keep required water chemistry of secondary circuit.

The pipelines of the steam generators blowdown system are used for chemical flushing and decontamination of the steam generators.

The system of steam generator drains dedicated to steam generators draining during the Unit shutdown is part of the system. Portion of the system pipelines is designed for hydraulic tests of the steam generators in secondary circuit.

The steam generators blowdown system is designed for the operation under the normal operating conditions including the modes of heating, cooldown, planned outages for maintenance, and abnormal conditions with limitations in the system working capacity. The system does not operate at the emergency modes.

The blowdown system consists of the pipelines, valves, heat exchangers for steam generators drains cooling, tank for water discharge from steam generators, pump of tank for water discharge from steam generators.

Auxiliary Feedwater System

The auxiliary feedwater system is designed :

- To provide steam generators with feedwater in the modes of startup, shutdown in the state of "hot" standby as well as cooldown;
- To provide steam generators with feedwater in case of failures accompained by the limitations in water supply from the system of the main feedwater pumps;
- To supply feedwater through the deaerator of the secondary circuit for deaeration of feed water prior to filling of steam generators;
- To provide the after-cooling of steam generators in the water-water mode when the reactor is shut down for repair.

Maximum flowrate of water from the pump of the auxiliary feed water system required to provide the shutdown in the "hot" standby state is no less than 150 t/hr. The flowrate up to 240 t/hr is required for the planned cooling mode with a rate equal to 30°C/hr at its initial stage during one-two hours. For this purpose a standby electric feedwater pump of the LAB system correspondingly for this time period is provided.

The system operates:

- During normal operation (prestarting deaeration, startup, maintenance of "hot" standby, cooldown);
- Under abnormal conditions associated with the limitation of the main supply.

In cases of accidents at the NPP, operation of the system is not required. However, if power supply is maintained or in case of the restoration of power supply from the general plant diesel-generator, it can fulfill its functions.

The system consists of one pump, valves and pipelines.

1.6.4 Cooling Water Supply Systems

Cooling water systems to cool the equipments at Kudankulam NPP are as given below:

- Main cooling water system
- Sea water cooling system for essential services
- Sea water cooling system for non-essential loads

All sea water cooling systems are once-through systems with single-stage sea water circulation via heat exchange equipment.

The cooling water source and the ultimate heat sink is the Gulf of Mannar in the Indian Ocean.

Sea water from the Gulf of Mannar is fed to the unit pump stations where pumps of all systems are installed. Pumps supply water to consumers from which the water goes back to the Gulf of Mannar via the discharge line.

At the pump station, the water supplied to all systems is purified of mechanical impurities and treated with sodium hypochlorite to prevent biological fouling of water conveyance system.

Fish barriers will be installed in front of the cooling service water pump stations.

Non-safety related normal operation pump stations are designed for the water level variations in the Gulf of Mannar from the maximum still water level to the minimum still water level.

The cooling water pump stations for essential consumers are designed for the water level variations in the Gulf of Mannar from the maximum water level of +5.740 m with the probability of 1 time in 10000 years to the minimum water level of minus 1.720 m.

Main Cooling Water System

The system is intended for heat removal from the turbine condensers and is part of a non-safety related normal operation system. The system performs its functions during and after a operation-basis earthquake.

The main cooling water system consists of :

- A mechanical purification system;
- A system of channels and pipelines;
- Pumps.

Sea water is supplied to the unit cooling water pump station via a water intake structure and is supplied to the turbine condensers by six pumps.

The heated water will be discharged in to the Gulf of Mannar via a discharge line downstream of the turbine condensers. Design limit for cooling water temperature (maximum and minimum) is based on meteorological data.

Sea Water Supply System for Reactor and Diesel Generator Building

Sea water supply system for the reactor and diesel generator building is designed based on direct flow sea water supply and is a part of total system of reactor plant heat removal.

This system is intended to remove heat from reactor building and Standby Diesel Power Station (SDPS) vital consumers intermediate circuit systems to the Gulf of Mannar.

The system is a support safety system, which also performs the normal operation functions during Unit power operation.

The system consists of four physically separated trains. Each train is capable of implementation of the whole scope of safety functions under any Unit operation conditions, design basis accidents included. Each train of the system incorporates:

- Pumps;
- Valves;
- Pipelines.

The main consumers of cooling sea water in each train of the system are reactor building intermediate circuit heat exchangers, the flowrate through them is 3000 m^3/hr and heat exchangers of diesel generator and standby diesel power station refrigeration plant, with flowrate through them as 1350 m^3/hr.

Sea Water Cooling System for Non-Essential Loads

The system is intended for removal of heat from intermediate circuits of non-essential loads and belongs to a non-safety related normal operation system.

Sea water is supplied to the heat exchangers of intermediate circuits by underground water line of the system from the pump stations.

Water goes back to the Gulf of Mannar through the discharge line.

Design of the service water supply system is based on approaches implemented both at Russian and Foreign power units.

1.6.5 Radioactive Waste Treatment System

The project envisages collection and processing of liquid and gaseous radioactive wastes, and also collection, processing and storage of solid radioactive wastes generated during operation of NPP.

Liquid Radioactive Wastes

Following are the different types of liquid wastes generated during the reactor operation :

- Borated active water, drained from the primary circuit during boron concentration changes during startup, power rise etc., collected in coolant grade storage system;
- Wastewater after decontamination of the equipment, pipelines, rooms, drains from active laboratory, reclaimed water from special purification system, technological drainage of equipments, pipelines etc.;
- Spent ion exchange resins and sorbents of purification system filters;
- Salt concentrate residue of the evaporator;
- Slimes drained from tank bottoms.

Borated active water from primary circuit is processed in the primary coolant treatment system and pure condensate and boric acid concentrate are separated by evaporation and are reused for make-up in the primary system.

Decontaminants, uncontrolled leakage and drainage from equipments, pipes and rooms, are collected in tanks in the reactor auxiliary building. They are then processed by evaporation in waste water processing system and condensate and salt concentrate are generated. Condensate is used as service water for water purification system, discharged after radiation and chemical monitoring and salt concentrate is sent to intermediate liquid radioactive media storage system.

Salt concentrate residue, spent ion exchange resins and sorbents of filters, slime from tank bottoms are received in tanks in intermediate liquid radioactive media storage system. They are stored here for sufficient time to allow for decay of shot-live isotopes, then further concentration of them is taken up using evaporation technique.

Highly concentrated (up to 800 g/l) residue is then solidified through cementation and sent for interim storage in solid waste depositary.

Monitoring and control of the liquid waste treatment facility is done through APCS. Liquid waste disposal system is equipped with radiation monitoring.

Gaseous Wastes

The sources of gaseous radioactive waste produced during the operation of the reactor are as follows :

- Degassing of the primary coolant in the deaerator of volume control system;
- Nitrogen blow offs from the equipments containing radioactive noble gases – Bubbler tank, sumps for collection of uncontrolled leak, nuclear sampling equipment, and equipments (tanks) located in reactor auxiliary building.

Radioactive gas treatment facility has two systems :

- System for burning hydrogen from process blow offs;
- Radioactive gas purification system

Radioactive gas purification system is designed to reduce the activity of process blow offs coming from hydrogen burning system and from other tanks containing radioactive media to admissible levels. After purifying through absorbing filters the gases are discharged in to the atmosphere through 100 m tall ventilation stack.

Solid Radioactive Waste System

Solid radioactive waste system is intended for solid radioactive waste reprocessing and for temporary storage of solid radioactive waste and solidified liquid radioactive media.

Solid Radioactive Wastes (SRW) are generated both during normal operation of NPP and during repair and accidents.

Treatment system for solid radioactive wastes includes reprocessing and storage of solid radioactive wastes. Solid radioactive wastes are reprocessed to reduce their volume.

The following types of reprocessing methods are used within the project :

- Burning;
- Compacting.

After reprocessing, the finished product is placed in standard 200 litres capacity barrels and is stored in the solid waste stores at solid waste management building.

Solid radioactive wastes are collected in special protective containers at the place of their formation.

Gradation according to the levels of activity and the methods of further reprocessing is made at the place of their collection when they are loaded in the containers.

Solidified liquid waste concentrates which are fixed using concentration are collected in 200 litres capacity stainless steel drums and stored in the intermediate storage area of solid waste management building.

The construction of the temporary solid radioactive waste store will be provided at the site of NPP. This store will be located in the special reinforced surface building. The thickness of walls and floors of storage sections ensures mechanical strength and biological protection. Storage sections of solid radioactive wastes belong to II category seismic resistance according to PN AE G-5-006-87.

The storage technology and storage structures and equipment permit to extract the wastes loaded and transport them for further reprocessing and storage in permanent storage yard in the future.

1.6.6 General Plan and Approach to the Layout of Main Buildings

General Plan

The basic scheme of the general layout of the NPP "Kudankulam" site has been developed for two reactors to be commissioned one after the other.

The final layout is the result of various revisions of earlier layouts. This layout was finalized based on discussions between Indian and Russian specialists and based on the following considerations :

1. The layout is based on independent operation of each unit. Units share common facilities only for reasons of economy without affecting safety.
2. Mirror image arrangement has been avoided.
3. Orientation and location of buildings are optimised from topographical consideration and minimum ground work point of view.
4. Separation of buildings and structures from safety class consideration.
5. Separation of buildings based on radiation zone philosophy.
6. Compactness of layout
7. Ease of construction of units in phased manner.
8. Provision of effective drainage system to protect site against flooding
9. Consideration of turbine missile on safety building
10. Consideration to geo-technical investigation carried out at site.
11. Provision for construction of additional units in future.

The reactors will be positioned with a centre to centre distance of 245 m between them.

The reactor buildings are proposed to be located on the northern side of the turbine buildings. The turbine buildings are located in between the reactor buildings and sea and will be located at a distance of about 100 m from the shoreline.

To the north of the reactor buildings, there will be standby diesel-generator plants (with fuel storage tanks) which will be united with the buildings of emergency power supply systems and safety control systems.

The unit pump houses and pump houses for essential loads will be located to the south of the turbine buildings.

The intake will be through specially designed and constructed intake structure and the discharge will be into the sea at shoreline.

In between the reactor buildings, a complex of NPP auxiliary buildings and structures are proposed to be located. Auxiliary buildings and structures will be located in such a way that a clear division exists between control access area and the common access area.

In the free access area between turbine buildings 1 and 2 a production and laboratory building of instrumentation control and electrical equipment, a chilling machine building for air conditioning facilities and common station compressor building are planned to be located.

In the control access area between the reactor buildings 1 and 2, a sanitary building with radioactive laundry, central repair workshops of controlled access area and a building for solid radioactive waste reprocessing plant with a storage facility are proposed to be located.

Auxiliary buildings and structures shall be connected with the reactor and turbine buildings by a pedestrian and transport gallery which will have a separate passageways for controlled access area and common access area.

Towards east of the reactor building 1, the building for fresh fuel storage, a reserved area for spent fuel storage building and a building for stand by common diesel power station will be located.

A fire fighting system pump house with water storage tanks will be located towards the north west area of Reactor Building 2.

A complex of buildings and structures for the electrical power output system will be located in a separate enclosed area towards north of the site and comprises the following buildings and structures:

- 400 kV and 230 kV complete switchgear (CSG) with SF_6 insulation;
- Central Control Board Building (CCBB);
- Building of 6 kV complete switchgear for the backup and NPP Auxiliary power supply

Outside the Nuclear island fence, towards the east, buildings and structures for lubricating oil and diesel fuel facility, bottled gas storage facility, start-up/standby boiler house with tanks for fuel and oil will be located. A treatment plant for purification of sewage contaminated with oil products will also be located.

Taking into account the local topography (the elevations vary from +2.5 m MSL to + 23 m MSL), a terrace type layout is considered for the NPP site.

Reactor Buildings and common NPP buildings will be located on terraces with elevations from +7.50m MSL to +9.30m MSL. The reactor buildings are planned to be located at a grade elevation of +8.70m MSL.

The complex of buildings and structures of the electrical power output system are proposed to be located on a terrace with an elevation of +13.00 m MSL.

At the east and west sides of the Nuclear island, two vehicle access ways are envisaged. These access ways will be connected to a bypass road that is connected with the state highway.

Along the whole perimeter of the Nuclear island, a double fence with engineered features of security will be provided. The power plant staff and vehicles will be admitted into the Nuclear Island through the checkpoints.

1.7 Safety Aspects of NPP at Kudankulam

The design of reactors at Kulankulam is being developed on the basis of the requirements of the modern safety regulations accepted in Russian Federation nuclear power, as well as International Atomic Energy Authority's (IAEA) recommendations and additional requirements of Indian side.

The design as a whole complies with the requirements and trends in the requirements of the safety regulations, accepted worldwide in developing the nuclear power installations.

In the design of Kudankulam NPP safety goals, principles and criteria, used in VVER-1000 designs, have been implemented.

Safety Objectives

The NPP meets the safety requirements if its radiation effect on the personnel, population and the environment under normal operating conditions and violation of normal operating conditions including the design basis accidents, does not result in any violations of the established exposure doses for the personnel and population, established values for releases and discharges and the content of radioactive substances in the environment and the radiological effects are limited during beyond design basis accident.

The permissible exposure doses for the personnel and for the population and, when necessary, the permissible emissions and discharges and the content of radioactive substances in the environment are established in accordance with the codes and regulations adopted Internationally, and also conforming to Indian Safety regulations. The levels of exposure doses to the personnel at the NPP and to the population resulting from releases and discharge of any radioactive substances from the NPP must be below the established limits, and as low level as is reasonably attainable. These are governed by ICRP and AERB guidelines.

The Concept of Defence in Depth

The safety of the NPP is ensured due to consecutive implementation of the defence-in-depth concept; this protection concept implies a system of physical barriers on the way by which the ionizing radiation and radioactive substances can release into the environment; this system is used together with a complex of engineering and managerial measures for protecting these barriers and maintaining their effectiveness, and measures for protecting the personnel, population and the environment.

The system of physical barriers of the NPP power unit incorporates: a fuel element, fuel element cladding, the pressure boundary of the reactor coolant and the containment.

The complex of engineering and managerial measures forms the following five levels of defence in depth.

Level 1: (Conditions of siting the NPP and prevention of anticipated operational occurrences):

- Assessing and selecting a site suitable for placing the NPP;

- Establishing a sanitary protection zone (exclusion zone), and an observation zone around the NPP in which the protective measures are planned;
- Developing the design using a conservative approach with a mature internal self-protection features of the reactor plant
- Ensuring the required quality of the systems (components) at the NPP and works being accomplished
- Operating the NPP in accordance with the requirements of the relevant normative documents, process stipulations and operating manuals
- Maintaining, in the proper condition, the systems (components) essential for safety by timely detecting flaws, taking preventive measures, replacing the equipment that have worked out its operating resource, and establishing an efficient system for documenting the results of work and checks
- Selecting the personnel for the NPP and maintaining their required qualification level to ensure their properly acting under normal and violation of normal operating conditions including pre - emergency situations, accidents, and creation of safety culture.

Level 2 (Preventing design-basis accidents by the systems of normal operation)

- Revealing deviations from normal operation and removing them
- Control under conditions of AOO.

Level 3 : (Preventing beyond the design basis accidents by safety system)

- Preventing initiating events from their developing into design basis accidents and employing the safety systems;
- Mitigating the consequences of the accidents whose prevention was not met with success, by localizing the releasing radioactive substances.

Level 4 (control of beyond the design basis accidents)

- Preventing beyond the design basis accidents from their developing, and mitigating their consequences

- Protecting the hermetic enclosure from destruction under beyond the design basis accidents, and maintaining its service operability

- Returning the NPP into a controllable condition, in which the chain fission reaction is stopped, the nuclear fuel is continuously cooled, and the radioactive substances are kept in the preset boundaries.

Level 5 (Emergency planning):

- Preparing and implementing when necessary, plans of emergency measures at the NPP site and beyond its boundaries.

The concept of defence-in-depth is conveyed at all phases of activities related to ensuring the NPP safety in the part touched by this kind of activities. Here, the strategy for preventing unfavourable initiating events, especially for the 1st and 2nd level is of primary importance.

In normal operating conditions, all of the physical barriers must be capable of functioning, whereas the measures on protecting them must be available. On detecting any problems in any of the barriers envisaged by the design, or unavailability of measures for protecting it, the reactor plant must be shut down and measures for bringing the nuclear power unit in a safe state must be taken.

The engineering measures and managerial, decisions meant for ensuring safety of NPP must be proven by the previous experience or tests, studies, or operating experience with prototypes. Such an approach should be applied not only when developing the equipment and designing the NPP, but when manufacturing the equipment, constructing and operating the NPP, and when reconstructing the NPP and upgrading its systems (components) as well.

The design and the reliability of the systems (components) essential for safety, the documents and activities that have an effect on ensuring the safety of the NPP, all these must be subject of activities aimed at quality assurance.

Normative Basis

Kudankulam NPP project is being developed on the basis of the requirements of special standards and nuclear safety regulations valid in Russia, as well as in accordance with the requirements of state, ministerial and manufacturer regulations. IAEA and AERB safety Guides and Codes are taken into account.

Additional Safety Provisions

In addition to the high level of safety consciousness in the design of reactors, the nuclear industry takes great care in the selection and training of its operating personnel. In India a nuclear training center will be established at the Kudankulam Nuclear Power Station where a simulator will be installed to train and retrain and expose the operators to the simulated abnormal conditions. Indian reactors are being operated to safety standards accepted internationally.

At each nuclear power station site, environmental survey laboatories are set up long before the plant goes into operation. These laboratories carry out analysis of background radio activity in the area. The purpose is to establish the baseline radiation levels. Thereafter, when the power plant is commissioned and operated, the radiation levels in the environment are monitored regularly upto 30 km distance from the reactors. Within the exclusion boundary, continuous monitoring of radiation situation is done by automated environmental radiation monitoring system. This is being done at all the nuclear power plants in India on continuous basis.

It has been reassuring to note that there has been no adverse impact on the environment due to operation of the Nuclear Power Plants in India.

1.8 Scope of Present Study

The scope of the study includes detailed investigations relating to the status of environment in an area of 30 km radius from the proposed nuclear power plant site for various environmental components viz. air, noise, water, land, biological and socio-economic. Under the scope of EIA, it is envisaged to undertake :

i. Assessment of the present status of air, noise, water, land, biological, marine and socio-economic components of environment including parameters of human interest and health

ii. Identification of potential impacts on various environmental components due to activities envisaged during construction and operational phases of the proposed nuclear power plant at Kudankulam as also prediction of significant impacts

iii. Preparation of environmental impact statement based on the environmental status and the results of prediction of impacts

iv. Delineation of Environmental Management plan (EMP) outlining preventive and control strategies for minimizing the potential adverse impacts during construction and operational stages of the proposed project alongwith the budgetory provisions to be made for implementation of EMP

v. Formulation of environmental quality monitoring programmes for construction and operational phases to be pursued by the NPCIL as per the requirement of statutory authorities.

1.9 Methodology for EIA

The nature of impacts due to nuclear power plant operations on surrounding environment are different from conventional industrial projects, since NPP dose not release conventional air pollutants e.g. SO_2, NO_2 and SPM. The releases from nuclear power plant at Kudankulam to air and water environment are primarily radioactive isotopes. However, the impacts during construction phase of the nuclear power plant would be similar to any other industrial project during construction phase. The sources of radioactivity in NPP arise from the production of radioactive fission products and certain activation products formed by neutron irradiation of reactor materials including coolant and moderator. The atmospheric discharges at KK nuclear power plant are mainly FPNG, iodine (I^{131}) and mixture of long lived nuclides (assumed as Sr^{90}). The nature of effects of radiological pollution on biological environment would be different from that for conventional pollutants. Unlike for chemical pollutants where biological effects depend both on concentration and duration of exposure, the effect of radioactive releases depends on total cumulative dosage. So, short term peaks which are treated as very important in conventional pollutants have no significance in radioactive pollution. Extreme care is taken at every stage viz. in site selection, during construction, commissioning and operational phases of the nuclear power plant to keep the radioactive releases within internationally acceptable limits and limits prescribed by AERB.

While siting nuclear power plants, three areas are defined as exclusion zone and sterilized zones and monitoring zone. Exclusion zone extends upto 2 km which will be under the exclusive control of the power station where no public habitation is allowed. Any existing population within the exclusion zone has, therefore, to be rehabilitated. The sterilized zone is the annulus between 2 kms and 5 km radius from the reactors where natural growth is permitted but new expansion of activities which lead to enhance population growth are not permitted. 5 to 30 km zone is the monitoring zone and is required for emergency preparedness. Other desirable features of the site are that there should not be large towns with population of more than 10,000 within 16 km and no population centres of more than

1,00,000 population within 30 kms radial distance from the reactor. The areas under plant zone, exclusion zone and sterilized zone for the KK Project are shown in **Figure 1.8**.

The plant property wall has been constructed at a distance of 2 kms from the center of the first and fourth reactor stack of a 4 unit site. The enclosed area measures 1053.225 hectares. This area is owned by NPCIL. However the exclusion radius for the purpose of calculating the doses to the public is 1.6 kms. In the sterilized zone (i.e., area between 2 kms and 5 kms) the total population is 17500 as per 1991 census and this area is mostly privately held land.

A circular area covering 30 km radial distance from the centre of the project site at Kudankulam Nuclear Power Plant was identified as an impact zone (**Figure 1.8**) for Comprehensive Environmental Impact Assessment (CEIA) purpose.

Even though the radiological pollution is a major factor to be considered in environmental assessment of nuclear power project, the impacts of conventional pollutants were also studied within the impact zone. The comprehensive EIA of proposed units 1 and 2 at Kudankulam project site, was carried out through reconnaissance survey, and assessment of baseline status during three seasons including identification and prediction of impacts, and evaluation of impacts under each environmental component viz. air, noise, water, land, biological and socio-economic environment including radiological parameters. The work carried out is briefly reported below and has been discussed in detail in subsequent sections.

1.9.1 Air Environment

The source of atmospheric radioactive releases from the nuclear power plant during normal operation, will be ventilation air passing through the stacks. The ventilation air of reactor building and reactor auxiliary building will be passed through High Efficiency Particulate Absolute (HEPA) filters and iodine filters (activated charcoal filters) before sending it to the stack. The nuclear reactor based on VVER technology is expected to generate radiations in the form of FPNG (Fission Product Noble Gases), radio iodine (I^{131}) and mixture of long lived nuclides. The radioactive nuclides released into atmosphere will undergo the dispersion and dilution process in the atmosphere like any other conventional air pollutants before reaching the receptors. Their impact on human body and other biological systems will depend upon the time integrated cumulative radiation dose from the different radio-isotopes. The impact of atmospheric releases on people and other biological life is given below:

- First of all, the released radioactive isotopes will be dispersed and diluted in the atmosphere by atmospheric diffusion process. The dispersed radioactive cloud leads to external dose due to Beta (β) and Gamma (γ) radiations and internal dose due to inhalation of the air containing radionuclides.

- The dispersed particulates can dry deposit on surface soil and vegetation, leading to direct external beta and gamma doses and ingestion (internal) dose by consumption of vegetables from affected zone and through cow milk route

- Soil contamination leading to contamination of agricultural products by uptake from soil and leading to internal dose due to ingestion

- Rainfall can deposit the radioactive particulates on soil and contaminate water which leads to internal dose by drinking this water

The inter-relationships of these different exposure pathways in air route have been depicted in **Figure 1.9**.

1.9.1.1 Data Collection

Site Related

The details related to topography of project site, general climatological conditions and processes involved in nuclear power generation, were collected through reconnaissance survey. The micro-meterological data was collected by installing a weather station at site. In addition, the micrometeorological data recorded at Kanyakumari and the data collected by NPCIL have also been used for characterizing atmospheric dispersion conditions within the impact zone.

Baseline Data - Conventional Air Pollutants :-

Different conventional air pollution parameters viz. Suspended particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM), Sulfur Dioxide (SO_2), and Oxides of Nitrogen (NO_x) were identified to assess prevailing status of ambient air quality within the impact zone. The baseline status of these parameters were monitored during three seasons at the selected sampling stations within the impact zone.

1.9.1.2 Baseline Background Radiation Data

Data related to Background Radiations in and around the proposed nuclear power plant site at selected sampling locations as monitored by BARC and other agencies was obtained from NPCIL and incorporated in the report.

1.9.2 Noise Environment

Noise often defined as unwanted sound interferes with speech communication, causes annoyance, distracts a person from work, and disturbs sleep, thus, deteriorating quality of human environment. Noise pollution survey has, therefore, been carried to assess the impact of the project on the acoustic environment.

Noise levels were measured around the proposed site of the plant, in several human settlements around the plant using precision sound level meter (Model) 2230, Bruel and Kjaer, Denmark).

1.9.3 Water Environment

Information on water resources (ground and surface water) was collected. The parameters of prime importance were selected under physical, chemical inorganic, chemical organic and nutrient groups including heavy metals. Samples were collected at different locations for assessing marine water quality. Baseline data for bacteriological parameters was also collected. Analysis for relevant parameters was also carried out for ground water sources within the impact zone. The analysis data on ground water and surface waters as collected by NPCIL authorities, was also made use of.

The aquatic discharges from the proposed NPP will be in the form of condenser cooling water discharges which will involve radioactive parameters such as gross beta, gamma activity. These discharges are through the average volume of excess water, including laundry water.

Similar to atmospheric releases, the nuclear power plant does generate liquid wastes to which the people, biological life and other systems get exposed and as a result of exposure, get adversely affected. Possible exposure pathways for releases from NPP to aquatic environment are depicted in **Figure 1.10**. In case of Kudankulam plant, liquid radioactive wastes will be stored for decay, concentrated by evaporation and solidified by vitrification and treated as solid wastes.

Sources of radioactive wastes and non-radioactive wastes were identified from the proposed nuclear power plant. The quantity and characteristics of these wastes was anticipated by collecting data from NPCIL. Based on the information available, treatment schemes as suggested in the project report of NPP, Kudankulam for the safe disposal of these wastes in environment were reviewed critically.

1.9.4 Land Environment

A reconnaissance survey was conducted by field visits to the nuclear power plant site and the surrounding areas. Soil samples were collected from different locations for determining characteristics of soils in the study area. in all 27 soil samples were collected and analyzed. The existing landuse pattern within the study area was studied from the available data and information.

As regards the solid wastes, information on expected quantities of solid wastes to be generated, their types, mode of collection, transportation and disposal methods was obtained from NPCIL and was reviewed critically from the view point of their safe disposal.

1.9.5 Biological Environment

For biological environment, baseline data on flora and fauna within the study area was collected. Water samples for aquatic and marine environment were collected for determining biological characteristics such as phytoplankton and zooplankton. Information was also collected about availability of common animals at various places around the project site. Scientific data on Terrestrial fauna was also collected around the project site.

1.9.6 Socio-economic Environment

Baseline information was collected within the study area of 30 km radius around the project. Data on the demographic pattern, population density per hectare, educational facilities, agriculture, income, fuel, medical facilities, health status, transport and entertainment centers were collected for surrounding villages and analyzed. Information related to health and safety aspects as also infrastructural facilities to be provided, number of workers to be employed etc. was obtained from NPCIL. The data and information collected was used to determine the quality of life indices in the region based on which strategies were formulated for achieving further improvement in quality of life indices in the study area.

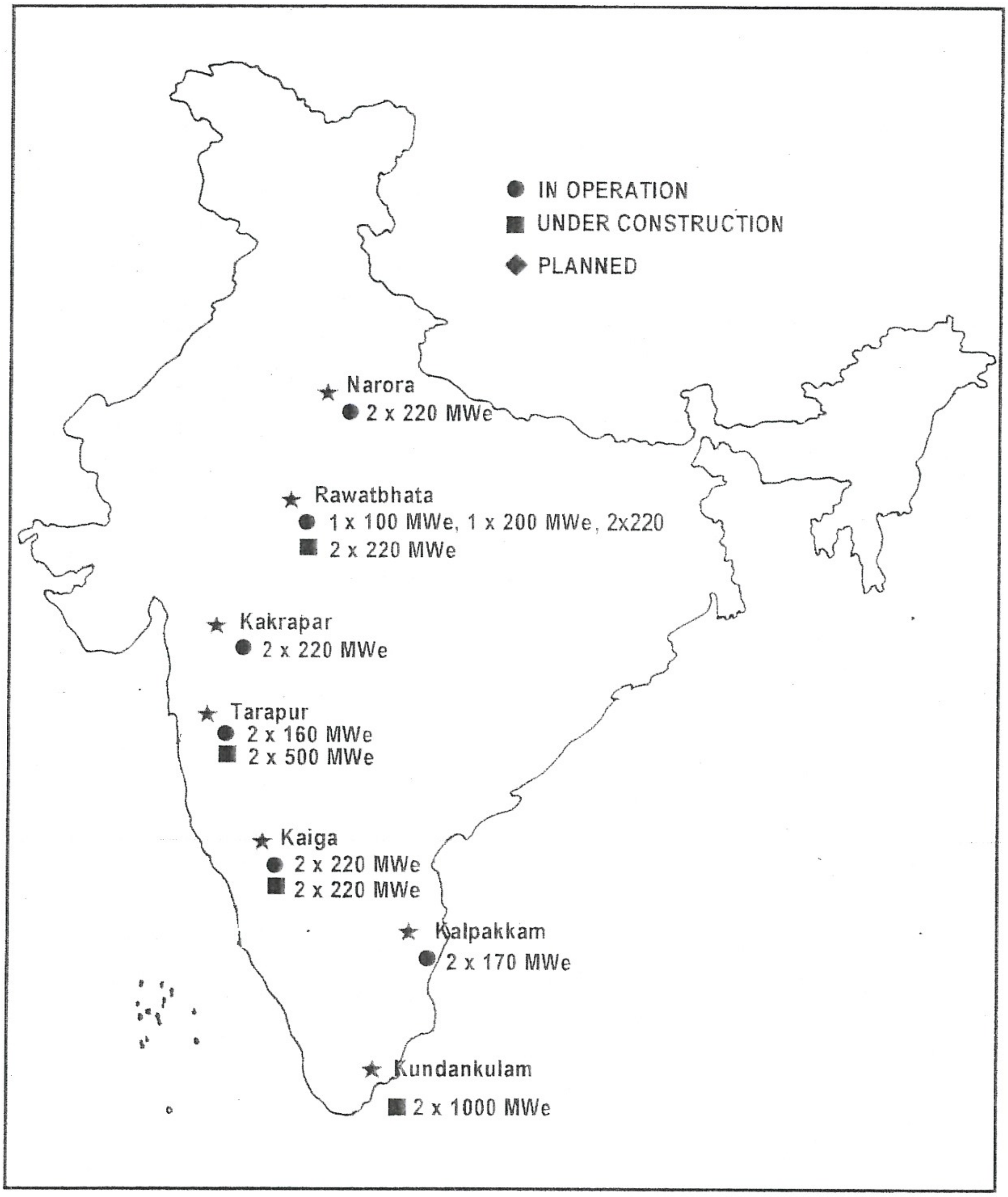
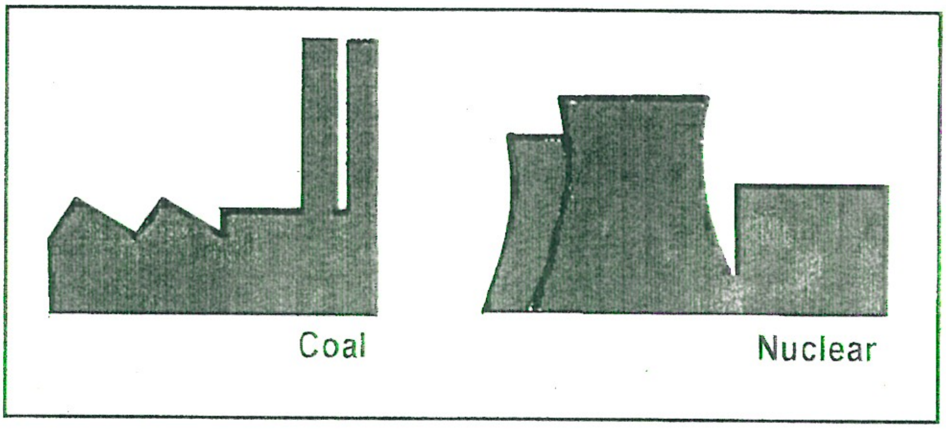


Fig. 1.1 : Map Showing Nuclear Power Plants in India



1,000 Megawatt Station			
Fuel use (in tons per year)		2,500,000	25
Wastes (in tons per year)	Ash	6,25,000	Used fuel 25
	CO_2	6,500,000	
	SO_2	9,000	
	NOx	4,500	

Source : IAEA paper in the 1989 World Energy Conference, Montreal

Fig. 1.2 : Nuclear Power and the Environment

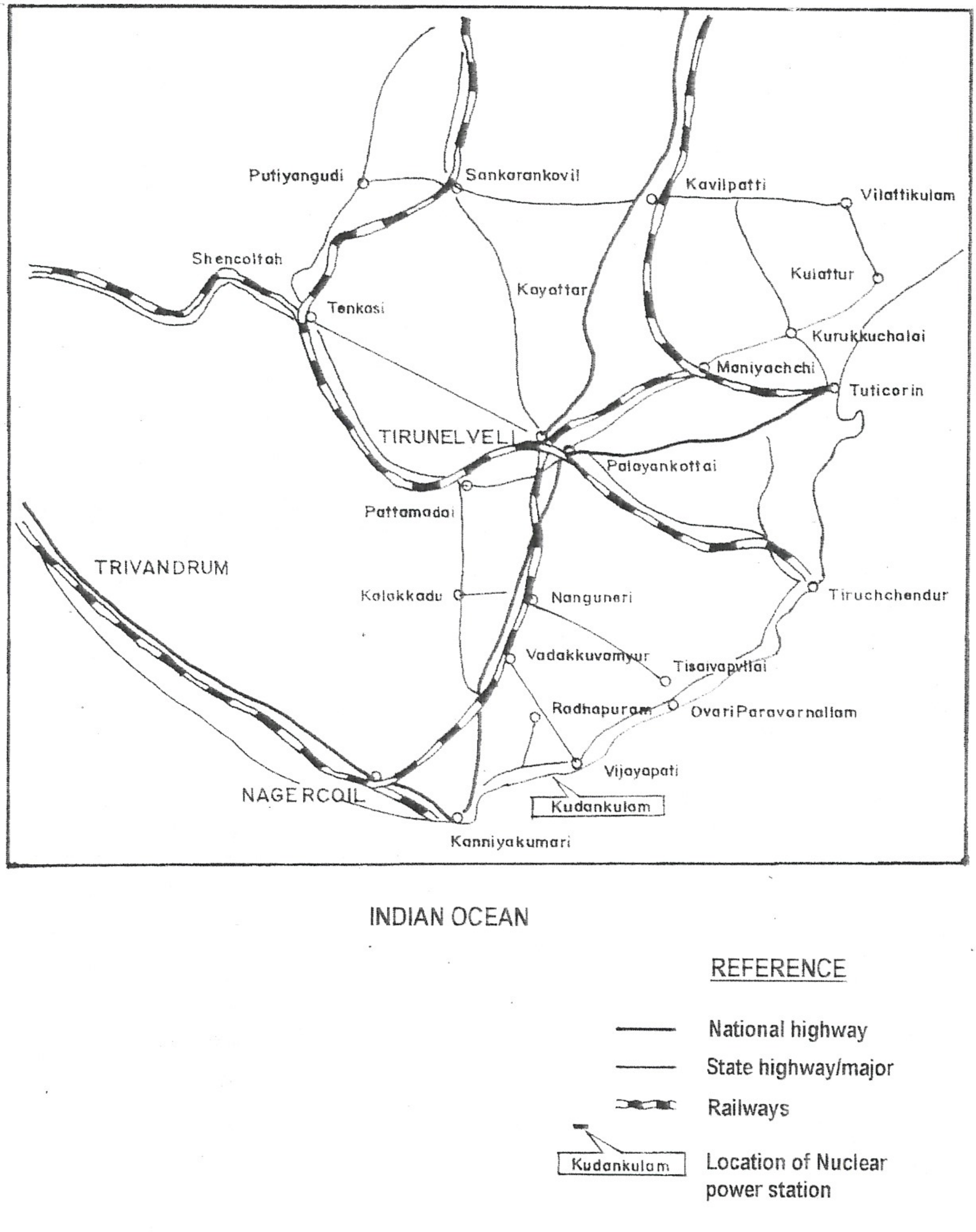
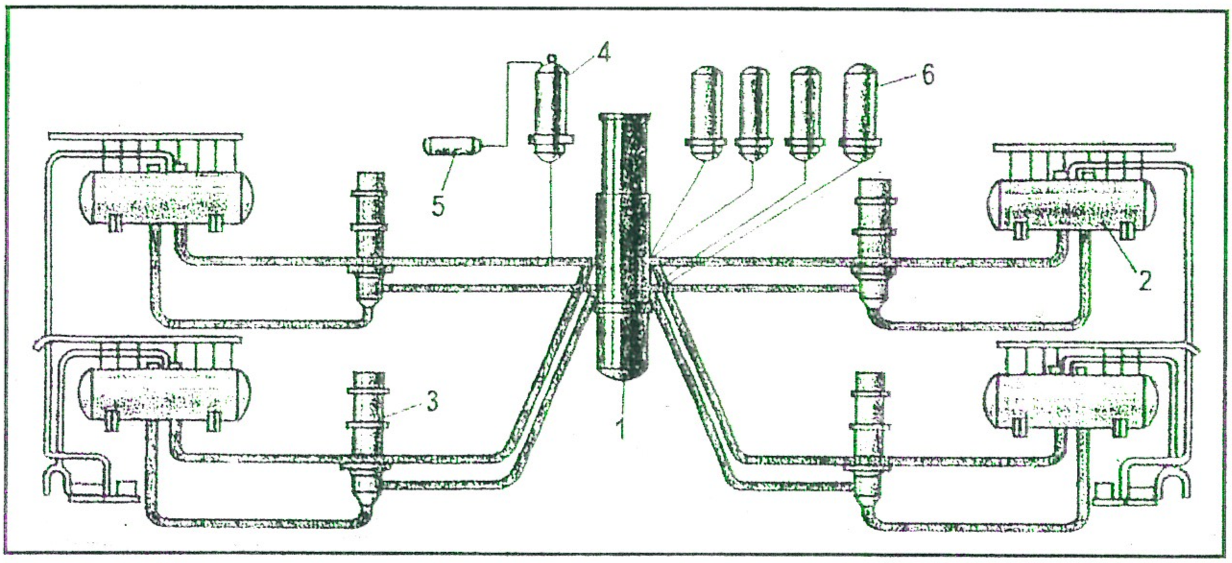


Fig. 1.3 : Location Plan for Kundankulam NPP Site



1- Reactor, 2-Steam generator, 3- Main circulating Pump, 4- Pressuriser,
5- Pressuriser Relief Tank and 6- Accumulator

Fig. 1.4 : Schematic Diagram of Reactor Plant

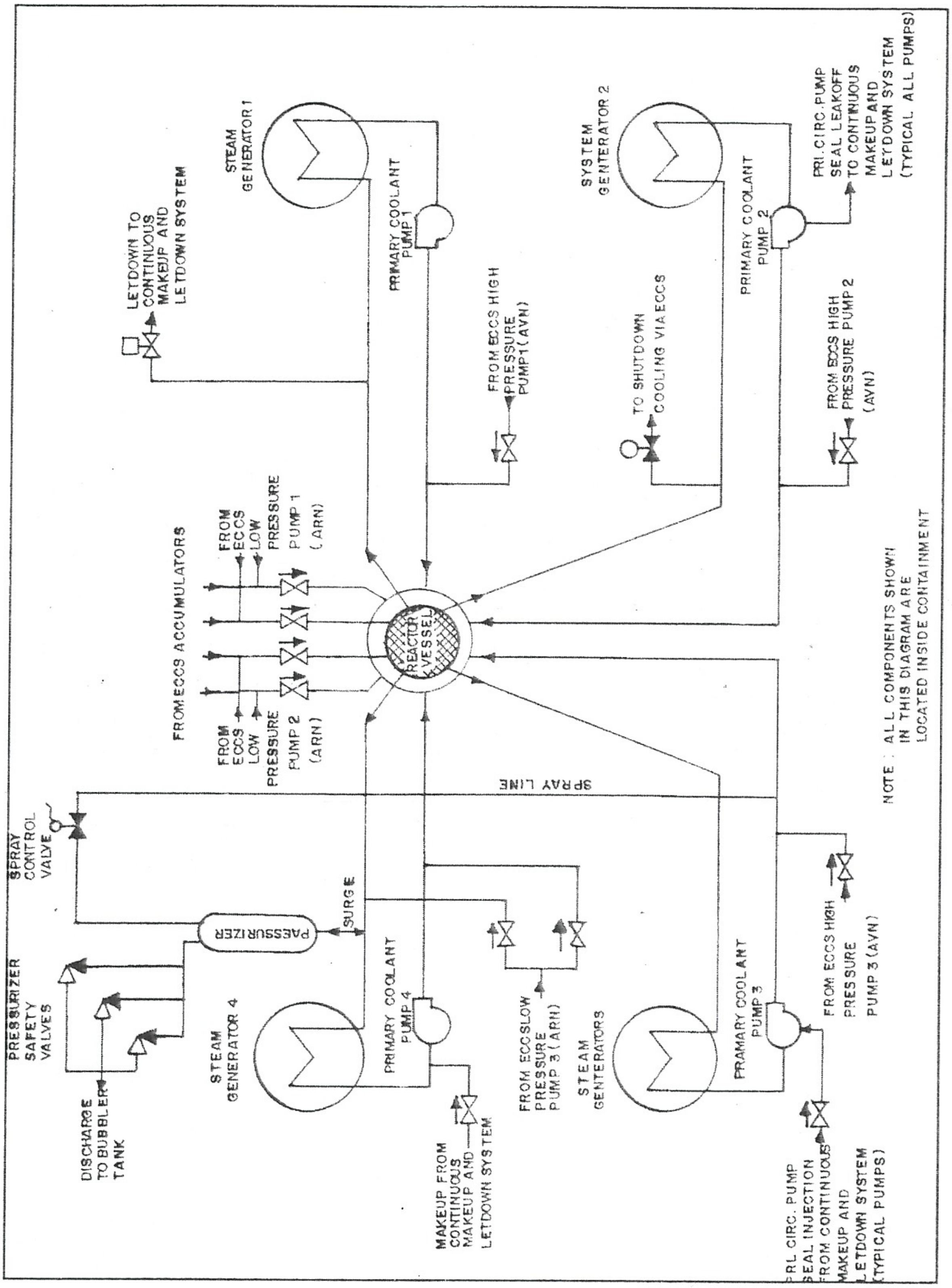


Fig. 1.5 : Simplified Diagram of VVER-1000 Reactor Coolant System

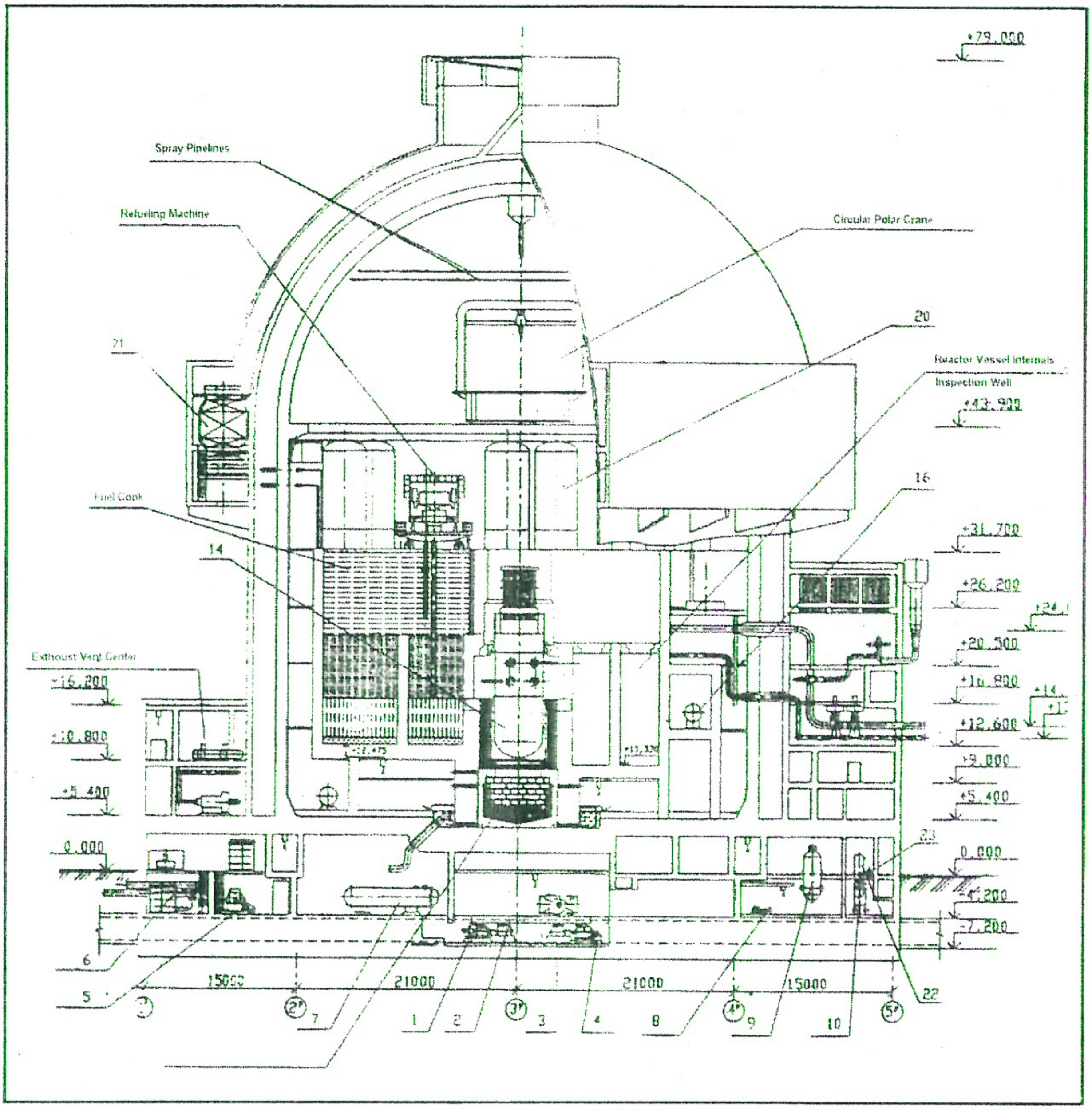


Fig. 1.6 : Containment and Process Safety Systems at NPP, Kudankulam

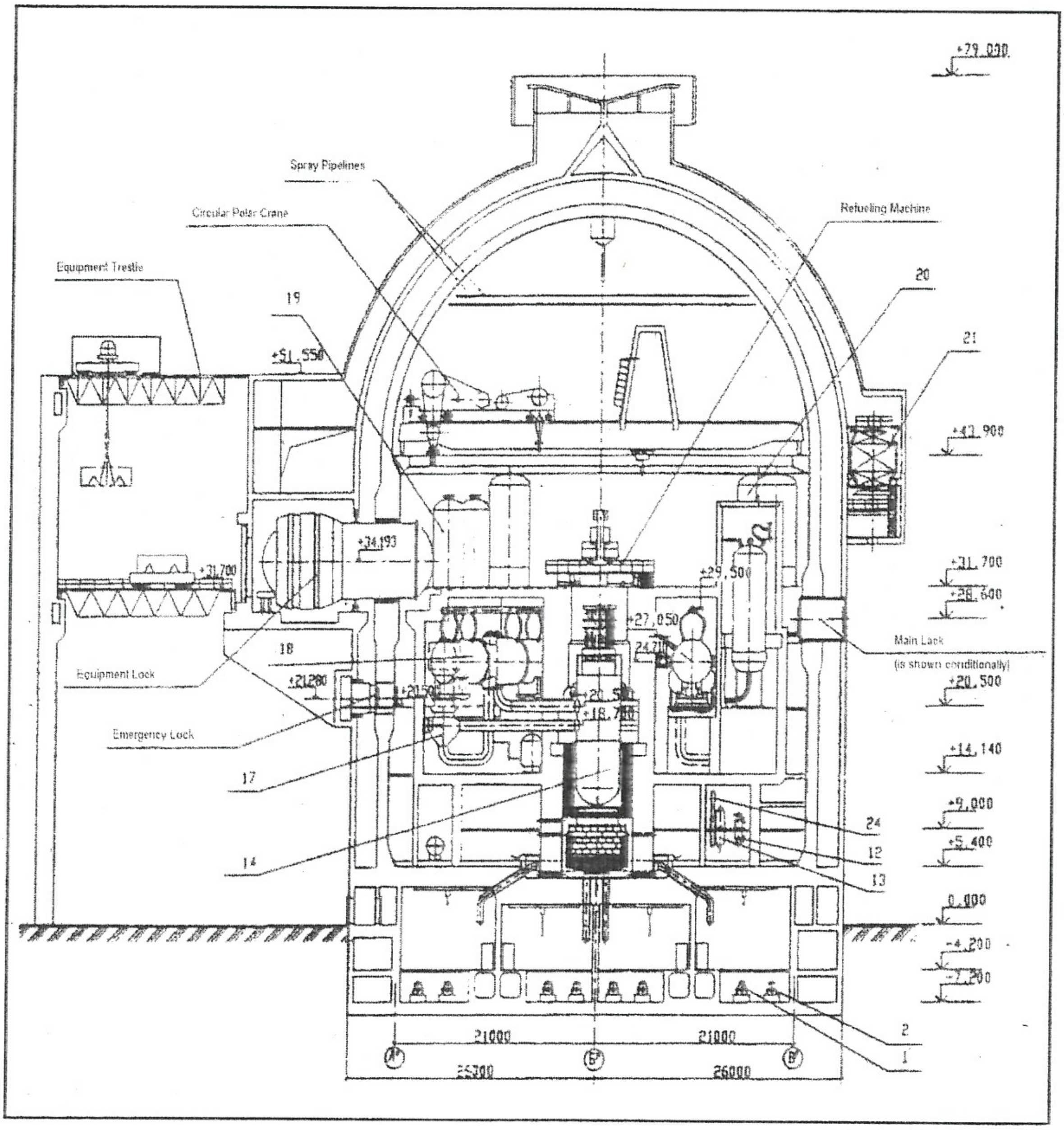


Fig. 1.7 : Containment and Process Safety Systems at NPP, Kudankulam

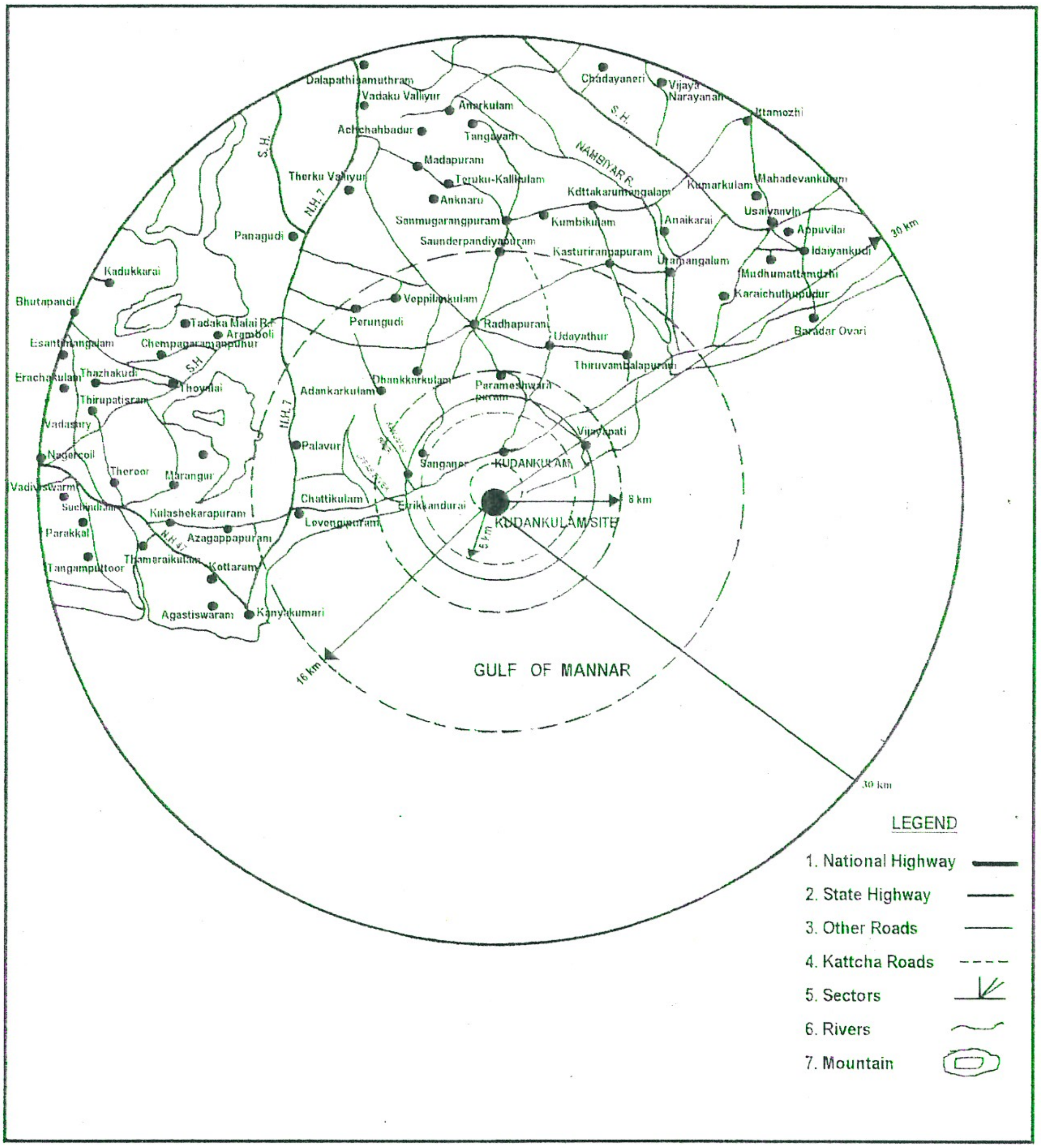


Fig. 1.8 : Impact Zone for EIA Study, NPP, Kunadankulam

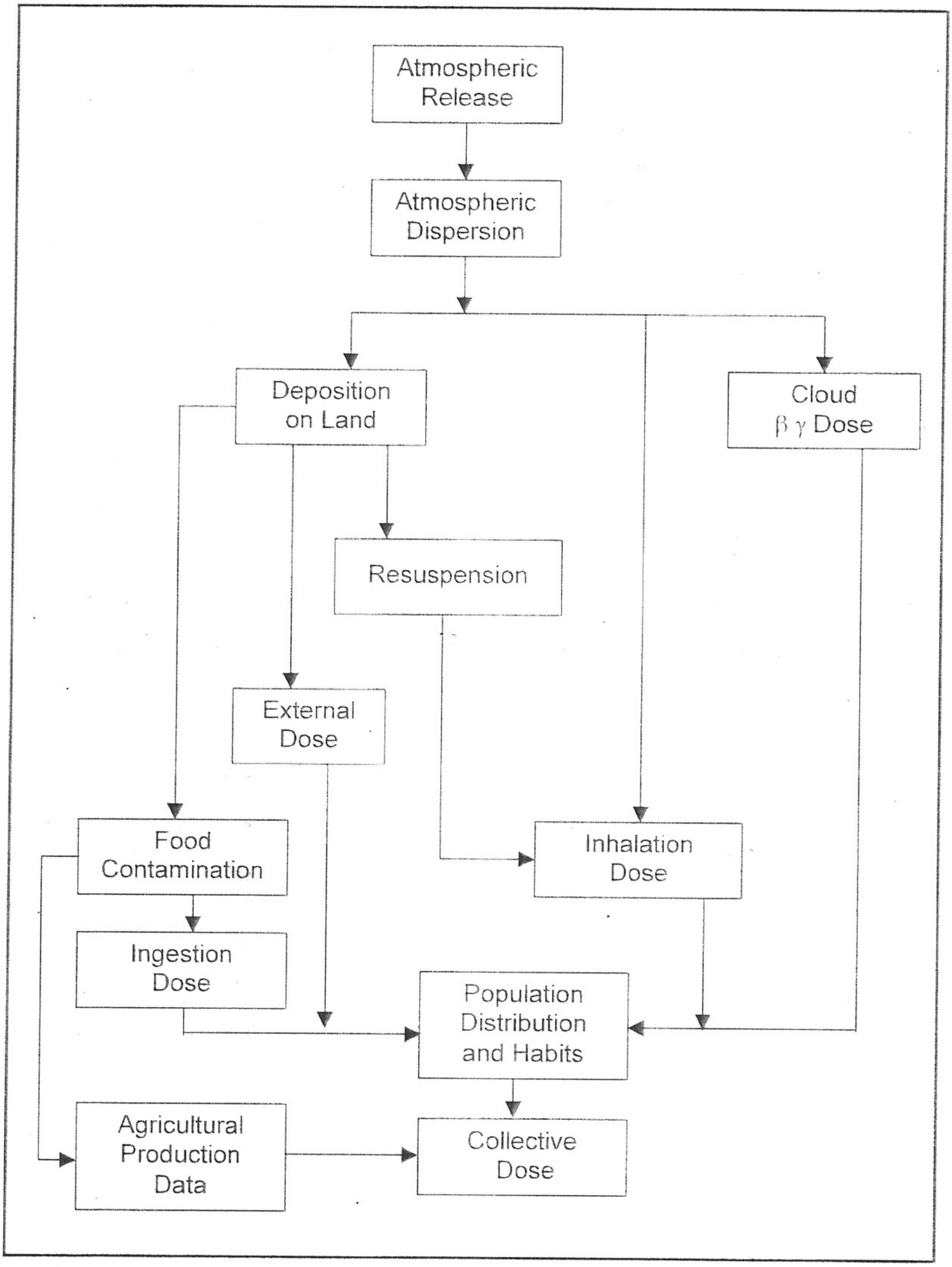


Fig. 1.9 : Exposure Pathways for Atmospheric Releases from NPP

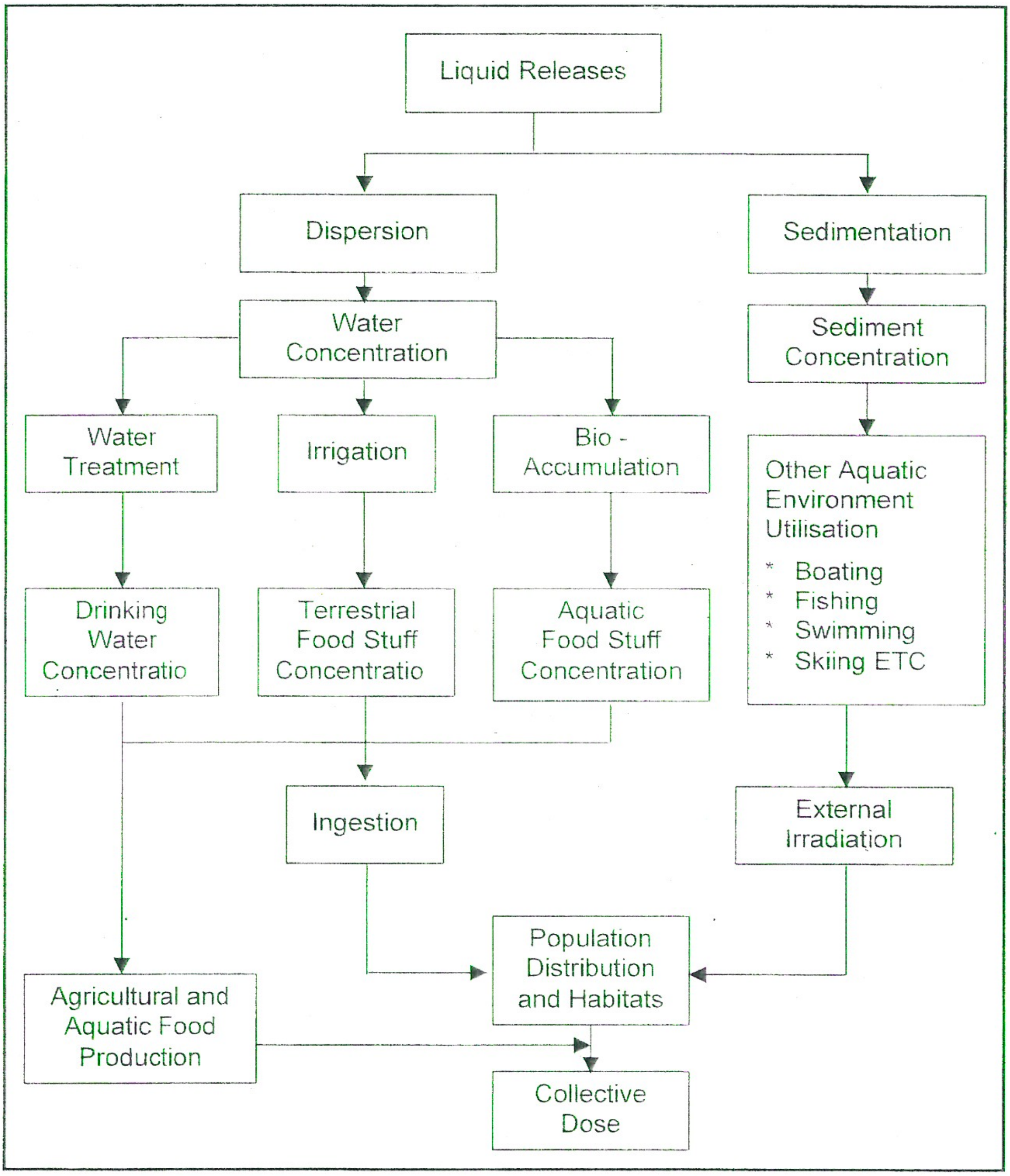


Fig. 1.10 : Exposure Pathways for releases by NPP to Aquatic Environment

Table 1.1

Indian Nuclear Power Programme

Category of Units	Capacity (MWe)	Cumulative Capacity (MWe)
Operational Units		
Tarapur (BWR)	2 x 160	320
Rajasthan	1 x 150 & 1 x 200	670
Madras	2 x 170	1010
Narora	2 x 220	1450
Kakrapar	2 x 220	1890
Rajasthan (Unit 3 and 4)	2 x 220	2330
Kaiga (Unit 1 and 2)	2 x 220	2770
Expansion Units under Construction		
Rajathan (Unit 5 and 6)	2 x 220	3210
Kaiga (Unit 3 and 4)	2 x 220	3650
Under Construction		
Tarapur (Unit 3 and 4)	2 x 500	4650
Kudankulam (Unit 1 and 2)	2 x 1000	6650

Reference:- NPCIL, Mumbai

Table 1.2

Comparison of Costs of Nuclear and Thermal Power Generation* (Commissioned in 1983)

Item	M. A. P. S. Unit - I 235 MWe	Singrauli S. T. P. S. (3 x 200 MWe) As located at Pithead	Singrauli S. T. P. S. (3 x 200 MWe) Notionally located 800 Kms from Pithead
Capital Cost (Rs. Lakhs)	11584	30375	
Capital cost (Rs. / KW)	4930	5060	
Unit Energy Price (P/KW)			
(a) IDC @ 7% and ROI 12%			
i) Generation 5500 KWH/KW (capacity factor 62.8%)	41.05 45.50 (1) 48.06 (2)	40.83	49.28
ii) Generation 6570 KWH/KW (capacity factor 75%)	35.16 38.89 (1) 42.16 (2)	37.14	45.59
b) IDC @ 7% and IRR 12%			
i) Generation 5500 KWH/KW (capacity factor 62.8%)	35.89	36.11	44.56
ii) Generation 6570 KWH/KW (capacity factor 75%)	30.85	33.14	41.59

Note :-

1) Actual gestation period and IDC at Govt. borrowing rates
2) Actual gestation period and IDC @ 7%

* Adopted from NPP, Narora EIA report, March 1992

Chapter 2
Baseline Environmental Status

Chapter 2

Baseline Environmental Status

2.1 Air Environment

The environmental impacts on ambient air quality from construction and operation of nuclear power plants, can be broadly classified into following three categories based on the nature of pollutants and their effects on surrounding population:

- Conventional pollution
- Radioactive pollution
- Thermal pollution

The baseline status of air environment with respect to above three types of pollution within the impact zone is essential and is also a primary requirement for impact assessment of proposed installation of the units 1 and 2 of the nuclear power plant under study. Such status would form a basis over which the anticipated impacts from proposed installation are super-imposed to derive final impacts on air environment.

Generally, the impact of conventional air pollutants viz. dust, chemical inorganic and organic gases, would be significant only during construction phase of the nuclear power plants since there is no possibility for emission of such pollutants during normal operation of these plants. However, knowledge about the prevailing background levels of Suspended Particulate Matter (SPM) and gaseous pollutants in the vicinity of nuclear power plant would be desirable.

The radioactive isotopes, once released into the atmosphere will undergo dispersion, dilution, transportation and deposition processes depending on prevailing meteorological conditions and affects surrounding population in the form of external and internal radiation doses following different routes. The extent of the radiological impacts depends on the physico-chemical properties of radioactive isotopes released into the atmosphere, their concentrations and the type of radiation. The effects of radioactive pollution are in the form of time integrated cumulative radiation dose over long periods.

2.1.1 Reconnaissance Survey

The ambient air quality depends upon the emission scenario, meteorological conditions and the background concentrations of the pollutants. The study on baseline ambient air quality status in the impact zone of the project is an essential and primary requirement for assessing the impacts on air environment due to proposed development activity. The study is necessary to identify environmentally significant issues prior to initiation of the proposed action as well as to enumerate the potential critical environmental changes likely to occur when the project is commissioned.

The baseline status of air environment includes identification of specific air pollution parameters expected to have significant impacts and assessing their existing levels in ambient air within the impact zone. The baseline status of air environment with respect to the identified conventional air pollutants can be accessed through air quality monitoring programme using methodically designed air monitoring network.

Micro-meteorological data collection is an indispensable part of any air pollution study. The meteorological data collected during ambient air quality monitoring is used for interpretation of baseline status and to simulate the meteorological conditions for prediction of impacts. The baseline studies for air environment within the impact zone were carried out through reconnaissance survey followed by ambient air quality monitoring programme and micro-meteorological study.

2.1.2 Design of Ambient Air Quality Monitoring Network

The studies on air environment consist of assessment of existing status of ambient air quality and collection of meteorological data to delineate the baseline status of the region. Representative selection of sampling locations is primarily guided by the topography and micro-meteorology of the region. A methodically designed ambient air quality monitoring (AAQM) network covering 10 sampling locations was designed using the following criteria:

- Persistence of wind direction and speed
- Representation of regional background
- Location of industries and their emission magnitude
- Inclusion of all the major conventional air pollution parameters

To establish the baseline status of air environment in the study area, 10 AAQM stations (7 for SPM, SO_2 and NOx and 3 for RSPM) were selected using network design criteria. The selected sampling stations are shown in **Figure 2.1.1 - 2.1.3.** The directions and distances of these stations during three seasons are reported in **Tables 2.1.1** to **2.1.3.** All the stations for monitoring of RSPM were located in downwind direction. Various site specific pollutants such as Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM), Sulphur Dioxide (SO_2) and Oxides of Nitrogen (NO_x) were identified as significant parameters for ambient air quality monitoring. The standard methods used for sampling and analysis of different pollutants during three seasons are summarised in **Table 2.1.4**.

The micro-meteorological data like wind speed, wind direction, temperature and relative humidity were collected for the study period through a weather station. The weather station was installed at the site keeping in view the free exposure of sensors to atmosphere with minimum interference from nearby structures.

2.1.3 Micro-meteorology

The micro-meteorological conditions at the proposed project site regulate the transport and diffusion of air pollutants released into the atmosphere. The principal meteorological variables are horizontal convective transport (average wind speed and direction), vertical convective transport (atmospheric stability, mixing height) and topography of the area. The data on surface meteorological parameters (wind speed and direction) in the study area were collected using portable weather monitoring station. The sensors of this equipment were kept at about 10m above ground level with free exposure to atmosphere. In addition, temperature and percentage humidity were also recorded simultaneously using a thermohygrometer.

Based on the meteorological data collected during three seasons wind rose diagrams have been prepared and these are presented in **Figures 2.1.4, 2.1.5 and 2.1.6** for summer, post-monsoon and winter season respectively.

During summer, the 24 hourly wind rose diagram shows the predominant winds are from W, SW and NW directions (**Figure 2.1.4**). The most prevailing wind speed class of 10-20 kmph occurred for about 55 % of the time followed by the range of 20-30 kmph, which occurred for about 23.4 % of the study duration. These high wind speed classes resulted in no calm condition being recorded in the region. During post monsoon season, the predominant wind directions were observed to be N, SE and NE. The most prevailing wind speed class of 10 - 15 kmph occurred for 21.6% of the time followed by the range of 1-5 kmph, which occurred for 20.3% of the study period. (**Figure 2.1.5**).

During winter season the predominant winds were from W (65.6%) and SW (30.9%) directions. The most prevailing wind speed class of 15-20 kmph occurred for about 38.9% of the time, which was followed by the range of 10-15 kmph occurring for 25.6% of the study duration. (**Figure 2.1.6**).

The average temperature recorded during summer season varied from 28.6-31^{O}C with a maximum temperature of 40^{O}C and minimum of 26^{O}C during the day and night time respectively. The average relative humidity (%) varied in the range of 71.6-96.4 % with maximum and minimum values of 100 % and 43 % respectively (**Table 2.1.5**).

During post - monsoon season (**Table 2.1.6**) maximum temperature observed was 40 ^{0}C while the minimum temperature was 23 ^{0}C. Average temperature varied between 25.3 ^{0}C and 28.4 ^{0}C. The average relative humidity was in the range of 81.6 to 100 %, wheras maximum and minimum values of relative humidity was 100% and 45% resepectively. During winter season (**Table 2.1.7**) the average temperature recorded during the study period ranged between 30 - 33 °C with a maximum and minimum temperatures of 42 °C and 27 °C during daytime and night time respectively. The average relative humidity varied from 79 to 95% with maximum and minimum values of 100% and 40% respectively.

2.1.4 Ambient Air Quality Survey

Since there are no industrial activities existing within the impact zone, it was decided to conduct AAQM study for a short period. The ambient air quality monitoring was carried out for a period of two weeks during summer, post-monsoon and winter season to assess the ambient air quality status in the region. At all these sampling stations SPM, as well as gaseous pollutants like SO_2 and NO_x were monitored on 24 hourly basis. Respirable suspended particulate matter was monitored at a few selected stations in each season. The data collected was subjected to statistical analysis to arrive at various percentile values.

2.1.5 Suspended Particulate Matter (SPM)

During summer season, higher SPM concentrations were observed at Uramangalum (135 μg/ m^3) and Vijayapathy (127 μg/ m^3) due to predominant high wind speed towards this area. In general, the average SPM concentrations in the study area varied from 31 - 94 μg/ m^3 and the highest average SPM concentration occurred at Vijayapathy site (94 μg/ m^3) (**Table 2.1.8**). The 98th percentile values of SPM were below the CPCB standard of 200 μg/ m^3 at all the stations. Frequency distribution levels of SPM in the study area indicate that maximum number of values fall in the range of 23 – 84 μg/ m^3.

During post monsoon season, higher SPM concentrations were observed at Erukkanthorai (152 μg/m^3) and Ovari (122μg/m^3) due to predominant high wind speed towards these villages. In general, the average SPM concentrations in the study area varied from 60 - 97 μg/m^3 and the highest average SPM concentration occurred at Erukkanthorai (97 μg/m^3). The 98th percentile values of SPM at all the sampling stations were below the CPCB standard of 200 μg/m^3. Frequency distribution levels of SPM indicate that maximum number of values fall in the range of 57 - 90 μg/m^3 (**Table 2.1.9**).

During winter season, higher SPM concentration were observed at Vijayapathy (98μg/m^3) and Ovari (97 μg/m^3) due to predominant wind speed towards these stations. In general the average SPM concentrations in the study area varied from 25 - 84 μg/ m^3 with highest average SPM concentration occurring at Ovari (84 μg/m^3). As regards the 98th percentile values, these were well within the CPCB limit of 200 μg/m^3 at all the sampling stations. Frequency distribution levels of SPM in the study area indicate that maximum number of values fall in the range of 22 - 85 μg/m^3 (**Table 2.1.10**)

2.1.6 Respirable Particulate Matter (RSPM)

During summer season, RSPM concentration was measured at 3 stations viz., Kudankulam, Thiruvambalapuram and Perungudui and all of them were established in downwind direction (**Table 2.1.8**). The average concentration varied in the range of 16-26 μg/ m^3 at these locations. The 98th percentile values at these locations (24-44μg/m^3) were well below the National Standards set up by CPCB (**Annexure I**).

During post-monsoon season, RSPM concentrations were monitored at 2 location namely Kudankulam and Agastiswaram. Average concentrations of RSPM at these locations were 77 and 83 μg/m^3 respectively. The 98th percentile values at these locations were below CPCB prescribed limit of 100 μg/m^3 (**Table 2.1.9**).

During winter season RSPM concentrations were monitored at 2 locations, viz. Kudankulam and Chettikulam. The average concentration varried in the range of 19-27 µg/ m^3 and the 98th percentile values were well within the National Standards set-up by CPCB (100µg/ m^3) (**Table 2.1.10**).

2.1.7 Sulphur Dioxide (SO_2)

The maximum concentration of sulphur-di-oxide (during summer season) was observed as 19 µg/ m^3 at Ovari site (**Table 2.1.11**). The average concentrations of SO_2 in the study area ranged from 6 – 10 µg/m^3 and the highest average concentration was observed at Ovari site (10 µg/m^3). The data reveals that at all the stations, SO_2 levels (98th percentile) are below 30 µg/m^3 (CPCB Standard for sensitive area **Annexure I**).

During post - monsoon season, maximum concentration of SO_2 was observed at Udayathur (10 µg/m^3) and highest average SO_2 concentration occurred at Udayathur site (7 µg/m^3). The 98th percentile values at all the stations were 6 µg/m^3 except at Udayathur where it was 10 µg/m^3 (**Table 2.1.12**).

During winter season the concentrations of SO_2 at all the stations were below the detectable limit of 6 µg/m^3 (**Table 2.1.13**)

2.1.8 Oxides of Nitrogen (NOx)

The 98th percentile values of NO_x during summer season indicate that at all the stations the observed concentrations are below 30 µg/m^3 (CPCB standard for sensitive areas) and varied from 3-23 µg/ m^3. The average NO_x levels observed during the study period showed little variance at all the stations (3-11 µg/m^3). The maximum concentrations were also observed to be below the CPCB prescribed limit (**Annexure I**) at all the stations in the study region as reported in **Table 2.1.14**.

During post- monsoon season, the 98th percentile values of NOx indicate that at all the stations, the observed concentrations were below 30µg/m^3 which is a prescribed limit of CPCB for sensitive areas and varied from 3 - 14µg/m^3. The average NOx levels varied in the range of 3-7µg/m^3 with the maximum concentration of 7µg/m^3 occurring at Kudankulam and Agatiswaram. However, this concentration is well within the limit of 30 µg/m^3 (**Table2.1.15**).

During winter season, the 98th percentile values of NOx indicate that at all the stations, these values were either equal to or less than the minimum detectable limit of 3 μg/m^3 except at Erukkonthorai where it was 4 μg/m^3. These values including the average concentrations are well within the CPCB standard limit of 30 μg/m^3 (**Table 2.1.16**).

2.1.9 External Radiation Field

The background radiation levels due to natural and fall out activity were measured by BARC within a radial distance of 30 km at 36 locations in October 2000 and at 61 locations in May 2001. The results are presented in **Table 2.1.17** and **Table 2.1.18** respectively. The background gamma radiation field was found to vary from 0.03 mSv/hr to 3.00 μSv/hr. The maximum gamma radiation field was observed at Vatakotai beach, where black patches were observed. Higher background areas, are generally on the beach, where black patches of Monazite could be clearly seen. Kalpakkam site is reported to have a background radiation field of 0.20 μSv/hr to 4.0 μSv/hr. It has been reported that there are monazite sand patches in the coastal areas of Kerala and Tamil Nadu, having thorium concentrations ranging from 8% to 10.5% by weight.

2.1.10 Underground Gamma Radiation Fields

Four bore wells were being bored during the survey in October 2000 at KK site. The opportunity was used to measure the under ground radiation field up to 10m depth using ultra sensitive micro R Surveymeter with 10 m probe leads. Up to 6 m depth, the field was varying in the narrow range of 0.08 - 0.11 μSv/hr, in the depth rage of 7-9 m the variations ranged between 0.07 - 0.10 μSv/hr and at 10 m depth the variations ranged between 5-7 μSv/hr. The data in respect of borewell 1 and 2 is reported in **Table 2.1.19**. Locations of borewell 1 and 2 are shown in **Figure 2.1.7**. Visual observation of the core sample indicated that up to 15 m depth, there is soil and between 20 - 130 m, it is rocks and beyond, it is fine soil.

2.1.11 Depth Profile of natural Radioactivity

Soil rock powder samples were collected from different depths of a bore-hole at Kudankulam site. 20 samples collected from different depths up to 200 meter depth were analyzed for gamma ray spectrometrically. The concentrations of samples collected from different depths are presented in **Table 2.1.20**. It has been observed that below 5 meter layer, ^{232}TH and ^{238}U concentrations were quite low.

2.1.12 Radioactive Wastes through Air Route

The sources of geseous radioactive waste likely to be produced during the operation of the reactors at Kudankulam are as follows:

- Degassing of the primary coolant in the deaerator of volume control system
- Nitrogen blow offs from the equipments containing radioactive noble gases - Bubbler tank, sumps for collection of uncontrolled leak, nuclear sampling equipment, and equipments (tanks) located in reactor auxiliary building.

Radioactive gas treatment facility will have two systems:

- System for burning hydrogen from process blow offs:
- Radioactive gas purification system

Radioactive gas purification system has been designed to reduce the activity of process blow offs coming from hydrogen burning system and from other tanks containing radioactive media to admissible levels. After purifying through absorbing filters, the gases would be discharged in to the atmosphere through 100 m tall ventilation stack.

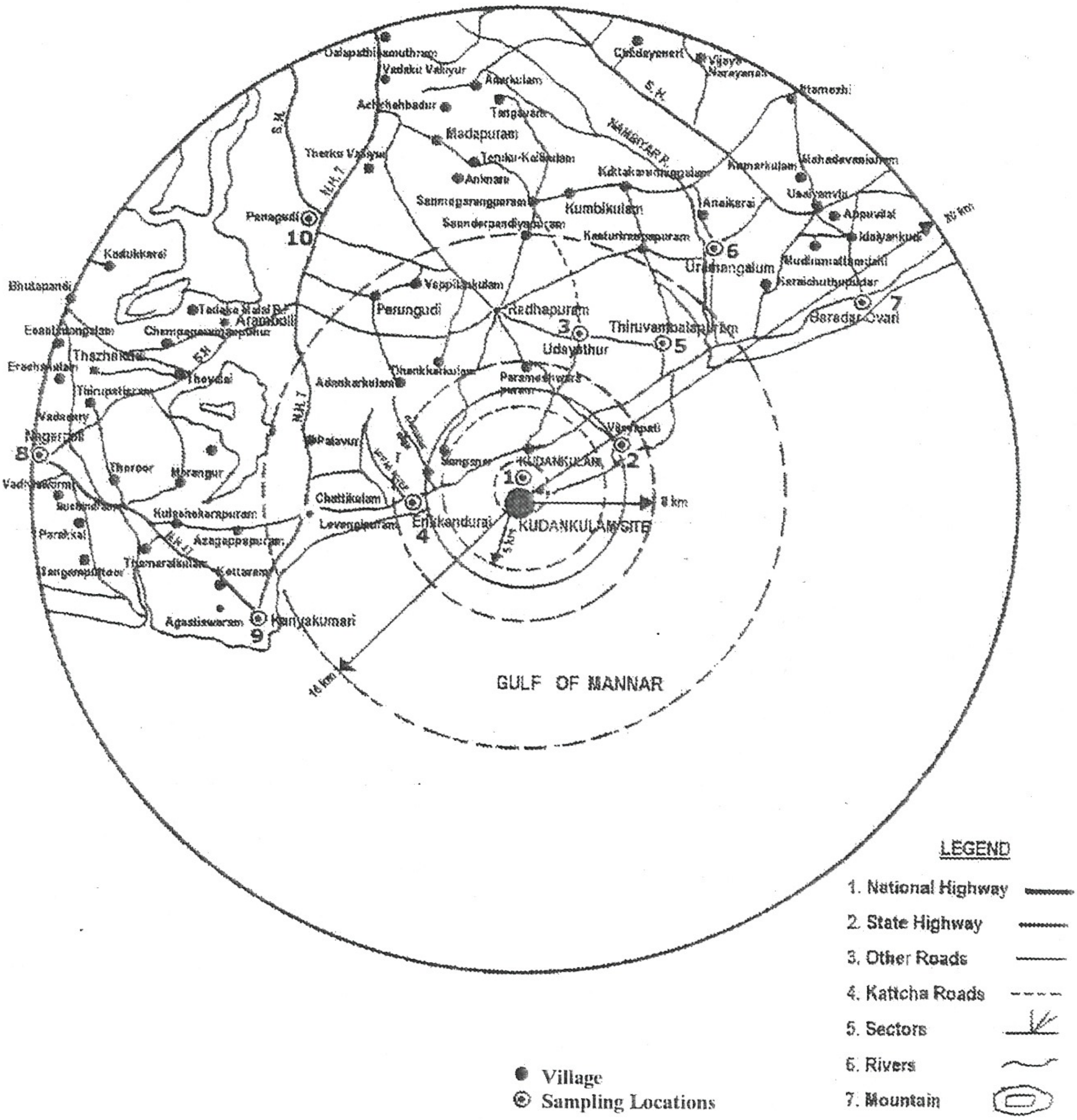


Fig. 2.1.1 : Locations of Ambient Air Quality Monitoring Stations in KK-Project Study Area (Summer seaon)

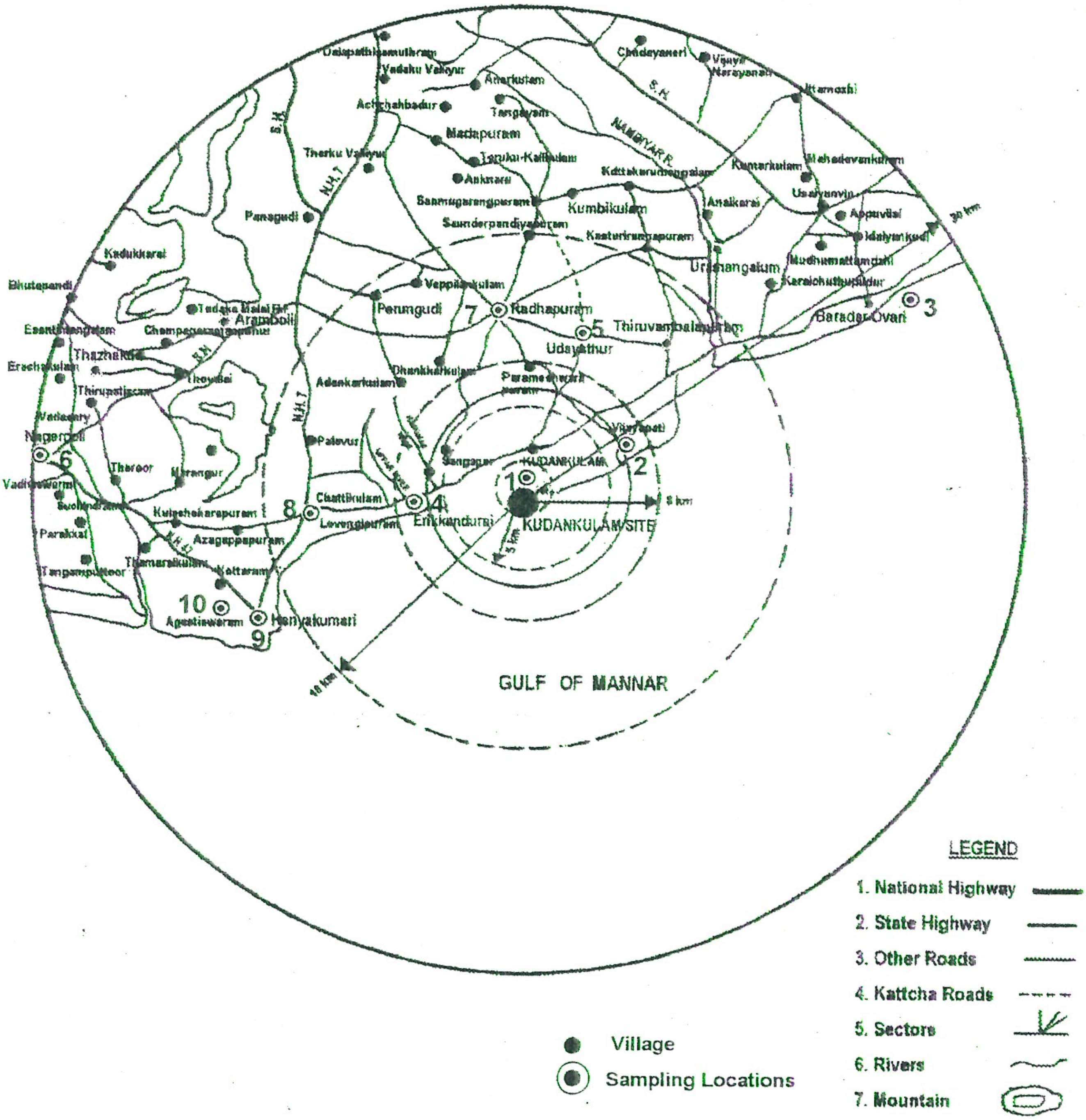


Fig. 2.1.2: Locations of Ambient Air Quality Monitoring Stations in KK-Project Study Area (Post - monsoon season)

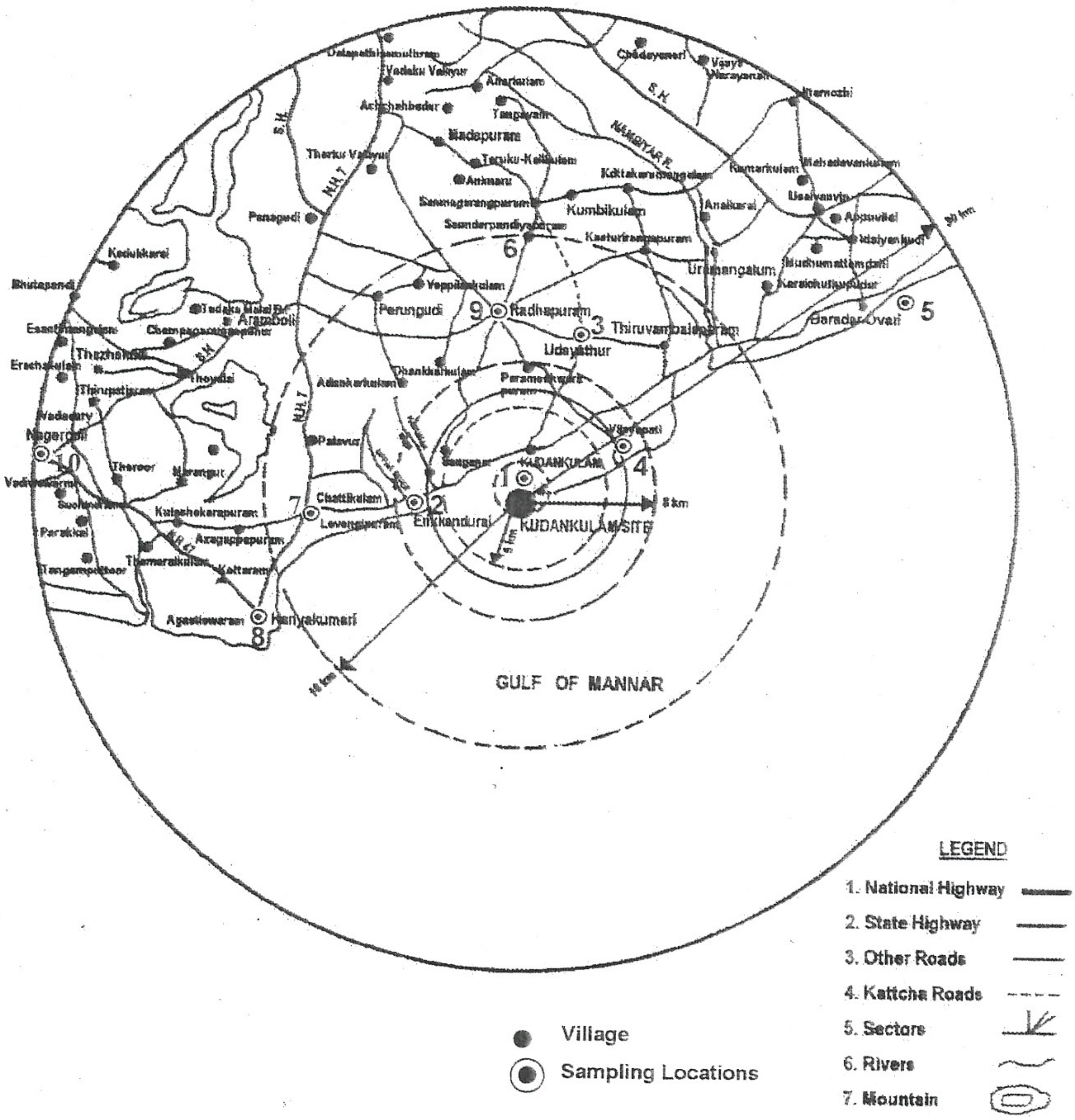


Fig. 2.1.3: Locations of Ambient Air Quality Monitoring Stations in KK-Project Study Area (Winter season)

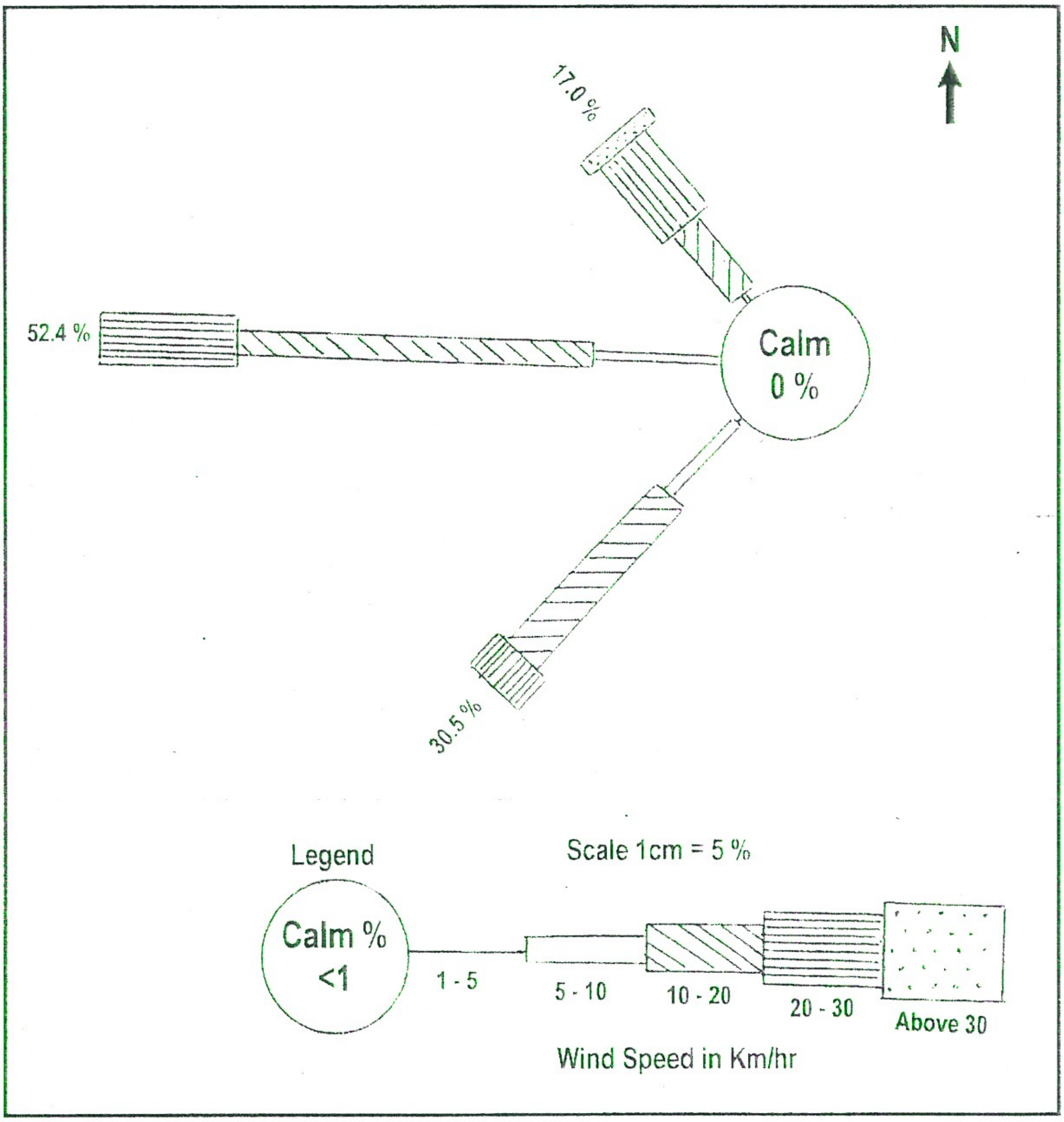


Fig. 2.1.4 : Wind Rose Diagram for Kudankulam NPP Study Area (Summer Season)

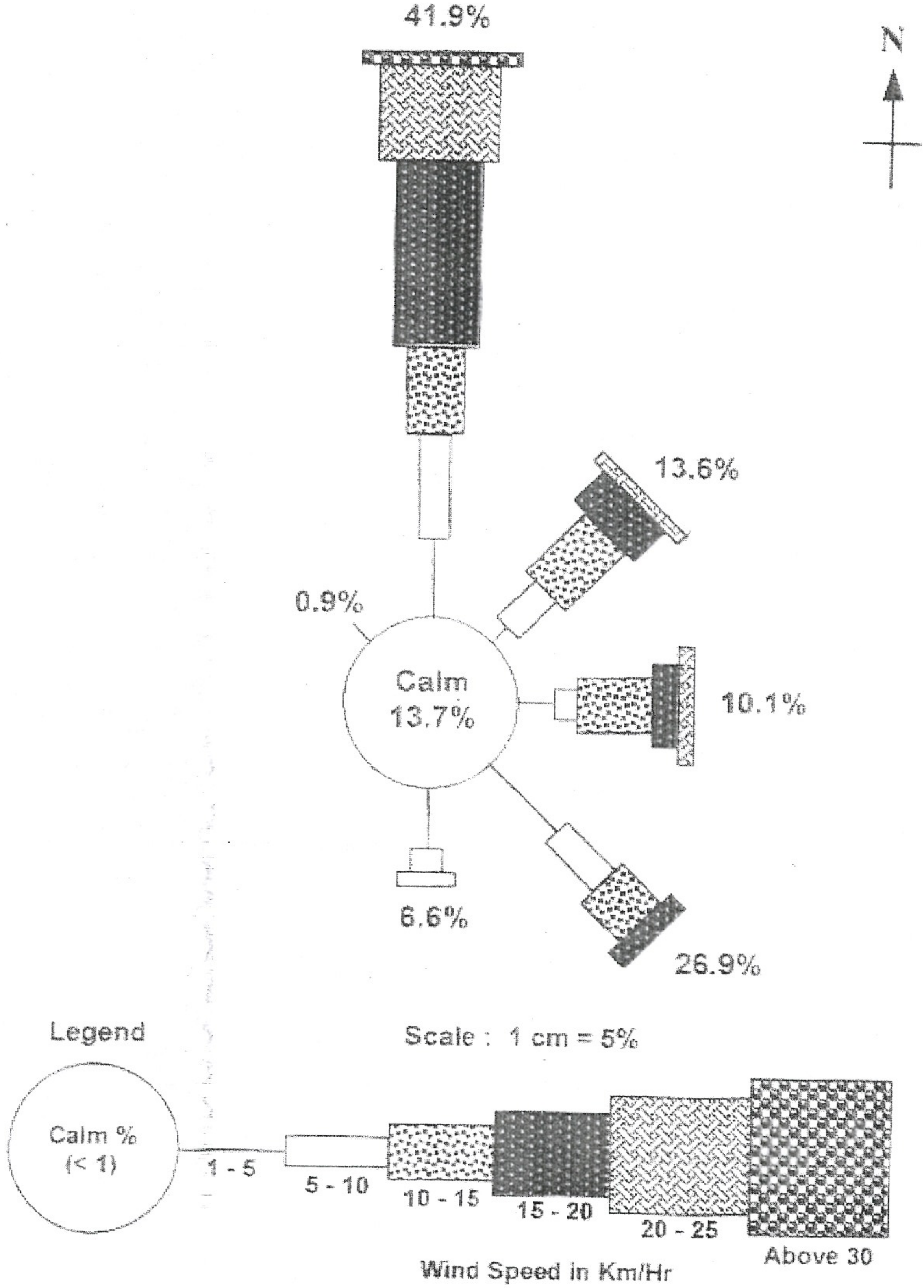


Fig. 2.1.5: Wind Rose Diagram for Kudankulam NPP (Study Area) (Post-monsoon season)

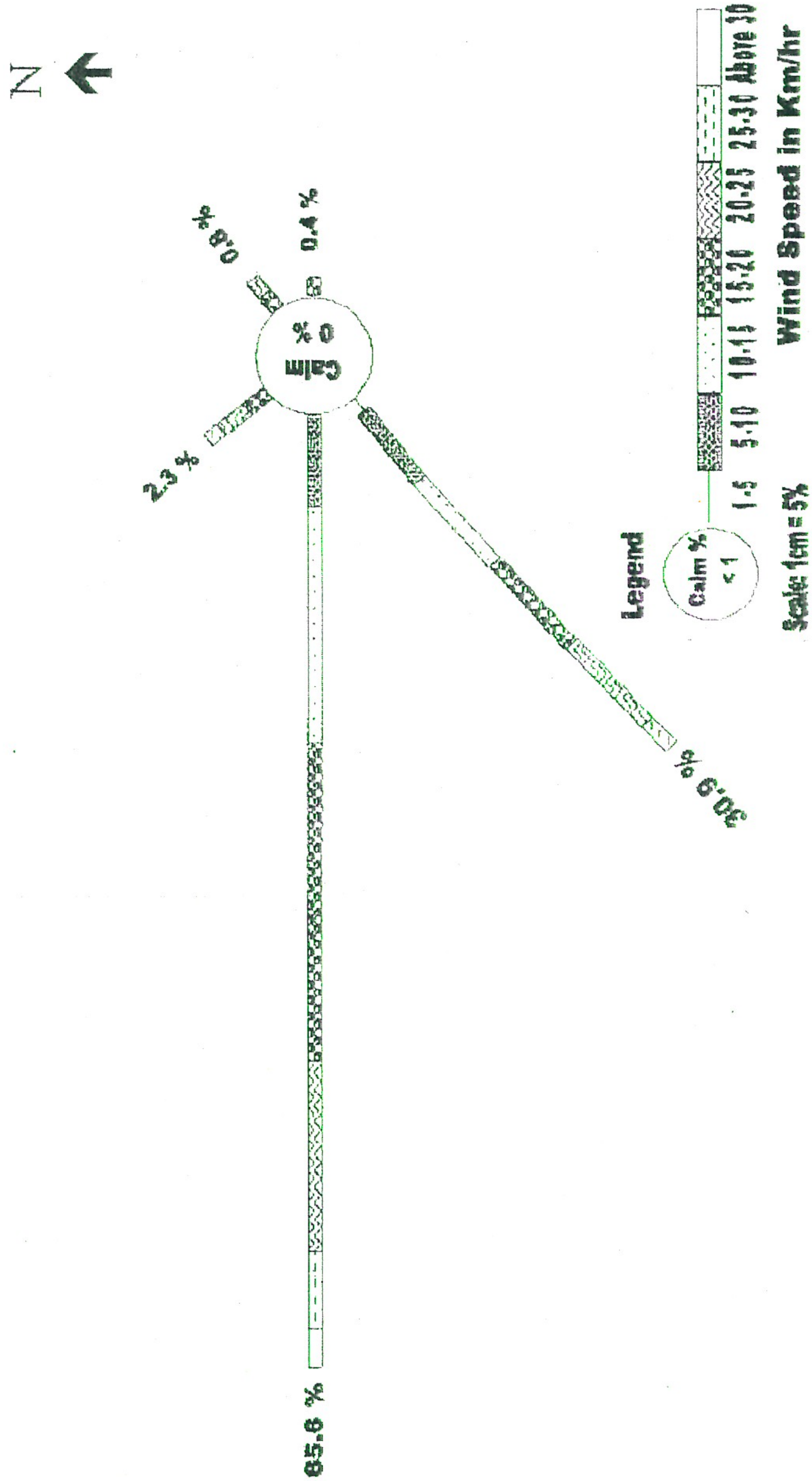


Fig. 2.1.6: Wind Rose Diagram for Kudankulam NPP (Study Area) (Winter season)

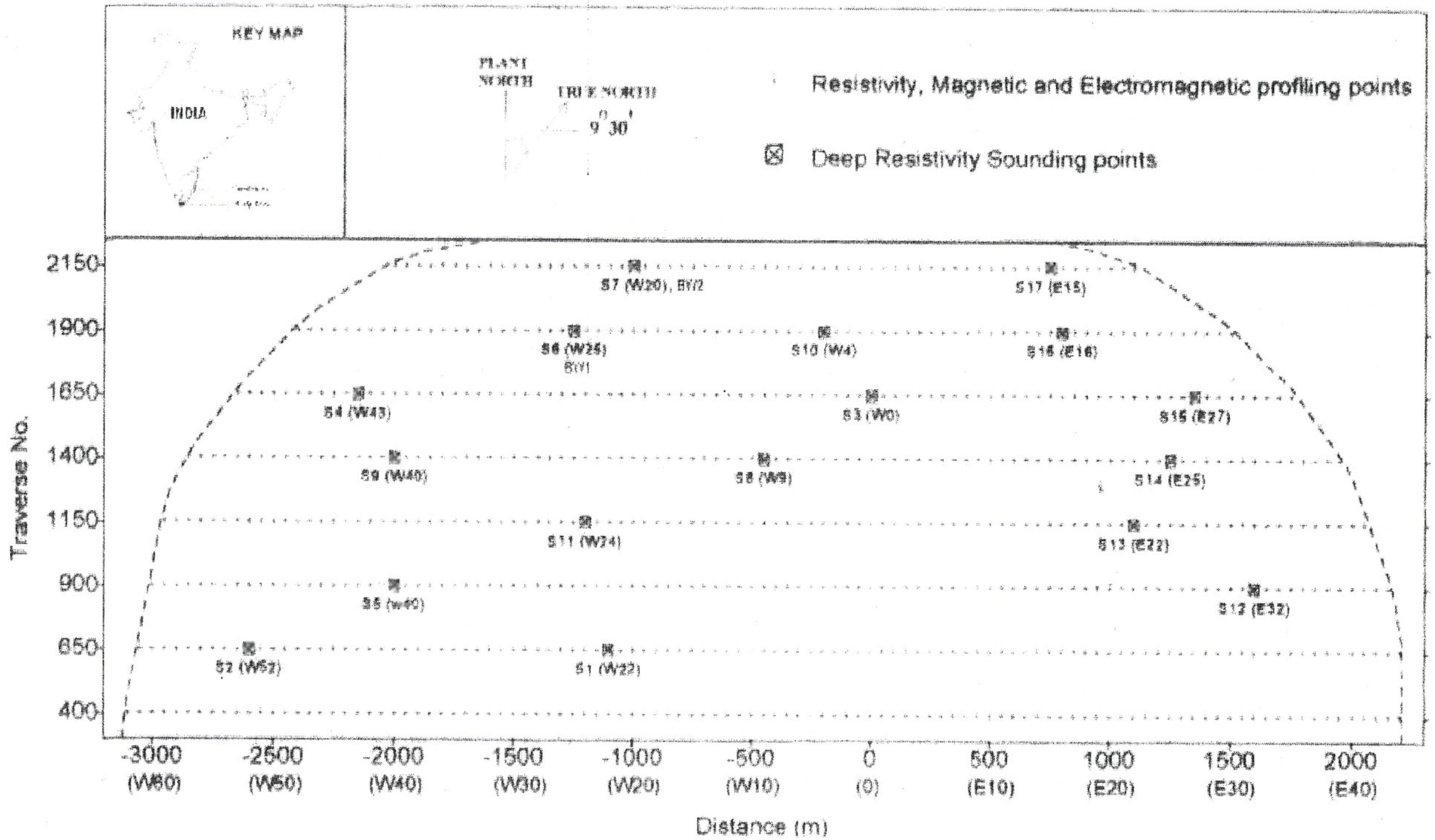


Fig. 2.1.7 : The base map showing measurement points of Integrated Geophysical Investigation, with travers spacing of 250 m and station interval of 50 m alongwith Locations of Borewell 1 and Borewell 2 i Kundankulam area, Tamil Nadu

Table 2.1.1

Ambient Air Quality Monitoring Stations (Summer Season)
(Location and Bearings)

Sr. No.	Sampling Location	Direction*	Distance* (Km)
1.	Kudankulam (Project site)**	-	-
2.	Vijayapathy	ENE	6.5
3.	Udayathur	NNE	8.8
4.	Erukkanthorai	WNW	6.5
5.	Thiruvambalapuram**	NE	12.3
6.	Uramangalum	NE	19.3
7.	Ovari	ENE	23.5
8.	Nagarcoil	W	30.0
9.	Kanyakumari	WSW	18.6
10.	Perungudi**	NW	15.6

* Direction and distances are with respect to Project Site

** Sampling stations for RSPM monitoring

Table 2.1.2

Ambient Air Quality Monitoring Stations (Post-monsoon Season)
(Location and Bearings)

Sr. No.	Sampling Location	Direction *	Distance *
1	Kudankulam Project site **	-	-
2	Vijayapathy	ENE	6.5
3	Ovari	ENE	23.5
4	Erukkanthorai	WNW	6.5
5	Udayathur	NNE	8.8
6	Nagarcoil	W	30
7	Radhapuram	N	11.2
8	Chettikulam	W	10
9	Kanyakumari	WSW	18.6
10	Agastiswaram **	WSW	22.0

* Direction and distances are with respects to project site

* * Sampling stations for RSPM monitoring

Table 2.1.3

Ambient Air Quality Monitoring Stations (Winter Season) (Location and Bearings)

Sr. No.	Sampling Location	Direction *	Distance *
1	Kudankulam Project site **	-	-
2	Erukkanthorai	WNW	6.5
3	Udayathur	NNE	8.8
4	Vijayapathy	ENE	6.5
5	Ovari	ENE	23.5
6	Soundarapandiyapuram	NNE	17.7
7	Chettikulam **	W	10
8	Kanyakumari	WSW	18.6
9	Radhapuram	N	11.2
10	Nagarcoil	W	30

* Direction and distances are with respects to project site

* * Sampling stations for RSPM monitoring

Table 2.1.4

Techniques Used in Ambient Air Quality Monitoring

Parameter	Technique / Method	Minimum Detectable Limit ($\mu g/m^3$)
Sulphur Dioxide (SO_2)	Colorimetric (West and Gaeke method)	6
Nitrogen Oxides (NO_x)	Colorimetric (Modified Jacob & Hocheiser method)	3
Suspended Particulate Matter (SPM)	Gravimetric (High Volume Sampler)	1

Table 2.1.5

Climatological Data at Kudankulam Project Site (Summer Season)

Day of Measurement	Temperature, (°C)			Relative Humidity, (%)		
	Max.	Min.	Avg.	Max.	Min.	Avg.
1	40.0	28.0	31.0	80	43	72.2
2	33.0	28.0	30.1	80	65	71.6
3	31.5	29.0	30.0	93	73	83.5
4	30.5	28.0	29.2	92	85	88.5
5	33.0	28.0	28.9	100	80	94.2
6	30.0	26.0	28.6	100	89	96.4
7	30.0	27.0	29.0	98	88	94.7
8	30.0	28.0	29.5	93	87	90.7
9	31.5	28.0	30.2	95	85	90.6
10	32.0	28.0	29.2	100	80	90.1
11	32.5	30.0	29.8	95	82	89.3
12	32.0	29.0	29.6	95	76	87.5
13	32.0	28.0	30.0	98	85	88.9
14	35.0	27.0	30.1	98	54	85.8

Table 2.1.6
Climatological Data at Kudankulam Plant Site
(Post-monsoon Season)

Day of Measurement	Temperature, (°C)			Relative Humidity, (%)		
	Max.	Min.	Avg.	Max.	Min.	Avg.
1	36.0	24.0	27.6	100	55	81.6
2	29.0	24.0	27.0	99	76	88.6
3	30.0	24.0	26.8	100	80	90.8
4	29.0	23.0	26.2	100	85	89.3
5	40.0	23.0	28.4	100	45	86.1
6	33.0	24.0	27.8	100	77	90.0
7	31.0	24.0	28.0	100	73	87.6
8	31.0	25.0	27.8	100	62	84.5
9	31.0	25.0	27.2	100	72	91.7
10	28.0	25.0	26.7	100	85	94.0
11	27.0	24.0	25.3	100	100	100

Table 2.1.7

Climatological Data at Kudankulam Plant Site (Winter Season)

Day of Measurement	Temperature, (°C)			Relative Humidity, (%)		
	Max.	Min.	Avg.	Max.	Min.	Avg.
1	37	29.0	31.8	100	70	93
2	40	29.5	31.5	100	51	87
3	34	30.0	32.1	98	59	93
4	34	29.0	31.7	98	84	95
5	35	29.0	33.0	97	68	88
6	40	29.0	32.8	96	40	79
7	41	28.5	31.5	95	62	82
8	41	28.5	30.5	99	85	94
9	42	27.0	30.0	100	69	92
10	42	27.0	31.0	98	59	88
11	40	27.5	30.5	100	54	88
12	42	28.2	31.5	98	50	82

Table 2.1.8

Ambient Air Quality Status of SPM and RSPM *
(Summer Season)

Averaging period: 24 Hrs

Unit: $\mu g/m^3$

Sr. No.	Station	Max.	Min.	Avg.	SD	Percentiles					
						10	25	50	80	95	98
1.	Vijayapathy	127	65	94	27	65	66	84	112	123	125
2.	Udayathur	62	30	42	13	30	30	37	44	57	60
3.	Erukkanthorai	60	26	43	13	26	29	42	47	57	59
4.	Uramangalum	135	15	54	48	15	16	32	56	115	127
5.	Ovari	77	54	64	9	54	55	60	67	74	76
6.	Nagarcoil	52	44	47	3	44	44	45	48	51	52
7.	Kanyakumari	65	7	31	22	7	10	23	36	58	62
8*	Kudankulam	37	10	18	11	10	10	13	18	32	35
9*	Thiruvambalapuram	46	17	26	12	17	17	21	25	41	44
10*	Perungudi	25	6	16	7	6	8	14	18	23	24

* RSPM was monitored at specific locations only (Sr. No. 8,9,&10)

Table 2.1.9

Ambient Air Quality Status of SPM and RSPM *
(Post-monsoon Season)

Averaging period: 24 Hrs

Unit: $\mu g/m^3$

Sr. No	Station	Max.	Min.	Avg.	SD	Percentiles					
						10	25	50	80	95	98
1	Kudankulam *	98	34	77	26	34	45	78	97	98	98
2	Vijayapathi	75	63	66	5	63	63	64	65	72	74
3	Ovari	122	72	95	20	72	74	90	102	117	120
4	Erukkanthorai	152	64	97	35	64	66	83	101	139	147
5	Udayathur	109	66	84	17	66	67	79	88	104	107
6	Nagarcoil	80	58	70	8	58	60	69	72	78	79
7	Radhapuram	69	51	60	7	61	52	57	65	68	69
8	Chettikulam	88	50	73	17	50	52	71	85	87	88
9	Kanyakumari	91	50	74	17	50	54	73	84	89	90
10	Agasteeswaram*	90	71	83	10	71	71	81	90	90	90

* RSPM monitored at specific locations only (Sr. No. 1 & 10)

Table 2.1.10

Ambient Air Quality Status of SPM and RSPM *
(Winter Season)

Averaging period: 24 Hrs

Unit: $\mu g/m^3$

Sr. No.	Station	Max.	Min.	Avg.	SD	Percentiles					
						10	25	50	80	95	98
1	Erukandurai	61	34	47	12	34	35	40	58	60	61
2	Udayathur	37	20	26	7	20	20	22	26	34	36
3	Vijayapathi	98	48	82	20	48	56	85	95	97	98
4	Ovari	97	65	84	12	65	69	84	89	95	96
5	Kanyakumari	33	15	25	7	15	17	24	31	32	33
6	Soundarapandiyapuram	42	31	37	5	31	32	35	41	42	42
7	Radhapuram	52	36	43	6	36	37	39	46	50	51
8	Nagarcoil	53	41	45	6	41	41	41	50	52	53
9 *	Kudankulam	78	10	27	26	10	10	15	25	62	72
10 *	Chettikulam	23	16	19	3	16	16	17	21	22	23

* RSPM monitored at specific locations only (Sr. No. 9 & 10)

Table 2.1.11

Ambient Air Quality Status of SO_2
(Summer Season)

Averaging period: 24 Hrs

Unit: $\mu g/m^3$

Sr. No	Station	Max.	Min.	Avg.	SD	Percentiles 10	25	50	80	95	98
1.	Kudankulam	6	6	6	0	6	6	6	6	6	6
2.	Vijayapathi	6	6	6	0	6	6	6	6	6	6
3.	Udayathur	6	6	6	0	6	6	6	6	6	6
4.	Erukkanthorai	6	6	6	0	6	6	6	6	6	6
5.	Thiruvambalapuram	6	6	6	0	6	6	6	6	6	6
6.	Uramangalum	6	6	6	0	6	6	6	6	6	6
7.	Ovari	19	6	10	5	6	6	7	12	17	18
8.	Nagarcoil	7	6	6	0	6	6	6	6	7	7
9.	Kanyakumari	7	6	6	0	6	6	6	6	7	7
10.	Perungudi	6	6	6	0	6	6	6	6	6	6

Table 2.1.12

Ambient Air Quality Status of SO_2 (Post-monsoon Season)

Averaging period: 24 Hrs — Unit: $\mu g/m^3$

Sr. No	Station	Max.	Min.	Avg.	SD	Percentiles 10	25	50	80	95	98
1	Kudankulam	6	6	6	0	6	6	6	6	6	6
2	Vijayapathi	6	6	6	0	6	6	6	6	6	6
3	Ovari	6	6	6	0	6	6	6	6	6	6
4	Erukkanthorai	6	6	6	0	6	6	6	6	6	6
5	Udayathur	10	6	7	2	6	6	6	6	9	10
6	Nagarcoil	6	6	6	0	6	6	6	6	6	6
7	Radhapuram	6	6	6	0	6	6	6	6	6	6
8	Chettikulam	6	6	6	0	6	6	6	6	6	6
9	Kanyakumari	6	6	6	0	6	6	6	6	6	6
10.	Agasteeswaram	6	6	6	0	6	6	6	6	6	6

Table 2.1.13

Ambient Air Quality Status of SO_2 (Winter Season)

Averaging period: 24 Hrs

Unit: $\mu g/m^3$

Sr. No	Station	Max.	Min.	Avg.	SD	Percentiles 10	25	50	80	95	98
1	Kudankulam	6	6	6	0	6	6	6	6	6	6
2	Erukkanthorai	6	6	6	0	6	6	6	6	6	6
3	Udayathur	6	6	6	0	6	6	6	6	6	6
4	Vijayapathi	6	6	6	0	6	6	6	6	6	6
5	Ovari	6	6	6	0	6	6	6	6	6	6
6	Soundarapandiyapuram	6	6	6	0	6	6	6	6	6	6
7	Chettikulam	6	6	6	0	6	6	6	6	6	6
8	Kanyakumari	6	6	6	0	6	6	6	6	6	6
9	Radhapuram	6	6	6	0	6	6	6	6	6	6
10	Nagarcoil	6	6	6	0	6	6	6	6	6	6

Table 2.1.14

Ambient Air Quality Status of NO_x (Summer Season)

Averaging period: 24 Hrs

Unit: $\mu g/m^3$

Sr. No	Station	Max.	Min.	Avg.	SD	Percentiles					
						10	25	50	80	95	98
1.	Kudankulam	3	3	3	0	3	3	3	3	3	3
2.	Vijayapathi	13	3	6	4	3	3	3	7	11	12
3.	Udayathur	3	3	3	0	3	3	3	3	3	3
4.	Erukkanthorai	9	4	5	2	4	4	4	5	8	9
5.	Thiruvambalapuram	4	3	3	0	3	3	3	3	4	4
6.	Uramangalum	23	3	11	10	3	3	3	19	23	23
7.	Ovari	7	3	5	2	3	3	5	7	7	7
8.	Nagarcoil	14	3	7	5	3	3	4	10	13	14
9.	Kanyakumari	4	3	3	1	3	3	3	4	4	4
10.	Perungudi	5	3	4	1	3	3	3	4	5	5

Table 2.1.15

Ambient Air Quality Status of NOx (Post -monsoon Season)

Averaging period: 24 Hrs

Unit: µg/m^3

Sr. No	Station	Max.	Min.	Avg.	SD	Percentiles					
						10	25	50	80	95	98
1	Kudankulam	12	4	7	3	4	4	5	7	11	11
2	Vijayapathi	3	3	3	0	3	3	3	3	3	3
3	Ovari	6	3	4	1	3	3	3	4	4	4
4	Erukkanthorai	4	3	3	1	3	3	3	4	4	4
5	Udayathur	14	3	5	5	3	3	3	3	11	13
6	Nagarcoil	7	3	5	2	3	3	4	5	6	7
7	Radhapuram	4	3	3	0	3	3	3	3	4	4
8	Chettikulam	3	3	3	0	3	3	3	3	3	3
9	Kanyakumari	10	3	5	3	3	3	3	4	8	9
10.	Agasteeswaram	14	3	7	5	3	3	4	7	12	13

Table 2.1.16

Ambient Air Quality Status of NOx (Winter Season)

Averaging period: 24 Hrs

Unit: $\mu g/m^3$

Sr. No.	Station	Max.	Min.	Avg.	SD	Percentiles					
						10	25	50	80	95	98
1	Kudankulam	3	3	3	0	3	3	3	3	3	3
2	Erukkanthorai	4	3	3.2	0.4	3	3	3	3	4	4
3	Udayathur	3	3	3	0	3	3	3	3	3	3
4	Vijayapathi	3	3	3	0	3	3	3	3	3	3
5	Ovari	3	3	3	0	3	3	3	3	3	3
6	Soundarapandiyapuram	3	3	3	0	3	3	3	3	3	3
7	Chettikulam	3	3	3	0	3	3	3	3	3	3
8	Kanyakumari	3	3	3	0	3	3	3	3	3	3
9	Radhapuram	3	3	3	0	3	3	3	3	3	3
10	Nagarcoil	3	3	3	0	3	3	3	3	3	3

Table 2.1.17

Background Radiation Levels Measured at Kudankulam in October 2000

Sr. No.	Location	Distance from site (km)	Radiation Field (µSv/h)
1	KK Village	<2	0.03-0.04
2	KK City Beginning	<2	0.14-0.15
3	KK City End	<2	0.15-.16
4	KK Site	<2	0.13-0.14
5	Vyravikinaru	2-5	0.14-0.15
6	Idinthakara	2-5	0.14-0.15
7	Vijaypatti (W)	2-5	0.12.-0.13
8	Vijaypatti (E)	2-5	0.45-0.50
9	Onnarkulm	2-5	0.10
10	Shivasabrahmaniapuram	2-5	0.13-0.14
11	Sreeranganarayanapuram (Near KK Township)	5-10	0.11-0.12
12	KK Township	5-10	0.14-0.15
13	Chettikulam Road Side	5-10	0.10-0.12
14	Chettikulam Beach	5-10	0.15
15	Udayathur	5-10	0.10-0.11
16	Parameswarapuram	5-10	0.10-0.11
17	Radhapuram	10-15	0.10-0.11
18	Koliyamkulam	10-15	0.10-0.11
19	Vadakkankulam	10-15	-
20	Anjugramam	10-15	0.10
21	Kannankulam (Near Anjugramam)	10-15	0.07
22	Kavalkkinaru	15-20	0.10-0.11
23	Kavalkkinaru Rly. Station	15-20	0.14-0.15
24	Azhakappapuram	15-20	0.06-0.07
25	Vattakkotai	15-20	0.10
26	Agasthewaram	15-20	0.25
27	Kanyakumari Rly Station	15-20	0.20
28	Kanyakumari Beach	15-20	0.08
29	Arogyapuram	15-20	0.16-0.17
30	Shuchindram	20-30	0.10-0.11
31	Ethankodu (Near Thamarakkulam)	20-30	0.11-0.12
32	Kottaram	20-30	0.11-0.12
33	Aravoimozhi	20-30	0.18-0.19
34	Thovalai	20-30	0.10-0.11
35	Vellamadam	20-30	0.11-0.12
36	Nagarcoil	>30	0.12-0.13

Source: BARC, Mumbai

Table 2.1.18

Background Radiation Levels Measured At Kudankulam in May 2001

Sr. No.	Location	Distance from site (km)	Radiation Field (μSv/h)
1	KK site away from Beach	0-2	0.15-0.20
2	MSSRF	0-2	0.20-0.25
3	KK site Beach black patch	0-2	0.40-0.45
4	KK site beach white sand	0-2	0.20-0.25
5	Vijaypathi start	02-5	0.20-0.25
6	Sriranganarayanpuram	02-5	0.15-0.20
7	Shivsubramaniapuram	02-5	0.10-0.15
8	KK village	02-5	0.10-0.15
9	Vijaypathi end	02-5	0.20-0.25
10	Kudankulam outer	02-5	0.10-0.15
11	Vairavikinaru	02-5	0.10-0.15
12	Idinthakrai	02-5	1.50-2.00
13	Udayattur	05-10	0.10-0.15
14	Nakkaneri	05-10	0.10-0.15
15	Chetikulam fish market	05-10	0.10-0.15
16	Chettikulam	05-10	0.10-0.15
17	Parmeshwarapuram	05-10	0.10-0.15
18	KK Township	05-10	0.15-0.20
19	Arsan kulam	05-10	0.15-0.20
20	Vadakankulam	10-15	0.20-0.25
21	Navvaladi	10-15	0.65-0.70
22	Near Mastanpali bridge Periar	10-15	0.20-0.25
23	Muruganandapuram	10-15	0.20-0.25
24	Anjugramam	10-15	0.10-0.15
25	Papankulam	10-15	0.10-0.15
26	Radhapuram	10-15	0.10-0.15
27	Kolian kulam	10-15	0.15-0.20
28	Vatakotai	15-20	0.10-0.15
29	Vatakotai near fort	15-20	0.20-0.45
30	Vatakotai Beach black patch	15-20	3.0
31	Kanyakumari sea side	15-20	0.20-0.25
32	Azhakappapuram	15-20	0.05-0.10
33	Kanyakumari away from beach	15-20	0.4
34	Kallikulam	15-20	0.10-0.15
35	Kottai karan kulam	15-20	0.15-0.20
36	Muppanthal	15-20	0.15-0.20

Sr. No.	Location	Distance from site (km)	Radiation Field (μSv/h)
37	Mithanthar kulam	15-20	0.15-0.20
38	Kavalkinaru	15-20	0.15-0.20
39	Samugarangapuram	15-20	0.15-0.20
40	Aralvoimozhi	20--30	0.10-0.15
41	Thovalay	20--30	0.05-0.10
42	Vellamadam	20--30	0.05-0.10
43	Madapuram	20--30	0.10-0.15
44	Pazhayar (Near Nagarcoil)	20--30	0.10-0.15
45	Kundal	20--30	0.60-0.65
46	Ovari temple	20--30	0.20-0.25
47	N-ovari beginning	20--30	0.55-0.60
48	Kuttam faram	20--30	0.55-0.60
49	Tisayanvillai	20--30	0.10-0.15
50	Tamarakulam	20--30	0.05-0.10
51	Nambiar dam	20--30	0.15-0.20
52	Suchindram	20--30	0.10-0.15
53	Kizhavaneri cross road	20--30	0.10-0.15
54	Valliyur farm	20--30	0.15-0.20
55	Ramalingapuram start	20--30	0.20-0.25
56	Pangudi brick factory	20--30	0.20-0.25
57	Idyangudi	20--30	0.15-0.20
58	Pangudi brick factory	20--30	0.15-0.20
59	After road cross Mannar kulam	20--30	0.15-0.20
60	Nagarcoil	>30	0.10-0.15
61	Nagarcoil end	>30	0.10-0.15

Source :BARC, Mumbai

Table 2.1.19

Underground Gama Radiation Levels Measured at Kudankulam in October 2000

Depth (m)	Bore well - 1	Bore well - 2
	(µSv/h)	
0	8-9	10
1	9-11	7.5
2	9-11	7.5-9
3	7-9	7.5
4	8-9	9
5	8-10	8-10
6	8-9	7.5-10
7	7-8	7.5-10
8	7-9	7.5-8
9	7	7.5-9
10	5-6	7.5

Source : BARC, Mumbai

Table 2.1.20

Natural Radioactivity At Different Depths of Bore-hole* At Kudankulam Site (October 2000)

Depth (mtr)	^{228}Ra/ ^{232}Th	^{226}Ra / ^{238}U	^{40}K
		(Bq/kg dry wt)	
5	265.0 + 4.0	33.2 + 1.2	447.7 + 14.3
10	70.7 + 1.2	8.7 + 0.7	405.0 + 12.5
15	14.2 +1.4	BDL	421.4 + 17.7
20	5.9 +0.8	BDL	479.5 + 12.3
30	26.5 + 1.1	BDL	499.1 + 11.5
40	9.6 + 0.7	4.6 + 0.9	423.4 + 10.3
50	2.7 + 0.8	BDL	782.7 + 25.2
60	2.4 + 0.5	BDL	733.9 + 13.7
70	11.5 + 2.3	BDL	964.5 + 39.2
80	148.9 + 3.4	6.5 + 1.1	956.6 + 21.0
90	33.0 + 1.5	5.8 + 1.2	781.7 + 14.2
100	40.2 + 1.3	1.1 + 0.5	559.1 + 12.2
110	16.6 + 2.1	BDL	1066.3 + 36.4
130	5.0 + 1.5	BDL	598.2 + 28.6
140	2.3 + 0.7	BDL	567.3 + 19.3
150	37.6 + 2.1	2.4 + 0.7	584.1 + 19.4
160	2.4 + 0.5	BDL	560.4 + 12.7
180	29.8 + 1.2	BDL	531.4 + 12.9
190	11.5 + 1.4	BDL	643.2 + 20.5
200	24.9 + 1.6	BDL	545.8 + 18.6

* Bore Hole No. 4

2.2 Noise Environment

The objective of the survey of Noise environment in around the site of proposed units 1 and 2 of the nuclear power plant is to monitor the background noise levels and assess the potential impact of noise that will be generated by the units and also the incremental rise in noise levels on the nearby human settlements within the study area. At present, construction activities of offices and other buildings are in progress. The studies were carried out in the following steps:

1. Reconnaissance Survey
2. Measurement of baseline noise levels at the proposed project site
3. Measurement of baseline noise levels in the neighbouring villages
4. Present noise exposure of general population and employees
5. Sources of noise in proposed nuclear power plant and their noise levels

2.2.1 Reconnaissance Survey

The site for the proposed 2 units of 1000 MWe capacity each nuclear power plant reactors is located in coastal area near to the Kudankulam village in Tamil Nadu. At present there are no major industries in the region and local activities in surrounding villages contribute to the noise levels. Presently, the construction activities of ancillary buildings and offices related to nuclear power plant are in progress. These have not added substantially to the existing ambient noise levels. The noise levels are expected to increase when the construction of reactor buildings and associated activities will be in full swing.

2.2.2 Noise Level Measurements in Nearby Human Settlements

The data with respect to ambient noise levels measured in nearby human settlements as shown in **Figure 2.2.1** is reported in **Tables 2.2.1** to **2.2.3**. The noise levels were monitored during day time between 10 a.m. to 5 p.m. during first set of monitoring while these were monitored during day and night time for the remaining two sets. The noise levels in the study area presented in **Table 2.2.1** indicate that these were low except at traffic junctions where vehicular movement was observed. At most of the places, the average noise levels varied in the range of 45-50 dBA. Highest noise levels were observed at Kanyakumari (70-75 dBA) and Nagercoil (65-70 dBA) being the major towns in the study area. Higher noise levels were prevailing due to the commercial activities and vehicular traffic. At project site, the noise levels were observed to be in the range of 50-55 dBA (**Table 2.2.1**).

Eventhough, noise levels do not change with the season, noise monitoring was continued in remaining two seasons with a view to cover the villages and human settlements, which were not covered earlier. The monitored data for the second set and third set of monitoring is presented in **Tables 2.2.2** and **2.2.3** respectively.

During second set of monitoring, the day and night levels in most of the surrounding villages were less than 55 dBA (day time) and 45 dBA (night time). Highest noise levels of 75 dBA and 71 dBA were observed during daytime and nighttime respectively at Nagarcoil due to commercial activities. The day and night time noise levels at the project site were also observed to be slightly on higher side for second and third set of monitoring than the permissible values due to initiation of construction activities and movement of vehicles (**Table 2.2.2**).

During third set of monitoring, highest day and night noise levels (**Table 2.2.3**) were recorded at village Aramboli located at a distance of about 24 kms in WNW direction from the project site. Higher noise levels during daytime were also recorded at Ovari, suchindram and Nagarcoil and these were due to local commercial activities including vehicular traffic. During nighttime, highest noise level of 70 dBA was observed at Aramboli. At other locations noise levels were observed to be more or less within the permissible limits.

The results of noise levels monitoring study indicate that in general, the noise levels measured at various places are within the standards prescribed by the central pollution control Board, MoEF 1998 (**Annexure II**).

2.2.3 Identification of Sources of Noise in the Proposed Plant

The main sources of noise in the nuclear power plant are 1) Turbines, 2) Air Compressors, 3) Ventilation inlets, 4) Diesel Generators, 5) Pump House Equipments, 6) Chillers, 7) Vents, 8) Exhaust Fans and 9) Heavy and medium automobiles moving around the plant. The noise levels likely to be generated by these sources are presented in **Table 2.2.4**. It is likely that improved technology may further reduce the noise levels. Most of the machines will be working continuously round the clock during operation of the nuclear power plant. However due to absence of any industry in the region, there is no addition to noise levels which would be generated after commissioning of the power plant.

Noise due to Traffic

Present density of traffic on the roads in the vicinity of the project site is very low. It is excepted to increase to about 200 heavy vehicle trips and 300 light vehicle trips per day during construction which is expected to be reduced considerably during operation of the nuclear power reactors.

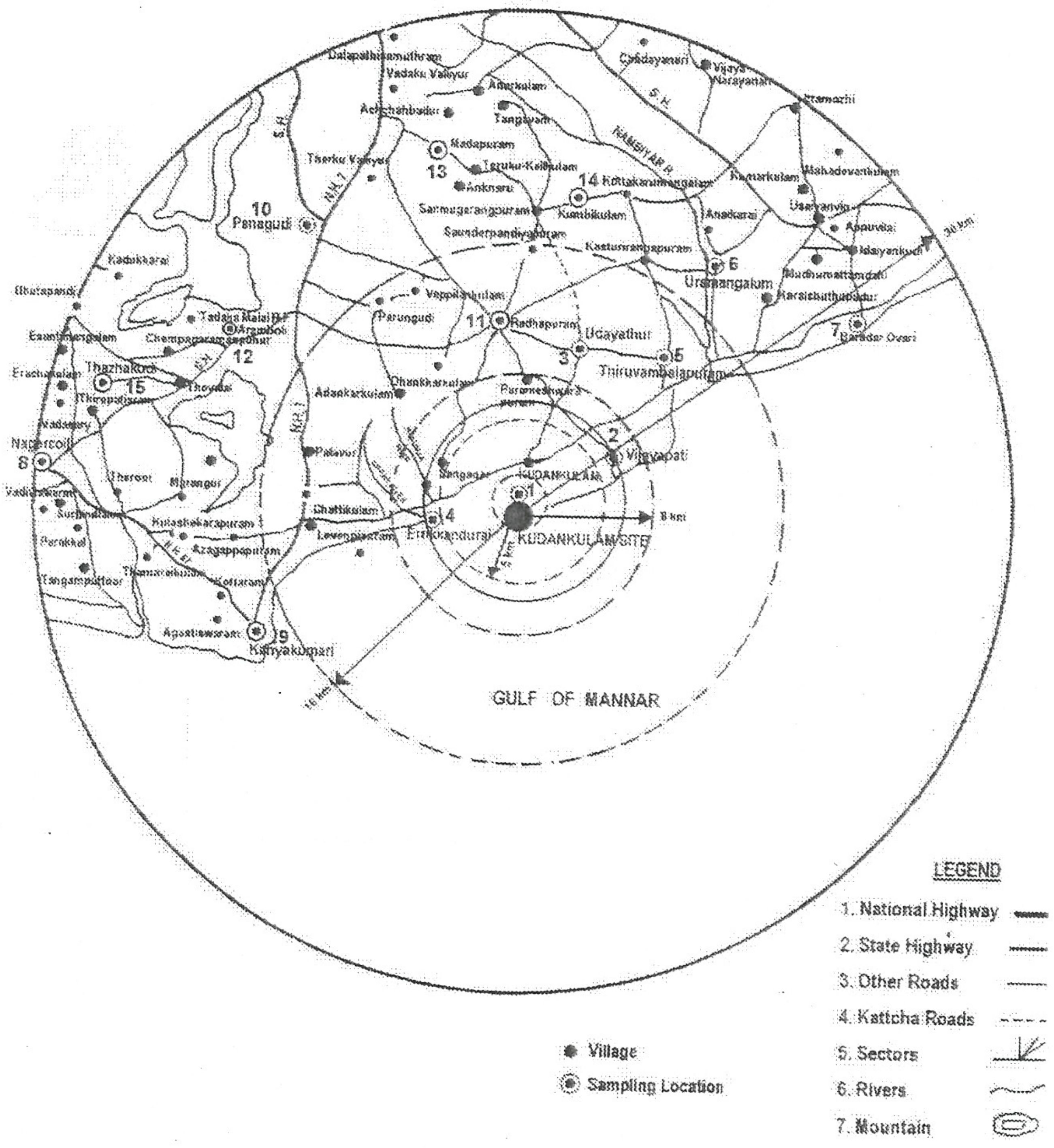


Fig. 2.2.1: Locations of Ambient Noise Level Measurement Stations Within the Study Area

Table 2.2.1

Noise Levels in Surrounding Villages within the Study Area (First Set of Monitoring)

Sr. No.	Location	Bearing with respect to project site	Distance from the project site (km)	Noise Levels (dBA) (10 am to 5 pm)
1.	Kudankulam (project site)	-	-	50 - 55
2.	Vijayapathy	ENE	7.0	50 - 55
3.	Udayathur	NNE	9.0	45 - 50
4.	Erukkanthorai	WNW	6.0	55 - 60
5.	Thiruvambalapuram	ENE	12.2	50 - 55
6.	Uramangulam	ENE	17.7	55 - 60
7.	Ovari	ENE	24.0	60 - 65
8.	Nagarcoil	W	28.0	65 - 70
9.	Kanyakumari	WSW	18.0	70 - 75
10.	Panagudi	NW	15.3	45 - 50
11.	Radhapuram	N	12.0	50 - 55
12.	Aramboli	WNW	23.5	65 - 70
13.	Madapuram	NNW	23.20	45 - 50
14.	Kumbikulam	NNE	19.8	45 - 50
15.	Thazhakudi	WNW	27.2	45 - 50

Table 2.2.2

Noise Levels in Surrounding Villages within the Study Area (Second Set of Monitoring)

Sr. No.	Location	Bearing with respect to project site	Distance from the project site km	Noise Level (dBA)	
				Day	Night
1.	Kudankulam (project site)	-	-	60	58
2.	Vijayapathy	ENE	7.0	55	50
3.	Udayathur	NNE	9.0	55	50
4.	Erukkanthorai	WNW	6.0	57	53
5.	Thiruvambalapuram	ENE	12.3	52	48
6.	Uramangulam	ENE	17.7	58	52
7.	Ovari	ENE	24.0	55	50
8.	Nagarcoil	W	28.0	75	71
9.	Kanyakumari	WSW	18.0	65	60
10.	Perungudi	NW	15.3	45	40
11.	Radhapuram	N	12.0	60	55
12.	Aramboli	WNW	23.5	72	68
13.	Madapuram	NNW	23.2	50	45
14.	Kumbikulam	NNE	19.8	50	45
15.	Thazhakudi	WNW	27.2	57	47
16.	Chadayameri	NNE	28.4	45	40
17.	Mahadevankulam	NE	24.6	45	42
18.	Kottakarumangalam	NNE	19.8	50	45
19.	Appuvilai	ENE	24.6	50	45
20.	Veppilankulam	NW	14.9	45	40
21.	Soundernandiyapuram	NNW	17.5	50	45
22.	Dhalapathisamudram	NNW	29.8	45	40
23.	Pamagodi	NW	21.1	45	40
24.	Dhankkarkulam	NW	9.8	50	45

Sr. No.	Location	Bearing with respect to project site	Distance from the project site km	Noise Level (dBA)	
				Day	Night
25.	Kadukkarai	WNW	28.8	45	40
26.	Tadakamalai	WNW	25.8	55	50
27.	Palavur	W	13.5	50	45
28.	Levengipuram	W	13.2	50	45
29.	Kottaram	WSW	20.0	45	40
30.	Thersor	W	25.1	50	45
31.	Bhutapandi	WNW	30.0	50	45
32.	Marangoor	W	21.2	45	40
33.	Vadasary	W	27.0	55	50
34.	Vadakku Valliyur	NNW	25.0	50	47

Table 2.2.3

Noise Levels in Surrounding Villages within the Study Area (Third Set of Monitoring)

Sr. No.	Sampling Location	Bearing from the site project	Distance w.r.t. Project site (km)	Noise Levels (dBA)	
				Day	Night
1	Kudankulam (Project Site)	-	-	60	55
2	Vijayapathy	ENE	6.1	55	45
3	Erukkanthorai	WNW	6.6	57	50
4	Chettikulam	W	8.8	51	45
5	Udayathur	NNE	9.0	55	50
6	Dhankkarkulam	NW	9.9	49	45
7	Radhapuram	N	11.2	60	55
8	Thiruvambalapuram	NE	12.4	50	45
9	Palavur	W	13.3	49	40
10	Levengipuram	W	13.8	50	45
11	Veppilankulam	NW	15	45	40
12	Perungudi	NW	15.9	49	40
13	Azhagappapuram	WSW	17.6	50	43
14	Soundarapandiyapuram	NNW	17.7	48	41
15	Uramangulam	NE	18.0	55	47
16	Kanyakumari	WSW	18.7	63	59
17	Kumbikulam	NNE	18.8	50	45
18	Kottaram	WSW	20.0	55	50
19	Anaikarai	NNE	20.0	49	45
20	Kottakarumangalam	NNE	20.2	45	40
21	Agasteeswaram	WSW	20.5	55	45
22	Therku Valliyur	NNE	20.9	50	45
23	Pamagodi	NE	21.2	53	45
24	Marangur	W	21.4	50	45
25	Madapuram	NNW	22.6	50	45
26	Ovari	ENE	23.6	80	60
27	Aramboli	WNW	23.6	80	70
28	Suchindram	W	25.0	80	55

Sr. No.	Sampling Location	Bearing from the site project	Distance w.r.t. Project site (km)	Noise Levels (dBA)	
				Day	Night
29	Appuvillai	ENE	25.2	50	45
30	Vadakku Valliyur	NNW	25.5	47	41
31	Theroor	W	25.5	50	45
32	Tadakamalai	WNW	25.9	50	45
33	Mahadevankulam	NE	26.4	50	45
34	Vadasari	W	27.1	60	52
35	Thamaraikulam	WSW	27.1	55	45
36	Thalakudi	WNW	27.4	55	50
37	Parakkai	W	27.4	45	40
38	Chadayameri	NNE	28.6	50	45
39	Kadukarai	WNW	29.0	55	45
40	Nagarcoil	W	29.6	75	65
41	Dhalapathi samuthram	NNW	29.9	60	53
42	Buthapandi	WNW	30	45	40

Table 2.2.4

Main Sources of Noise in Proposed NPP & Their Noise Levels

Sr. No.	Source	Noise Levels Range, dB	Distance from Noise Source
1	Turbine (2 Nos.)	94 - 96	5 m
2	Diesel Generator (9 Nos.)	92 - 98	2 m
3	Air Compressor	92 - 98	2 m
4	Cooling Water Pump	89 - 95	2 m
5	Deaerator	92 - 94	2 m
6	Intake Ventillator	94 - 97	5 m
7	Exhaust Ventillator	92 - 96	2 m

Source : NPCIL

2.3 Water Environment

2.3.1 . Water Resources

Surface Water

There are no major rivers or lakes at or near the plant site. There are two small streams near the plant site at a distance of about 5-6 kms west of the site. These two streams are practically dry throughout the year except during monsoon for a period of 2 months. There are few village ponds and wells around the area. There are four dams located at a distance of around 65 kms form the plant site. These are Pechipparai, Perunchani, Chittar I and Chittar II. Since these dams are located on the western side of Western Ghats, their effect on the proposed plant site is negligible. In absence of lakes, reservoirs, rivers and perennial streams, no water storage structures are planned in the area.

Ground Water

The availability of ground water at or near Kudankulam is very much limited. Borehole studies conducted in the region indicated very low yield. The ground water levels near the plant site vary from 5 m to 7 m below ground level. For recharge of ground water, the main source is only monsoon. The flow of groundwater is towards south i.e. into the Bay of Bengal. Due to limited yield of groundwater and limited water bearing formations in the area, scope for development of ground water is very less. At about 1.5 km from the plant site, there is a limited quantity of ground water available which has been estimated as 90 m^3/d in 4 to 5 bore wells sunk to a depth of about 50m (Ref. Project Report - NPP).

The water table level at the site is fairly stable and variation in level is of the order of 3 - 4 meters. The ground water level increases during rainfall period of November to January and thereafter tends to decrease slowly with time.

2.3.2 Water Requirement

2.3.2.1 Fresh Water

Fresh water from Pechipparai dam, which is about 65 kms NW of the project site, is proposed to be used for meeting various water demands. The quantities and purposes of use of fresh water are as follows:

Domestic use	414 m^3/d
Service Water	480 m^3/d
Fire Water Make-up	500 m^3/d
Chemical Water Treatment (Process water)	4800 m^3/d

For meeting fresh water demands, water from Pechipparai dam will be brought to the site through embeded pipeline. This pipeline will be adequately designed to withstand all design forces. At project site, it is proposed to construct a reservoir with a capacity to store 7 days requirement of process and drinking water (of capacity approximately 60000m^3 for 2 units). This reservoir is planned to be located at an elevation of 35 m, which is much above the safe grade elevation of the reactor building.

Fresh water for make up to the plant systems will be passed through sand filters and D.M. plant. For domestic use within the township, the sea water will be passed through reverse osmosis plant and will be treated in a conventional water treatment plant followed by chlorination. The capacity of R.O. plant would be 2 x 25 m^3 per hour.

2.3.2.2 Sea Water

For the proposed 2 units of the nuclear power plant, it is proposed by NPCIL to draw seawater for cooling purposes. Condenser cooling water will be drawn from the sea through open channel/pipeline. The cooling water requirements are as under:

Turbine Building

i)	by CCW pumps	:	2,82,342 m^3/hr
ii)	by intermediate cooling	:	10080 m^3/hr
iii)	Reactor building and DG cooling	:	17400 m^3/hr
	Total	:	3,09,822 m^3/hr

Rise in temperature at the discharge point in the sea is expected to be around 7°C, which meets the statutary requirement notified by MoEF.

2.3.3 Groundwater Quality Status

After thorough physical survey of the study area, 12 ground water sampling locations were selected for establishing the water quality status of groundwater resources. Out of the 12 locations, 6 sources were open wells and the other 6 were bore wells. While assessing the baseline water quality status, established standards of Bureau of Indian Standards (BIS No. 10500-1991 (**Annexure III**) were made use of. In the area under study, the ground water table is very low and it is reported that the area receives very less rainfall. There are no other surface water bodies in the area. The sampling locations, type of source, depth of water column, distance and bearing from project site are given in **Table 2.3.1** and the sampling locations are shown in **Figure 2.3.1**. The samples of water were subjected to detailed characterization for physical, inorganic, nutrient, and organic parameters, heavy metals and bacteriological parameters and the related data for 3 seasons is presented in **Tables 2.3.2** to **2.3.16**.

2.3.3.1 Physical & Inorganic Parameters

Physical Parameters

During summer season, pH of the water samples varied from 6.63 to 8.54 and the conductivity varied from 720 to 10800 μmhos/cm. The concentration of total solids ranged from 489 to 9900 mg/l while the concentration of total dissolved solids varied from 473 to 9885 mg/l (**Table 2.3.2**).

During post-monsoon season, all the eleven samples has no turbidity and pH varied from 6.85 to 7.84. Conductivity varied from 700 to 14600 μmhos/cm. Samples from dug wells in Shri Ranganarayana Puram and Chettikuklam exhibited conductivity values of more than 10,000 μmhos/cm with corresponding TDS values of 9560 and 11680 mg/l respectively. These samples were drawn from the wells located in the vicinity of aquaculture farms. The concentrations of suspended solids were very low with a range of 8.5 - 18 mg/l (**Table 2.3.3**).

During winter season, pH of all samples excepting sample numbers G_5 and G_{10} exhibited alkaline range. pH of sample G_5 showed slightly acidic pH of 6.3. All other values are close to the acceptable range of 6.5-8.5. High concentrations of more than 6000 mg/l of TDS was observed in sample G_2, G_{11} and G_{12} indicating thereby either over withdrawal or saline water intrusion in the well. Sample G_6 also showed TDS concentration of 2160 mg/l which is more than the prescribed value of 2000 mg/l for a source in absence of alternate source. High TDS values have reflected in higher conductivity values at G_2, G_{11} and G_{12}.

Similar trend was observed during summer season also. Relatively lower values of suspended solids and turbidity were observed in all well water samples (**Table 2.3.4**).

Inorganic Parameters

It is seen from **Table 2.3.5** that during summer season, the alkalinity of the ground water samples varied from 168 to 388 mg/l while the total hardness varied from 155 to 3950 mg/l and the chloride concentration varied from 85 to 3900 mg/l. High chloride concentration is due to saline water intrusion and also due to nearness of sampling source to sea. Similarly higher values of hardness are due to geological formations at well sites.

As regards the inorganic parameters, during post-monsoon season, alkalinity was observed to be in the range of 84-384 mg/l. Samples G_2, G_{11} and G_{12} exhibited total hardness values of more than 4000 mg/l indicating thereby that water from these sources is unfit for human consumption. Sample numbers G_1, G_8 and G_9 also showed hardness values higher than the permissible limit of 300 mg/l. The concentration of chloride varied from 150-4150 mg/l. Similar trend was observed during summer season. High concentration of chlorides in samples G_2, G_{11} and G_{12} is due to saline water intrusion. High values of hardness are due to local geological conditions (**Table 2.3.6**).

During winter season, values of more than 5000 mg/l for hardness in samples G_2, G_{11} & G_{12} were observed. Samples G_6, G_7 and G_8 also indicated hardness values of more than the permissible limit of 300 mg/l. However, the values were relatively lower than those observed in samples G_2, G_{11} and G_{12}. The concentration of chloride in samples G_2, G_{11} and G_{12} was found to be more than 4000 mg/l (range 65-6500 mg/l) with the highest value for sample G_{12} (6500 mg/l). These high concentrations are due to saline water intrusion and nearness of sampling locations to the sea (**Table 2.3.7**).

2.3.3.2 Nutrient & Organic Parameters

During summer season, dissolved oxygen concentration varied from 2.2 to 5.4 mg/l. Low D. O. values observed at locations G_5, G_8 and G_{10} might be due to more depth of the well and non exposure of water to atmospheric oxygen. BOD values were 3.6 mg/l and below and the COD values varied from 7.0 to 39.0 mg/l. Concentrations of nitrate and phosphate were found to be below 2.2 mg/l and 0.09 mg/l respectively as can be seen from **Table 2.3.8**.

During post-monsoon season, except at samples G_{11} and G_{12}, in other samples BOD values were less than the lowest detectable value of 3 mg/l. The dissolved oxygen concentration varied from 1.7 - 7.4 mg/l. Relatively higher values of 7.4 mg/l, 5.3 mg/l and

5.4 mg/l were observed in samples G_1, G_4 & G_7, due to turbulence at the time of sampling. Concentrations of nitrate and phosphate were found to be in the range of 0.25 to 10.5 mg/l and traces to 0.030 mg/l respectively. Values of nitrate were well below the permissible limit of 45 mg/l (**Table 2.3.9**).

During winter season, dissolved oxygen concentration in the ground water samples varied from 2 mg/l to 5.8 mg/l. The low values of D.O. were observed in samples G_5, G_8, G_{10}, G_{11} and G_{12}. This might be due to prevalence of septic conditions and absence of turbulence in the water. The BOD values of the samples ranged from less than 3 mg/l to 31 mg/l with the highest BOD value of 31 mg/l detected in the open well water of Kudankulam (G_{12}). This has also reflected in COD values of the water samples and highest COD value of 165 mg/l was observed in G_{12}. The concentration of nitrates in all ground water samples were less than the stipulated limit of 45 mg/l. The concentration of phosphate was observed to be in the range of BDL-0.4 mg/l and these values are very low. (**Table 2.3.10**).

2.3.3.3 Heavy Metals

During summer season, amongst heavy metals, chromium and copper were detected in all open well and bore well samples. Their concentrations were observed to be more than their respective limits prescribed for drinking water. Cadmium was detected in 10 out of 12 ground water samples while lead was present in 8 out of 12 samples. In general, the concentrations of heavy metals in bore well water samples were on higher side as compared to open dug well due to more depth of bore-well. Moreover, the chances of heavy metals getting in solution at higher depth are more due to geological formations existing over there. This warrants adequate treatment of water before its use for drinking purposes (**Table 2.3.11**).

During post-monsoon season, cadmium concentration of more than the desirable limit of 0.01 mg/l was observed in 7 out of 11 samples. At these concentrations, water can become toxic requiring adequate treatment before consumption. Similarly the concentration of chromium was observed to be more than 0.01 mg/l in 5 samples (G_3, G_4, G_7, G_{11} & G_{12}). The concentration of copper in 7 out of 11 samples tested was more than 0.05 mg/l while in remaining 4 samples the values were below detectable limit. The concentration of zinc and manganese in all the samples tested were either below detectable limit or very low. Iron concentration exceeded in samples G_1 and G_{12}. In all other samples, the concentration of iron was well within the desirable limit of 0.3 mg/l (**Table 2.3.12**).

During winter season, the concentrations of almost all heavy metals excepting cadmium were within acceptable limit. Cadmium values were higher in 6 samples (G_2, G_6,

G_7, G_{10}, G_{11} & G_{12}), than the desirable limit of 0.01 mg/l indicating that these wells are not suitable sources for the potable use since there is no relaxation in this limit as per BIS 10500-1991 (**Annexure III**). Higher concentration of cadmium could be either due to geological formations or due to discharge of polluted water on land near these wells (**Table 2.3.13**).

2.3.3.4 Bacteriological Quality of Groundwater

Table 2.3.14 presents the bacteriological quality of the ground water and it is seen that all the samples are contaminated except samples G_2, G_3, G_4, G_9, G_{10}, G_{11}, and G_{12} which are negative to Fecal Coliform and E. Coli. The total coliform count varied from 4 to 93 per 100ml with maximum count at sample G_3 i.e. bore well at Vairavikinnani. Presence of fecal coliform in open wells and bore wells indicates inadequate sanitary facilities at those places and warrants disinfection of water prior to its supply for potable use. The fecal streptococci count of more than 10 in samples G_1, G_2, G_3, and G_4 indicate fecal pollution of recent origin and demands adoption of corrective measures before its use as drinking water.

During post-monsoon season, total coliform count was almost zero in 4 samples (G_6, G_8, G_9 & G_{10}) and this has reflected in the counts of fecal coliforms, E.Coli and fecal streptococci with all counts being zero. Thus, indicating that these waters are bacteriological safe for drinking. Fecal contamination was severe (count 240 nos./100ml) in sample G_7, & G_{11} due to insanitary conditions and land disposal of sewage. Fecal contamination was also present in sample G_4, G_7 & G_{11}. Such water sources need adequate chlorination prior to their use as drinking water. Fecal streptococci were detected in 5 samples out of which 4 samples G_3, G_4, G_7 and G_{11} indicated count of more than 10 nos./100ml (**Table 2.3.15**).

During winter season the total coliform count varied from ND to TNC (too numerous to count) and fecal coliforms were detected in 7 out of 10 samples indicating fecal contamination of these sources. Highest coliform count of 920 Nos./100ml was detected in samples G_1 and G_4 indicating the need of chlorination prior to their use. In remaining samples G_2, .G_5, G_6, G_8 and G_{12}, coliforms were also detected due to land disposal of domestic wastes and absence of proper drainage facilities. The fecal streptococci count of more than 10 Nos./100ml in the water samples tested varied from 11 to 220 Nos./100 ml indicating presence of fecal contamination of recent origin and need adoption of adequate control measures before these water sources are used as drinking water source (**Table 2.3.16**).

2.3.4 Marine Water Quality Status

Marine water sampling was carried out in June 2001 at a distance of 50 m from the shore in a stretch of nearly 2 kms. starting at the Central Point which is just opposite to the proposed nuclear power plant site. Samples were also collected at a distance of 100 m from the shore for establishing baseline marine water quality status. The details of sampling locations are presented in **Table 2.3.17**.

Marine water quality with respect to physical parameters is presented in **Table 2.3.18**. It is seen that the temperature of the samples collected at 50 m distance varied from 27.0^{0}C to 28.5^{0}C while the samples collected at 100 m distance exhibited temperature varying from 27.5^{0}C to 29.0^{0}C. It is seen from the Table that the suspended solids concentration in the samples collected at 50 m distance (19-22 mg/l) are slightly higher than the SS concentrations of the samples collected at 100 m distance(15-18 mg/l).. The characteristics of marine water with respect to inorganic parameters are reported in **Table 2.3.19**. The data indicates high values of all the parameters, particularly hardness, chloride and sulphate.

Marine water quality with respect to inorganic parameters is presented in **Table 2.3.19**. It is seen that the Magnesium hardness is higher than the Calcium hardness in all the samples. The characteristics for organic parameters are presented in **Table 2.3.20**. It is observed from **Table 2.3.20** that the Dissolved Oxygen concentration in the samples collected are higher at 100 m distance than the samples collected at 50 m distance which might be due to wave action. Low D. O. values of 1 mg/L and 0.7 mg/L observed at locations M-4 for 50 m distance and M-5 for 100 m distance from sea shore respectively might be due to stagnant water and absence of turbulence at the time of sampling. Similarly BOD was lower in samples collected at 100 m distance than the samples collected at 50 m distance. The nearshore samples i.e. M-1 in both the cases (irrespective of distance) exhibited higher COD values. This might be due to less turbulence at the shore. However, the BOD and COD values are very less. Nitrate was not detectable in all the samples except in sample M-2 collected at 50m distance. Phosphate was detected in all samples but the values are very low. The marine water quality data with regard to heavy metals is presented in **Table 2.3.21**. The data indicates presence of high concentrations of cadmium, chromium,, copper and lead in the water samples. The other constituents viz. iron, manganese and zinc are present in the water samples but their concentrations are low as compared to their prescribed limits.

2.3.4.1 Bacteriological Quality

All samples collected at 50 m distance were observed to be negative to Fecal Coliform and E.Coli while they were positive for Fecal Streptococci. Almost similar results were obtained for the samples collected at 100m distance as seen from **Table 2.3.22**. The presence of total coliform and fecal streptococci was detected in all the samples but their count was less then 10 in all samples.

2.3.4.2 Marine Sediment Quality

Marine sediment sample collected at 50m distance from the shore was analysed for heavy metal parameters. The analysis data indicated that Cadmium (Cd) concentration was 0.0005 g/kg, Chromium (Cr) 0.013 g/kg, Copper (Cu) 0.0038 g/kg, Iron (Fe) 2.05 g/kg, Manganese (Mn) 0.0059 g/kg, Zinc (Zn) 0.0079 g/kg and Lead (Pb) was found to be below detectable levels in the sediment sample. The lower values of the heavy metals in sediment indicate that the marine water did not get adversely affected due to industrial water pollution and this is due to absence of any industrial activity or port and harbour activity in the region.

2.3.4.3 Previous Water Quality Monitoring Data of NPCIL

During 1987, ground water quality from two wells near the proposed nuclear power plant site was monitored by NPCIL. The results of analysis of ground water samples are presented in **Table 2.3.23**. The data indicates fairly good quality in respect of well No. 2 as compared to well 1 where the concentration of most of the parameters was on higher side. High TDS, chloride, sulfate, calcium, magnesium and hardness might be due to nearness of location of well No. 1 to the sea. The total solids and iron values exceed the respective permissible limits of 500 mg/l and 1 mg/l in both the samples.

The data on seawater characteristics for the samples collected during Dec. 1987 is reported in **Tables 2.3.24** and **Table 2.3.25**. The data in **Table 2.3.24** indicates almost all parameters representing concentration of different parameters for a marine environment. In absence of data on D. O., BOD or COD, it is not possible to draw inference about the pollution status of seawater.

The characteristics of seawater at 15 ft (about 5m) and 20 ft (about 6 m) depth at two different locations in the sea near the power plant site are reported in **Table 2.3.25**. The values of different parameters are more or less similar to those reported in **Table 2.3.24**.

Comparison of ground water quality data of the year 1987 (**Table 2.3.23**) with that of the year 2001 (**Table 2.3.2 and Table 2.3.5**) indicates higher values in terms of TS, TDS, hardness, calcium, sulphates, magnesium and chlorides in the year 1987. However, due to non-availability of exact locations of samples collected in the year 1987, it is difficult to draw concrete conclusions.

As regards seawater quality reported in **Table 2.3.18 and 2.3.19** for the year 2001, the values of various parameters are on higher side in the sample collected during the year 1987 (**Table 2.3.24**).

2.3.5 Background Radiation Field in Water and Other Items

The environmental radiological laboratory, Kaiga had conducted background radiation survey and environmental sampling at and around Kudankulam nuclear power plant site. The details of sampling location, types of samples collected and respective radiation fields as measured by ESL in October, 2000 are furnished in **Table 2.3.26.**

2.3.5.1 Aquatic Monitoring

Water

Water samples from sea, well and pond were collected from different locations and are analyzed for fallout radiouclides ^{137}Cs and ^{90}Sr. The results of analysis of samples collected during October 2000 and May 2001 are shown in **Table 2.3.27** and **Table 2.3.28** respectively. As expected, seawater samples were found to have higher concentrations of ^{137}Cs as compared to fresh water samples. ^{137}Cs concentration in fresh water varied from BDL to 6.0 and in seawater from 7.4 to 16.6 mBq/l and that of ^{90}Sr, values were below detection in all the samples. The levels at Kudankulam are in the same range as observed elsewhere.

2.3.5.2 Aquatic Sediment Samples

Natural radioactivity levels in aquatic sediment samples collected during October 2000 were observed to be 8330 $\pm$ 890 mBq/kg for Cesium and 1380 $\pm$ 490 mBq/kg for Strontium.

2.3.6 Wastewater

The wastewaters likely to be generated after commissioning of the proposed nuclear power plant are mainly from the processing units and the residential township as also sanitary wastes from the canteen, toilets and bathrooms within the plant premises.

2.3.6.1 Liquid Radioactive Wastes from the Plant

Following are the different types of liquid wastes likely to be generated during the reactor operation :

- Borated active water, drained from the primary circuit during boron concentration changes during startup, power rise etc., collected in coolant grade storage system
- Wastewater after decontamination of the equipment, pipelines, rooms, drains from active laboratory, reclaimed water from special purification system, technological drainage of equipments, pipelines etc.
- Spent ion exchange resins and sorbents of purification system filters
- Salt concentrate residue of the evaporator
- Slimes drained from tank bottoms.

2.3.6.2 Proposed Liquid Waste Management at NPP

Radioactive Wastes

Borated active wastewater from the primary circuit will be processed in the primary coolant treatment system and pure condensate and boric acid concentrate shall be separated by evaporation and reused for make-up in the primary system.

Decontaminants, system leakage and drainage from equipments, pipes and rooms, will be collected in tanks in the reactor auxiliary building. They will then be processed by evaporation in wastewater processing system as a result, condensate and salt concentrate will be generated. Condensate will be used as service water for water purification system and salt concentrate will be sent to intermediate liquid radioactive media storage system. Any condensate to be discharged, will be discharged after chemical and radiation monitoring.

Salt concentrate residue, spent ion exchange resins and sorbents of filters, slime from tank bottoms are proposed to be received in tanks in intermediate liquid radioactive media storage system. They will be stored here for sufficient time to allow for decay of short-live isotopes, then further concentration of them will be achieved using evaporation technique.

Highly concentrated (up to 800 g/l) residue will be solidified through cementation and sent for interim storage in solid waste depositary.

Monitoring and control of the liquid waste treatment facility will be done through AERMS (Automated Environmental Radiation Monitoring System). Liquid waste treatment and disposal system is proposed to be equipped with radiation monitoring. All the radioactive wastes will be discharged only through a treatment and monitoring system within authorized limits derived from ICRP dose equivalent limits and AERB stipulations. Calculated discharge rate, discharge limit and dose apportionment for one unit of 1000 MWe capacity at Kudankulam are presented in **Annexure IV**.

Non - Radioactive Wastes

Under this category, the sources would be conventional type including domestic wastewater from the employees township, canteen and sanitary wastes from toilets and bath rooms within the plant. Other major source would be water from once through cooling system.

The main cooling water system is provided for removal of heat from the condensers of the turbine. The system has been designed as once through cooling system wherein water from the sea would be drawn and discharged back into the Gulf of Mannar in Indian ocean and it is expected that the temperature of sea water would increase by about 7^{o}C or so.

Wastewater from Township

A township is being built near Chettikulam village which is 8 km from the plant site for the staff and workers. For the proposed nuclear power plant, it is proposed to employ unskilled, skilled workers and O and M staff as also management officers. A housing colony is proposed to be built for 1200 employees. A sewage treatment plant to treat around 300 m^3/d of domestic sewage comprising primary, and secondary biological treatment based on either activated sludge system or oxidation ditch will be constructed. The treated wastewater from the STP will preferably be utilized on land for green belt development. The treated wastewater will satisfy the requirements of State Pollution Control Board as also the requirements contained in BIS 2490-1982 (**Annexure V**).

The sanitary wastewater to be generated from toilets/ bath rooms and canteen will be adequately treated and the treated effluents will be used for gardening.

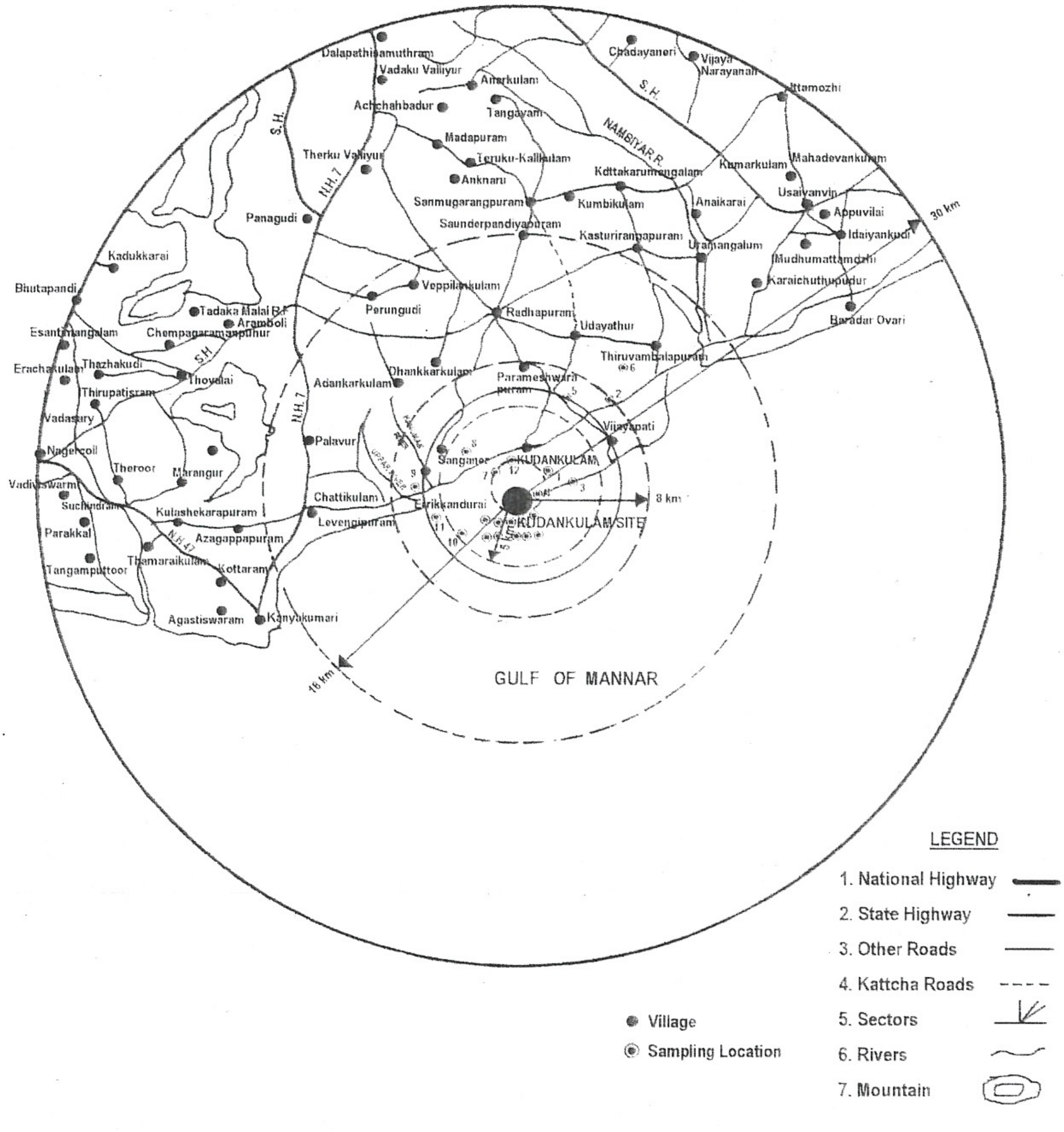


Fig. 2.3.1 : Locations of Groundwater and Marine Water Sampling in KK Project Study Area

Table 2.3.1

Groundwater Quality - Sampling Locations

Sr. No.	Location Name	Type of Source	Depth of Water Column (m)	Distance from the Project Site (km)	Bearing from Project Site
G_1	Kudankulam Outer	Open Well	0.6	1	NE
G_2	Kamaneri	Open Well	0.6	5	NE
G_3*	Vairavi Kinaru	Bore Well	NA	2	E
G_4	Kudankulam (Project Site)	Open Well	1.2	0	Site
G_5**	Shivagangai Nagar	Bore Well	NA	5	NNE
G_6	Vayathur Koil Madam	Bore Well	NA	7	NE
G_7	Erukanthorai Farm House	Open Well	1.2	1	NW
G_8	Vamakulam Junction	Bore Well	NA	3	NW
G_9*	Yerkandurai Putteri	Bore Well	NA	7	W
G_{10}	Padgal Junction	Bore Well	NA	5	W
G_{11}	Shri Ranganarayana Puram	Open Well	1.0	6.5	WSW
G_{12}	Kudankulam (near Aqua Park)	Open Well	1.5	1	N

NA - Not Available

* Samples G_3 and G_9 could not be collected during winter season due to non-availability of water at these locations

** Samples G_5 could not be collected during Post-monsoon season due to non-availability of water at this location

Table 2.3.2

Groundwater Quality - Physical Parameters (Summer Season)

Sr. No.	Sampling location	pH	Temperature (^{o}C)	Turbidity (NTU)	Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Total Solids (mg/l)	Conductivity (μS/cm)
1	G_1	7.01	37	ND	27	1201	1228	1670
2	G_2	7.05	37	ND	19	5979	5998	6200
3	G_3	7.25	37	0.6	26	635	661	830
4	G_4	7.47	34	14.3	14	908	922	1380
5	G_5	6.47	37	0.4	16	473	489	630
6	G_6	7.80	35	0.3	17	2895	2912	4200
7	G_7	8.54	37	--	23	665	688	1200
8	G_8	6.63	36	--	16	2728	2744	2900
9	G_9	6.65	38	4.6	17	3075	3092	3400
10	G_{10}	6.89	38	1.5	17	531	548	720
11	G_{11}	7.45	35	0.3	17	8881	8898	9900
12	G_{12}	6.69	36	--	15	9885	9900	10800

ND - Not Detectable

Table 2.3.3

Groundwater Quality - Physical Parameters
(Post-monsoon Season)

Sr. No.	Parameters	Sampling Locations										
		G_1	G_2	G_3	G_4	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}
1	Temperature (^{0}C)	32	32	31	31	30	31	31	30	31	30	30
2	Turbidity (NTU)	ND	ND	5.2	mm	ND	ND	ND	ND	1.2	ND	ND
3	pH	7.67	7.53	7.79	7.72	6.86	7.84	6.92	6.85	7.25	7.27	7.0
4	Conductivity (μmhos/cm)	2700	8700	700	1260	1800	1130	2500	3400	1300	11500	14600
5	Total Solids (mg/l)	1915	6208.5	406	937.5	1096	573.0	1609	2177	622	9572	11695
6	Suspended Solids (mg/l)	15.0	8.5	16.0	17.5	18.0	15.0	9.0	10.0	10.0	12.0	15.0
7	Total Dissolved Solids (mg/l)	1900	6200	390	920	1078	568	1600	2167	612	9560	11680

ND - Not Detectable

Table 2.3.4
Groundwater Quality - Physical Parameters
(Winter Season)

Sr. No.	Parameters	Sampling Locations									
		G_1	G_2	G_4	G_5	G_6	G_7	G_8	G_{10}	G_{11}	G_{12}
1	Temperature (^{0}C)	29.5	29.0	29.0	29.5	30.0	29.0	29.0	30.0	28.5	29.0
2	Turbidity (NTU)	ND	2.4	15.0	0.5	1.6	10.0	1.5	1.5	0.3	1.0
3	pH	7.43	7.02	7.81	6.3	7.61	8.05	7.03	6.9	7.56	7.9
4	Conductivity (μmhos/cm)	1340	9700	1180	620	3000	1000	1950	1020	11100	12600
5	Total Solids (mg/l)	858	6175	747	392	2180	633	1191	646	8591	9544
6	Suspended Solids (mg/l)	28	16	16	14	20	23	21	19	21	24
7	Total Dissolved Solids (mg/l)	830	6159	731	378	2160	610	1170	627	8570	9520

ND - Not Detectable

Table 2.3.5

Groundwater Quality - Inorganic Parameters (Summer Season)

Sr. No.	Sampling location	Total Alkalinity	Total Hardness	Calcium Hardness	Magnesium Hardness	Chloride	Sulphates	Calcium	Magnesium	Sodium	Potassium
		(as $CaCO_3$)									
1	G_1	206	435	252	183	450	92.5	100.8	44.50	316	17.6
2	G_2	168	3950	2380	1570	2200	262.5	952.0	381.50	425	66.0
3	G_3	242	225	160	65	128	200.0	64.0	15.80	180	14.0
4	G_4	288	245	132	113	338	48.5	52.8	27.50	265	8.6
5	G_5	284	155	88	67	138	47.5	35.2	16.30	248	12.4
6	G_6	388	490	210	280	1080	128.8	84.0	68.04	960	54.0
7	G_7	244	260	108	252	125	43.5	43.2	36.94	100	18.0
8	G_8	256	850	200	650	710	222.5	260.0	48.60	400	64.0
9	G_9	304	1060	250	810	810	180.0	274.0	91.13	450	216.0
10	G_{10}	232	175	90	85	85	39.5	33.6	22.11	105	10.0
11	G_{11}	248	2600	1640	960	3900	400.0	384.0	398.52	1400	45.0
12	G_{12}	208	3500	1800	1700	3000	490.0	1160.0	558.90	920	560.0

All parameters are expressed in mg/l

Table 2.3.6

Groundwater Quality - Inorganic Parameters (Post Monsoon Season)

Sr. No.	Parameters	Sampling Locations										
		G_1	G_2	G_3	G_4	G_6	G_7	G_8	G_9	G 10	G_{11}	G_{12}
1	**Total Alkalinity (mg/l, $CaCO_3$)**	140	128	214	278	384	84	270	384	280	238	180
2	**Total Hardness (mg/l, $CaCO_3$)**	736	4030	240	200	360	200	590	880	268	4600	5500
3	**Calcium Hardness (mg/l, $CaCO_3$)**	480	2260	148	104	228	114	400	584	128	3300	3200
4	**Magnesium Hardness (mg/l, $CaCO_3$)**	256	1770	92	96	132	86	190	296	140	1300	2300
5	**Chlorides (mg/l, Cl)**	680	3000	150	340	280	160	460	760	180	4150	3900
6	**Sulphates (mg/l, SO_4)**	145	270	30	21	130	38	85	50	40	600	340
7	**Calcium (mg/l, Ca)**	192	904	59.2	41.6	91.2	45.4	160	233.6	51.2	1120	1080
8	**Magnesium (mg/l, Mg)**	62.2	430.1	22.34	23.32	32.07	20.9	46.17	71.92	34.02	701.9	650.0
9	**Sodium (mg/l, Na)**	325	700	140	196	260	110	240	225	200	1800	1260
10	**Potassium (mg/l, K)**	24.0	110	12.0	8.0	18.0	10.0	64	22.4	24.0	32.0	48.0

All parameters are expressed in mg/l

Table 2.3.7
Groundwater Quality - Inorganic Parameters
(Winter Season)

Sr. No.	Parameters	Sampling Locations									
		G_1	G_2	G_4	G_5	G_6	G_7	G_8	G_{10}	G_{11}	G_{12}
1	Total Alkalinity (mg/l, $CaCO_3$)	260	230	310	210	220	270	350	310	260	1180
2	Total Hardness (mg/l, $CaCO_3$)	268	5660	180	140	1220	380	500	300	5000	7000
3	Calcium Hardness (mg/l, $CaCO_3$)	120	4220	96	68	650	180	180	100	2000	3500
4	Magnesium Hardness (mg/l, $CaCO_3$)	148	1440	84	72	570	200	318	200	3000	3500
5	Chlorides (mg/l, Cl)	360	4050	210	65	625	210	625	230	5100	6500
6	Sulphates (mg/l, SO_4)	100	400	40	20	300	50	70	50	1100	900
7	Calcium (mg/l, Ca)	48	1688	38.4	27.2	260	72.0	73	40	800	1400
8	Magnesium (mg/l, Mg)	35.96	349.9	20.41	17.5	138.5	48.6	77.1	48.6	729	850.5
9	Sodium (mg/l, Na)	240	445	95	175	305	115	180	110	1130	920
10	Potassium (mg/l, K)	16.0	44	10	26	24	14	66	8	60	52

All parameters are expressed in mg/l

Table 2.3.8

Groundwater Quality - Nutrient and Organic Parameters (Summer Season)

Sr. No.	Sampling location	Nitrate (as N)	Total Phosphate (as PO_4)	Dissolved Oxygen (DO)	Chemical Oxygen Demand (COD)	Biochemical Oxygen Demand (BOD)
1	G_1	0.30	0.046	3.7	39.0	3.6
2	G_2	1.5	0.020	4.0	11.0	<3.0
3	G_3	0.90	0.004	3.4	11.0	<3.0
4	G_4	ND	0.005	5.4	31.3	<3.0
5	G_5	0.90	0.008	2.2	10.0	<3.0
6	G_6	ND	0.034	3.5	25.0	<3.0
7	G_7	1.40	0.044	3.5	20.0	<3.0
8	G_8	2.20	0.004	2.4	7.0	<3.0
9	G_9	2.10	0.005	3.5	11.0	--
10	G_{10}	0.80	0.024	2.3	10.0	--
11	G_{11}	2.10	0.090	2.9	30.0	3.0
12	G_{12}	1.65	0.002	2.9	28.0	<3.0

ND - Not Detectable

All parameters are expressed in mg/l

Table 2.3.9
Groundwater Quality - Nutrient and Organic Parameters
(Post-monsoon Season)

Sr. No.	Parameters	Sampling Locations										
		G_1	G_2	G_3	G_4	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}
1	**Dissolved Oxygen**	7.4	4.0	4.4	5.3	2.2	5.4	2.7	2.4	4.5	1.7	2.2
2	**BOD* (mg/l)**	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5.0	5.0
3	**COD (mg/l)**	1.6	4.8	3.2	4.8	1.6	2.2	5.0	4.8	1.6	21.6	24.4
4	**Nitrate as NO_3 (mg/l)**	1.294	7.25	4.75	0.25	7.0	7.5	10.5	10.5	6.5	9.5	9.5
5	**Phosphate as PO_4 (mg/l)**	0.024	0.016	0.024	0.027	0.030	0.024	0.006	ND	0.012	0.024	0.012

ND - Not Detected

* BDL - Below Detectable Limit of 3 mg/l
All parameters are expressed in mg/l

Table 2.3.10
Groundwater Quality - Nutrient and Organic Parameters
(Winter Season)

Sr. No.	Parameters	Sampling Locations									
		G_1*	G_2	G_4	G_5	G_6	G_7	G_8	G_{10}	G_{11}	G_{12}
1	**Dissolved Oxygen**	5.0	5.8	5.3	2.6	5.8	4.8	3.7	2.3	3.5	2.0
2	**BOD**	8.0	4.0	19.0	6.0	9.8	3.0	<3.0	<3.0	8.0	31.0
3	**COD**	29.0	13.0	67.9	18.0	31.0	12.9	5.0	10.0	32.5	165.0
4	**Nitrates as NO_3**	33.6	24.36	BDL	18.6	37.2	27.6	23.0	23.4	12.1	23.0
5	**Phosphate as PO_4**	BDL	0.06	0.045	0.004	0.024	0.009	0.08	0.09	0.4	BDL

* Different Source

BDL - Below Detectable Limit

All values are expressed in mg/l

Table 2.3.11

Groundwater Quality - Heavy Metals (Summer Season)

Sr. No.	Sampling location	Cadmium	Chromium	Copper	Lead	Iron	Manganese	Zinc
1	G_1	BDL	0.058	0.148	0.12	0.294	BDL	0.078
2	G_2	0.110	0.053	0.208	0.91	0.073	BDL	BDL
3	G_3	0.258	0.114	0.171	3.75	1.306	BDL	0.085
4	G_4	0.102	0.053	0.186	BDL	0.011	0.027	0.072
5	G_5	0.114	0.014	0.214	BDL	BDL	BDL	0.723
6	G_6	0.069	0.024	0.342	1.23	0.012	0.01	BDL
7	G_7	0.203	0.083	0.265	1.27	BDL	BDL	0.013
8	G_8	0.167	0.038	0.293	BDL	0.076	0.005	0.077
9	G_9	0.218	0.054	0.340	0.31	0.631	0.014	0.017
10	G_{10}	0.104	0.035	0.329	BDL	0.246	BDL	0.177
11	G_{11}	0.210	0.059	0.337	1.22	BDL	0.03	0.028
12	G_{12}	BDL	0.104	0.337	1.64	BDL	BDL	0.198

BDL : Below Detectable Limit

All parameters are expressed in mg/l

Table 2.3.12
Groundwater Quality - Heavy Metals
(Post-monsoon Season)

Sr. No.	Parameters	Sampling Locations										
		G_1	G_2	G_3	G_4	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}
1	Cadmium (Cd)	BDL	0.033	0.05	BDL	0.01	0.08	BDL	0.095	0.09	0.067	0.041
2	Chromium (Cr)	0.002	0.002	0.08	0.05	BDL	0.04	0.01	BDL	0.01	0.06	0.08
3	Copper (Cu)	BDL	0.08	BDL	BDL	0.08	0.15	0.1	BDL	0.15	0.08	0.15
4	Iron (Fe)	0.496	0.174	BDL	0.038	BDL	0.074	BDL	BDL	0.06	0.148	0.369
5	Manganese (Mn)	BDL	BDL	BDL	0.015	BDL	BDL	BDL	BDL	BDL	BDL	BDL
6	Zinc (Zn)	BDL	BDL	0.05	0.01	BDL	BDL	BDL	0.0366	0.01	BDL	0.0163

All the values are expressed in mg/l

BDL - Below Detectable Limit
Sample G5 could not be collected during Post-monsoon season due to non-availability of water at this location

Table 2.3.13
Groundwater Quality - Heavy Metals
(Winter Season)

Sr. No.	Parameters	Sampling Locations									
		G_1*	G_2	G 4	G 5	G 6	G 7	G 8	G 10	G 11	G 12
1	**Cadmium (Cd)**	0.001	0.025	BDL	0.01	0.02	0.04	BDL	0.06	0.055	0.03
2	**Chromium (Cr)**	0.001	0.001	0.03	0.01	0.01	0.03	0.01	0.01	0.05	0.05
3	**Copper (Cu)**	BDL	0.01	BDL	BDL	BDL	BDL	BDL	BDL	0.002	0.001
4	**Iron (Fe)**	0.15	0.21	0.03	0.11	0.05	0.06	BDL	0.15	0.12	0.08
5	**Manganese (Mn)**	0.001	BDL	0.01	0.03	BDL	BDL	BDL	BDL	BDL	0.41
6	**Zinc (Zn)**	0.02	BDL	0.03	0.15	0.05	0.02	0.03	0.15	0.12	0.22

Different source

BDL - Below Detectable Limit

All the values are expressed in mg/L

Table 2.3.14

Groundwater Quality - Bacteriological Parameters (Summer Season)

Sr. No.	Sampling location	Total Coliform	Faecal Coliform	E. Coli	Fecal Streptococci
		(MPN/100 ml)			
1	G_1	43	21	21	23
2	G_2	9	Nil	Nil	15
3	G_3	93	Nil	Nil	23
4	G_4	90	Nil	Nil	23
5	G_5	45	20	20	9
6	G_6	65	23	23	4
7	G_7	29	9	9	9
8	G_8	42	23	9	4
9	G_9	15	Nil	Nil	4
10	G_{10}	4	Nil	Nil	4
11	G_{11}	75	Nil	Nil	4
12	G_{12}	75	Nil	Nil	4

Table 2.3.15

Groundwater Quality - Bacteriological Parameters
(Post-monsoon Season)

Sr. No.	Parameters *MPN/100 ml*	Sampling Locations										
		G_1	G_2	G_3	G_4	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}
1	**Total Coliform**	9	9	430	93	4	240	0	0	0	43	4
2	**Fecal Coliform**	4	0	240	23	0	93	0	0	0	23	4
3	**E. Coli**	4	0	23	23	0	23	0	0	0	23	4
4	**Fecal Streptococci**	0	9	23	23	0	240	0	0	0	240	0

Table 2.3.16

Groundwater Quality - Bacteriological Parameters (Winter Season)

Sr. No.	Parameters *MPN/100 ml*	Sampling Locations									
		G_1	G_2	G_4	G_5	G_6	G_7	G_8	G_{10}	G_{11}	G_{12}
1	**Total Coliform**	920	14	920	2	2	74	24	ND	2	TNC
2	**Fecal Coliform**	920	11	920	2	2	ND	10	ND	ND	16
3	E. Coli	23	2	23	1	1	0	0	0	0	9
4	**Fecal Streptococci**	33	5	220	2	2	4	2	2	4	11

ND - Not Detected .

TNTC - Too Numerous to Count

Table 2.3.17

Sampling Locations for Marine Water Quality Study

Longitudinal Distance (m)	Distance from the Seashore (50 m) Sample No.	Distance from the Seashore (100 m) Sample No.
1000	M-1	M-1
500	M-2	M-2
0 (near project site)	M-3	M-3
500	M-4	M-4
1000	M-5	M-5

Table 2.3.18

Marine Water Quality - Physical Parameters

Sr. No.	Sampling location	pH	Temperature (°C)	Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Total Solids (mg/l)	Conductivity (μS/cm)
50 meters from the Sea-Shore							
1	M-1	7.86	28.0	22	39480	39502	43
2	M-2	7.84	28.5	20	44047	44067	45
3	M-3	7.91	27.0	19	43250	43269	45
4	M-4	7.88	28.0	20	40976	40996	42
5	M-5	7.92	28.0	20	43784	43804	44
100 meters from the Sea-Shore							
6	M-1	7.46	29.0	18	41982	42000	44
7	M-2	7.88	28.0	18	42994	43012	45
8	M-3	8.06	28.5	17	43008	43025	45
9	M-4	8.05	28.0	17	41500	41517	42
10	M-5	7.90	27.5	15	42885	42900	45

Table 2.3.19

Marine Water Quality - Inorganic Parameters

Sr. No.	Sampling location	Total Alkalinity	Total Hardness	Calcium Hardness	Magnesium Hardness	Chloride	Sulphates	Calcium	Magnesium	Sodium	Potassium
		(as $CaCO_3$)									
	50 meters from the Sea-Shore										
1	M-1	132	6050	1120	4930	22500	2450	448	1440.9	10000	360
2	M-2	120	6650	1020	5630	23500	3000	408	1368.1	10300	360
3	M-3	120	6750	1020	5730	23000	2900	408	1392.4	10200	400
4	M-4	120	6500	1060	5400	22500	2300	424	1311.9	9500	350
5	M-5	132	6750	1040	5710	22750	3000	416	1387.5	9700	480
	100 meters from the Sea-Shore										
6	M-1	120	6700	1000	5700	22500	3000	400	1385.1	10000	520
7	M-2	124	6700	1040	5660	22000	3000	416	1375.4	9850	480
8	M-3	120	6600	1000	5600	22250	3100	400	1360.8	9700	320
9	M-4	132	6700	1060	5640	21500	2850	424	1370.5	9800	480
10	M-5	120	6650	1020	5630	22250	2750	408	1368.1	10200	504

All parameters are expressed in mg/l

Table 2.3.20

Marine Water Quality - Nutrient and Organic Parameters

Sr. No.	Sampling location	Nitrate as N	Total Phosphate as PO_4	Dissolved Oxygen (DO)	Chemical Oxygen Demand (COD)	Biochemical Oxygen Demand (BOD)
50 meters from the Sea-Shore						
1	M-1	ND	0.001	2.4	65.1	5.0
2	M-2	0.1	0.004	2.2	55.5	4.0
3	M-3	ND	0.001	2.0	50.0	4.0
4	M-4	ND	0.001	1.0	50.5	4.0
5	M-5	ND	0.002	1.2	48.0	5.0
100 meters from the Sea-Shore						
6	M-1	ND	0.001	3.1	58.3	3.0
7	M-2	ND	0.002	3.1	55.0	3.0
8	M-3	ND	0.004	2.6	49.0	3.0
9	M-4	ND	0.002	3.5	55.0	3.5
10	M-5	ND	0.001	0.7	48.2	3.0

All parameters are expressed in mg/l

Table 2.3.21

Marine Water Quality - Heavy Metals

Sr. No.	Sampling location	Cadmium	Chromium	Copper	Lead	Iron	Manganese	Zinc
50 meters from the Sea-Shore								
1	M-1	0.056	0.117	0.244	5.94	0.279	0.009	0.058
2	M-2	0.017	0.145	0.237	1.46	0.279	0.027	0.022
3	M-3	0.044	0.137	0.156	0.22	0.162	0.021	0.015
4	M-4	0.063	0.153	0.199	2.81	0.235	0.019	0.033
5	M-5	0.068	0.154	0.219	3.82	0.443	0.030	0.039
100 meters from the Sea-Shore								
6	M-1	0.152	0.149	0.233	1.98	0.151	0.024	0.010
7	M-2	0.130	0.160	0.146	3.98	0.359	0.025	0.090
8	M-3	0.172	0.158	0.325	3.92	0.053	0.036	0.034
9	M-4	0.181	0.155	0.234	3.28	0.213	0.024	0.037
10	M-5	0.177	0.156	0.322	2.52	0.056	0.005	0.069

All parameters are expressed in mg/l

Table 2.3.22

Marine Water Quality - Bacteriological Parameters

Sr. No.	Sampling location	Total Coliform	Faecal Coliform	E. Coli	Fecal Streptococci
		(MPN/100 ml)			
50 meters from the Sea-Shore					
1	M-1	4	Nil	Nil	4
2	M-2	4	Nil	Nil	<3
3	M-3	7	Nil	Nil	4
4	M-4	4	Nil	Nil	4
5	M-5	4	Nil	Nil	4
100 meters from the Sea-Shore					
6	M-1	7	Nil	Nil	<3
7	M-2	7	Nil	Nil	4
8	M-3	7	Nil	Nil	<3
9	M-4	7	Nil	Nil	4
10	M-5	4	Nil	Nil	4

Table 2.3.23

Characteristics of Ground Water at Kudankulam (Samples Collected During Dec. 1987)

Sr. No.	Parameter	Well 1	Well 2
1	Total Solids	980.0 p. p. m	790 p. p. m
2	Suspended Solids	80.0 p. p. m	18.0 p. p. m
3	Dissolved Solids	950.0 p. p. m	778.0 p. p. m
4	Total Alkalinity as ($CaCO_3$)	864.8 p. p. m	744.2 p. p. m
5	Normal Carbonates (as $CaCO_3$)	89.29 p. p. m	Nil
6	Bicarbonates (as $CaCO_3$)	775.5 p. p. m	744.2 p. p. m
7	Chlorides (as Cl)	230.2 p. p. m	154.7 p. p. m
8	Total Hardness (as $CaCO_3$)	141.6 p. p. m	112.2 p. p. m
9	Silica	70.0 p. p. m	73.99 p. p. m
10	Iron (as Fe)	1.78 p. p. m	2.5 p. p. m
11	Calcium (as Ca)	32.35 p. p. m	18.60 p. p. m
12	Magnesium (as Mg)	14.75 p. p. m	15.98 p. p. m
13	Sulphate (as SO_4)	213.1 p. p. m	144.0 p. p. m
14	pH value	9.0	9.9
15	Conductivity	0.05 mho/cc	0.04 mho/cc

Source : NPCIL, Mumbai

Table 2.3.24

Characteristics of Sea Water
(Sample Collected During December 1987)

Sr. No.	Parameters	Value
1.	Total Solids	39520
2.	Suspended Solids	5
3.	Dissolved solids	39515
4.	Loss on Ignition	4960
5.	pH Value	8.5
6.	Total Hardness (as $CaCO_3$)	6180
7.	Sulphates (as SO_4)	2675
8.	Iron (as Fe)	0.15
9.	Silica (as SiO_2)	50
10.	Chlorides (as Cl)	19617
11.	Total Alkalinity (as $CaCO_3$)	114
12.	Colour	Saltwhitish
13.	Conductivity	60000 µS/cm
14.	Sodium (as Na_2O)	13750
15.	Potassium (as K)	401
16.	Silt Content, %	97.5

Source : NPCIL, Mumbai
All parameters except otherwise mentioned are expressed in mg/l

Table 2.3.25

Characteristics of Sea Water (Sampling at Kudamkulam During Dec 1987)

Sr. No.	Parameter	Values at	
		A distance Where there is 15 ft. depth	A distance Where there is 20 ft. depth
1.	pH value	7.6	7.7
2.	Chloride (as Cl)	19140	19200
3.	Total Hardness (as $CaCO_3$)	6371	6410
4.	Calcium (as Ca)	479.6	462
5.	Magnesium (as Mg)	940.7	1268
6.	Silica (as Si)	7	8
7.	Total Solids	4000	40460
8.	Suspended Solids	35	48
9.	Sulphate (as SO_4)	2751	2754
10.	Total Alkalinity (as Ca CO_3)	132	132
11.	Normal Carbonate (as $CaCo_3$)	22.80	19
12.	Bicarbonate (as Ca CO_3)	109.2	113
13.	Iron and Al. Oxides	33	32
14.	Sodium (as Na_2O)	16550	16240
15.	Potassium (as K_2O)	140.7	58.52

Source : NPCIL, Mumbai
All values except pH are expressed in mg/l

Table 2.3.26

Background Radiation Survey and Environmental Sampling at and around Kudamkulam (KK) Project site (October, 2000)

Sr. No.	Location	Distance from Site (km)	Radiation Field (μSv/h)	Types of Samples Collected
1	KK village	<2	0.03-0.04	Well water, Fruits, seeds, nuts, fish, milk, cereals, vegetation, vegetables, grass
2	KK city beginning	<2	0.14-0.15	
3	KK city end	<2	0.15-0.16	
4	KK site	<2	0.13-0.14	Sea water, well water, vegetation, soil, sand, seeds, bore-well core sample from different level sea weed
5	Vyravikinaru	2-5	0.14-0.15	
6	Idinthakara	2-5	0.14-0.15	Tapioca
7	Vijaypatti (W)	2-5	0.12-0.13	Ground nuts, soil
8	Vijaypatti (E)	2-5	0.45-0.50	
9	Onnarkulm	2-5	0.10	
10	Shivasabrahmaniapu ram	2-5	0.13-0.14	
11	Sreeranga Narayanapuram (near KK/T.ship)	5-10	0.11-0.12	
12	KK township	5-10	0.14-0.15	Soil
13	Chettikulam Road side	5-10	0.10-0.12	Pond water, sediment
14	Chettikulam beach	5-10	0.15	Sea water, sand, sea weed
15	Udayathur	5-10	0.10-0.11	
16	Parameswarapuram	5-10	0.10-0.11	
17	Radhapuram	10-15	0.10-0.11	
18	Koliyamkulam	10-15	0.10-0.11	
19	Vadakkankulam	10-15	-	Bore - well water
20	Anjugramam	10-15	0.10	
21	Kannankulam (near Anjugramam)	10-15	0.07	

Sr. No.	Location	Distance from Site (km)	Radiation Field (µSv/h)	Types of Samples Collected
22	Kavalkkinaru	15-20	0.10-0.11	
23	Kavalkkinaru Rly. Station	15-20	0.14-0.15	
24	Azhakappapuram	15-20	0.06-0.07	Grass
25	Vattakkotai	15-20	0.10	Common salt
26	Shuchindram	20-30	0.10-0.11	
27	Agasthewaram	15-20	0.25	
28	Kanyakumari Rly. Station	15-20	0.20	
29	Kanyakumari beach	15-20	0.08	Sea water, sand, sea weed, Algae
30	Arogyapuram	15-20	0.16-0.17	
31	Ethankodu (Near Thamarakkulam)	20-30	0.11-0.12	
32	Kottaram	20-30	0.11-0.12	
33	Aravoimozhi	20-30	0.18-0.19	
34	Thovalai	20-30	0.10-0.11	
35	Vellamadam	20-30	0.11-0.12	
36	Nagarcoil	>30	0.12-0.13	

Bore-well Monitoring Radiation field was monitored at different depths in two bore wells. In the Bore-well no.1, the dose rate ranged from 0.05-0.11 µSv/h. In bore-well no.2 the dose rate ranged from 0.07 to 0.10 µSv/h. No significant change in radiation field with depth of borewell was observed.

Ref: - Report by ESL, Kaiga, Oct. 2000 at KK Project Site

Table 2.3.27

^{137}Cs and ^{90}Sr Activity Levels in Water Samples Collected from Kudankulam Site (October 2000)

Sr. No.	Type of Sample	Sampling Location	Date of Collection	^{137}Cs Activity (mBq/l)	^{90}Sr Activity (mBq/l)
1.	Sea Water	K. K. Site	20-10-00	16.6 + 1.5	BDL
2.	Open Well	K. K. Site	20-10-00	BDL	BDL
3.	Sea Water	Chettikulam	21-10-00	8.5 + 1.5	BDL
4.	Pond	Chettikulam	21-10-00	2.6 + 0.8	BDL
5.	Sea Water	Kanyakumari	22-10-00	7.4 + 1.4	BDL
6.	Bore Well	Vadakkankulam	22-10-00	6.0 + 1.6	BDL
7.	Open well	K. K. Village	21-10-00	BDL	BDL

MDL = 2.5 mBq/l

Source :- BARC, Mumbai

Table 2.3.28

^{137}Cs and ^{90}Sr Activity Levels in Water Samples Collected from Kudankulam Site (May 2001)

Sr. No.	Type of Sample	Sampling Location	Distance from the Site (km)	Date of Collection	^{137}Cs Activity (mBq/l)	^{90}Sr Activity (mBq/l)
1	Sea	Kudankulam site	00-02	29-5-01	7.5 + 1.4	BDL
2	Pond	Chettikulam	05-10	29-5-01	BDL	BDL
3	Bore well	Vadakankulam	10-16	29-5-01	3.6 + 1.1	BDL
4	Sea	Vatakotai	16-20	30-5-01	12.4+ 1.7	BDL
5	Sea	Kanyakumari	16-20	30-5-01	12.6 + 2.0	BDL
6	Pond	Vellamadam	20-30	29-5-01	BDL	BDL
7	Open well	Valliyur	20-30	31-5-01	3.8 + 1.3	BDL
8	Bore well	Tisayanvillai	20-30	31-5-01	BDL	BDL
9	Pazhayar river	Nagarcoil	20-30	01-6-01	3.9 + 1.3	BDL
10	Bore well	Suchindram	20-30	29-5-01	BDL	BDL

MDL = 2.5 mBq/l

Source :- BARC, Mumbai

2.4 Land Environment

2.4.1 Reconnaissance

Pre-operational studies on land environment have been carried out within the impact zone of 30 km radius of proposed site of Nuclear Power Plant. The studies include assessment of overall baseline environmental status of land environment and secondary data on soil radioactivity. Information on land use pattern has also been collected and compiled.

The topography of the site is such that it has slope towards the sea. Groundwater occurrs under unconfined water table conditions and shows a gradient towards the sea. The site is generally underlain by banded and foliated biotite granite gneissic rocks covered by varying thickness of weathered gneiss and shell limestones. The bed rock of biotite granite gneiss encloses lenticular bands of charnockites and quartzites. Rock outcrops are seen at the tie between the high and low tide lines all along the shore and also in high ground and nalla cuttings in the area. Bore hole investigations at the proposed project site indicates fairly competient foundation grade rocks of biotite granite gneiss with lenticular bodies of Charnockite and quartzites is available at depths ranging from 5 m to 16 m below ground level beneath the shell limestone cover. Boulderly weathered zones are likely to be encountered within the depth of 16 m below ground level.

2.4.2 Baseline Data

Twenty-seven sampling locations within 30 km radius of the proposed project site were identified for collection of soil samples. The sampling locations are shown in **Figure 2.4.1** and their details are reported in **Table 2.4.1**.

2.4.3 Physical Characteristics

Physical characteristics of soil samples are delineated through specific parameters, viz., particle size distribution, texture, bulk density, porosity and water holding capacity. The particle size distribution in terms of percentage of sand, silt and clay is furnished in **Table 2.4.2** and depicted in **Figure 2.4.2**. It is observed that soil texture varied from sandy loam to loamy sand.

Regular cultivation practices increase the bulk density of soils, thus, inducing compaction. This results in reduction in water percolation rate and penetration of root through soils. The bulk density of soils in the region is found to be in the range of 1.20-1.85 gm/cm^3 which is considered as moderately good.

Soil porosity is a measure of air filled pore spaces and gives information about movement of gases, inherent moisture, development of root system and strength of soil. Variations in soil porosity are presented in **Table 2.4.2**. The porosity and water holding capacity of soils are in the range of 34 to 48% and 21 to 44% respectively. The soils in the impact zone have a sandy loam texture with moderate water holding capacity.

2.4.9 Chemical Characteristics

Data was collected for chemical characterization of soils through select parameters, viz. pH, electrical conductivity, soluble anions and cations, cation exchange capacity (CEC), exchangeable cations, exchangeable sodium percentage, nutrients, organic content and heavy metals and the same is presented in **Tables 2.4.3-2.4.10**.

pH is an important parameter indicative of the alkaline or acidic nature of the soil. It greatly affects the microbial population as well as the solubility of metal ions and regulates nutrient availability. Variation of pH of soils in the study area is presented in **Table 2.4.3** and it was observed to be acidic to neutral (within the range of 5.28 to 8.25) thus indicating that the soils are conducive for the growth of plants.

Electrical conductivity, a measure of soluble salts in the soils, is in the range of 0.17 to 5.00 mS/cm as seen from **Table 2.4.3**. The important cations present in soils are calcium and magnesium. It is observed that calcium and magnesium concentrations are in the range of 0.28 to 7.52 meq/l and 0.04 to 5.56 meq/l respectively, whereas sodium and potassium are in the range of 0.18 to 25 meq/l and 0.09 to 3.84 meq/l respectively. Chlorides are in the range of 0.05 to 27.63 meq/l whereas bicarbonates vary from 0.24 to 6.24 meq/l.

Variations in Cation Exchange Capacity (CEC) of the soils are presented in **Table 2.4.4**. Amongst the exchangeable cations, Ca^{2+} and Mg^{2+} are observed to be in the range of 0.32 to 3.06 meq/100 gm and 0.3 to 7.61 meq/100 gm and for Na^{+} and K^{+}, the CEC values are in the range of 0.02 to 0.24 and 0.002 to 0.064 meq/100 gm of soil respectively. Exchangeable sodium percentage ranged from 0.27 to 3.25 indicating that the soils are free from sodicity. The relationship of CEC with productivity and absorptivity is presented in **Tables 2.4.5-2.4.6**.

Organic matter present in soil influences its physical and chemical properties. It commonly accounts for as much as one third or more of the cation exchange capacity of the surface soils and is responsible for stability of soil aggregates. Organic carbon and available nitrogen in soil samples vary in the range of 0.08 to 1.95 and 0.98 to 3.25 mg/100 gm respectively. Available phosphorus varies from ND to 0.05 mg/100 gm (**Table 2.4.7**). This shows that the soils are moderately good in organic and nutrient content. The fertility status of soils is presented in **Table 2.4.8**.

Plants require some of the heavy metals at microgram levels for their metabolic activities. These heavy metals are termed as micronutrients. Their deficiency becomes a limiting factor for plant growth, but at the same time their higher concentration in soils may lead to toxicity for plant growth. Levels of heavy metals in soils are presented in **Table 2.4.9**.

2.4.5 Soil Radioactivity

2.4.5.1 Baseline Data

The west coast of Southern part of Indian Peninsula is rich in monazite deposits, a thorium bearing mineral. The distribution of monazite and its impact on background radiation levels forms basis for radiation survey in this region. This survey helps in change in environmental radiations, if any due to reactor operation of the proposed nuclear power plant.

This report covers the data for 1990 made available by NPCIL within 2 km stretch of beach sands on either side of the proposed site and villages situated within 2 to 5 km and 5 to 10 km radius of the project site.

Beach Sand

Samples of beach sand were collected from 28 locations and the ambient radiation levels in these samples were recorded. Beach surveys revealed a rapidly changing, non-uniform radiation dose profile ranging from 10 to 310 μR/h. The higher radiation levels were usually traceable in patches of black sand in the vicinity. These hot spots were confined to small pockets except in a stretch of one km towards Idindakarai village where the readings were ranging between 65 to 310 μR/h. Similar type of black sand and the enhanced radiation levels had also been observed on Kalpakkam beach sand. The analysis of the Kalpakkam beach black sand revealed the presence of monazite. The discontinuous nature of monazite occurrence and distribution is evident from the varying radiation levels observed in the coastal beaches.

A typical gamma spectrum of soil sample collected from Kudankulam beach (**Figure 2.4.3**) identified the daughter products of Th-232 viz., Pb-212, Ac-228, Tl-208, Bi-212, Ac-228, Bi-212 and Tl-208. The spectra clearly reveals the presence of thorium in almost all the soil samples.

Villages between 2-5 km Radius

Samples of soils were collected in 14 villages. Kudankulam being nearest to project site with population of 15000, ten samples were collected for extensive monitoring. Four samples were collected from Idindakarai village which is nearer to the seashore and again a thickly populated village. These spectra corresponding the soil samples collected from different villages are Panchal 15 μR/h (**Figure 2.4.4**), Kudankulam 50 and 160 μR/h (**Figures 2.4.5-2.4.6**), and Idindakarai 200 and 270 μR/h (**Figures 2.4.7-2.4.8**). The numbers in indicate the levels as measured by the Scintilla meter at the point of soil sample collection. The spectrum contains all the characteristic peaks of thorium and its daughter products, especially the peaks due to Pb-214, Ra-224 and Pb-212. The throrium activity has been estimated as 50 Bq/kg, the K-40 activity as 8 Bq/kg and the uranium activity is below the detection limit of 37 Bq/kg. In the village Idindakarai which is on the seashore, it was observed that even the road sands were black in colour and hence were suspected to be having higher thorium content. This was confirmed by dose rate measurements as well as the gamma spectrum of the soil samples. Here the estimated thorium activity was as high as 1800 Bq/kg.

Villages between 5 to 10 km Radius

Forty-five villages are situated within 5 to 10 km radius of NPP site. Soil samples from these villages were collected and the gamma dose rates were measured. Out of 45 villages, nine were located on the seashore and the dose rates were ranging from 30 μR/h to 250 μR/h. In the remaining inland villages, the dose rates never exceeded 20 μR/h. All the 45 soil samples were subjected to detailed gamma ray spectrometry analysis. The spectra correspond to different villages are Arasarkulam (10 uR/h) (**Figure 2.4.9**), Perumanal (40 uR/h) (**Figure 2.4.10**), Viswamitrar Thapas temple (75 uR/h) (**Figure 2.4.11**), Nadar Koothangudi (225 uR/h) (**Figure 2.4.12**) and Alagar Koothangudi (250 uR/h) (**Figure 2.4.13**). The spectra of soil samples indicates that at Kudankulam and in the surrounding villages, the type of radioactive content (presence of thorium and its daughters) in the soil is the same but with varying levels. (***Source*** : Report on the background radiation survey at Kudankulam Project site and its environs. Meenakshi College for Women, Kodambakkam, Madras, 1990).

2.4.5.2 Baseline Data for October 2000 and May 2001

Pre-operational studies were carried out at Kudankulam to establish baseline data on soil radioactivity in October 2000 and May 2001. Soil samples were analysed for natural radioactivity and fall out nuclides ^{137}Cs and ^{90}Sr as per the standard procedure. Land within

2 km from the proposed plant site is barren with no agricultural activity. Soil samples were kept in sealed container for one month for analysis of daughter products to reach in equilibrium with their respective parents.

The concentrations of radionuclides ^{137}Cs and ^{90}Sr in soil samples collected during October 2000 and May 2001 are shown in **Tables 2.4.10-2.4.11** respectively. ^{137}Cs values were observed to be varying from BDL to 8.3 Bq/kg dry wt. and ^{90}Sr values were found to be varying from BDL to 1.4 Bq/kg dry wt.

It is assumed that ^{232}Th is in equilibrium with ^{228}Ra and ^{238}U is in equilibrium with ^{226}Ra. The gamma emissions of ^{228}Ac (daughter product of ^{228}Ra) and ^{214}Bi (daughter product of ^{226}Ra) were used for the estimation of ^{232}Th and ^{238}U respectively. A High Purity Germanium Detector was used for Gamma Ray spectrometry. The estimated Natural radioactivity levels of ^{238}U, ^{232}Th and ^{40}K in soil samples are shown in **Tables 2.4.12-2.4.13**. ^{232}Th concentration was much higher compared to that of ^{238}U. ^{232}Th concentration was higher in the areas, where the background radiation field was higher. Maximum ^{232}Th concentration observed was 4364 Bq/kg dry wt. in soil collected from Idinthakarai. ^{238}U values were found to be varying from 3.3 to 427.8 Bq/kg dry wt. The maximum value was observed at Idinthakarai. From the table, it can be observed that ^{40}K values in soil are varying from place to place. Generally coastal sand showed a lower concentration of ^{40}K as compared to interior and farmlands.

It is known that the fall out radioactivity in soils and terrestrial biota is directly related to the rainfall. Kudankulam, being a scanty rainfall area, is expected to have less fallout radioactivity.

Depth Profile of Natural Radioactivity

Soil/rock powder samples were collected from different depths of a borehole at Kudankulam site. 20 samples collected from different depths of up to 200 meter were analysed for gamma ray spectrometrically. The concentrations of samples collected from different depths are shown in **Table 2.4.14**. It has been observed that below 5-meter layer, ^{232}Th and ^{238}U concentrations were quite low. Gamma ray spectral analysis of the soil is an essential input data for estimating the exposure of the population living in such area. The coastal strip in Tamil Nadu nearer to Kudankulam was identified as an area with high natural radiation hence soil sampling of this region was undertaken.

Analysis of soil samples collected from different depths of borewells indicated that ^{232}Th and ^{238}U concentrations were maximum in the top 1 meter soil layer.

(***Source :*** Report on the pre-operational Environmental Radiological Survey at Kudankulam Atomic Power Project Site, October 2000 and May 2001, Health Physics Department, BARC-Mumbai).

2.4.6 Soil Microbiology

Various ecological cycles in the Rhizosphere of the plant depend upon microbiological population. The population of bacteria, fungi and actinomycetes are vital components of soils and they help in maintaining their stability. Characteristics of soil micro-organisms are presented in **Table 2.4.15**.

Rhizobium and Azotobactor are symbiotic and non-symbiotic nitrogen fixing micro organisms respectively and improve soil fertility by fixing nitrogen in soil. Fungi also constitute an important part of the microflora of normal soil. They are active in initial stages of decomposition of plant residues and actively participate in the process of soil aggregation. Total viable microbial population per gram of soil varied from 28×10^5 to 289×10^5 CFU. Different microflora observed per gram of soil were fungi (6×10^3 to 44×10^3 CFU), actinomycetes (ND to 24×10^3 CFU), rhizobium (ND to 84×10^3 CFU) and azotobacter (2×10^3 to 95×10^3 CFU).

2.4.7 Landuse Pattern

The landuse pattern in different villages falling within 30 km radial distance from the proposed project site is depicted in **Figure 2.4.14** and the data is summarized in **Table 2.4.16**.

About 60% of the area within 30 km radius around the site falls in the sea. The remaining area consists of agricultural land and barren land. The main agricultural crops are paddy, millets and chillies and subsidiary crops are tobacco, pulses, cotton and oil seeds. About 35% of the area within 2 km radius (exclusive zone) around the proposed reactors falls in the sea. An area of 650 to 700 hectares of land was acquired at Kudankulam. The land identified is barren and unirrigated. The top soil of the land acquired is with limestone, lack of irrigation and poor agricultural yield which has formed the criteria for the selection of site.

2.4.8 Solid Radioactive Wastes

2.4.8.1 Quantity and Composition

In the proposed nuclear power plant of 2000 MWe capacity, solid waste generated would be about 350 m^3/year which, after treatment and conditioning, would be reduced to 250 m^3/year.

The waste consists of waste cotton, paper, mops, plastic, equipment parts, spent resins filters, strainers, filter cartridges, filter sludges etc. These wastes will be generated during normal operation, maintenance and repair. Characteristics of solid radioactive wastes are presented in **Table 2.4.17**.

2.4.8.2 Classification of Radioactive Solid Wastes

Radioactive solid wastes generated from nuclear power plant are classified into **Category I** with surface dose rate of upto 200 mR/hr. This category includes dry ventilation filter paper tools, clothes, spent filter resins etc. This is further segregated into combustible and non-combustible waste. **Category II** includes waste with dose rate varying between 0.2 to 5.0 mR/hr. This category includes waste from process equipment, ion exchange columns, filter etc. **Category III** with surface dose rate of more than 50 mR/hr which is further classified as **IIIA** which includes waste with surface dose rate of upto 50 mR/hr. This category includes high active reactor components, slurries and sludges, spent ion exchange resins. **Category IIIB** include surface dose rate of more than 50 mR/hr. This waste includes liquid filters, spent liquid filter, spent ion exchange resins etc.

2.4.8.3 Segregation and Collection of Wastes

The segregation is carried out with a view :

i. To ensure that the combustible waste has no major non-combustible items

ii. To segregate the non-combustible wastes into compactable and non-compactable groups

iii. To segregate oversize combustible parts for shredding/cutting to size and then repacking for bailing machine feed or to incinerator feed, along with other compactable wastes

In order to reduce unnecessary exposure, the seggregation of the waste is carried out at the source inside the plant. Wastes are seggregated as per dose-rate classification. Wastes belonging to **Category I** are collected in polythene bags which are kept in drums. The drums are properly capped before sending them to the exclusion zone. Wastes of **Category II** having dose-rate between 200 mR/hr and 2 mR/hr are collected in drums with shielding arrangement. The waste belonging to the **Category II**, are collected in properly shielded casks. The manual separation of **Category I** wastes into combustibles and non-combustible categories will be carried out in globe box or fume hood.

2.4.8.4 Solid Radioactive Waste Treatment System

Solid radioactive waste system is intended for solid radioactive waste reprocessing and for temporary storage of solid radioactive waste and solidified liquid radioactive media.

Solid radioactive wastes (SRW) are generated both during normal operation of NPP and during repair and accidents.

Treatment system for solid radioactive wastes includes reprocessing and storage of solid radioactive wastes. Solid radioactive wastes are reprocessed to reduce their volume. A schematic flowchart of solid radioactive waste treatment system at NPP, Kudankulam is presented in **Figure 2.4.15**.

The following types of reprocessing are used within the project :

- burning
- compacting

After reprocessing the finished product is placed in standard 200 litres capacity barrels and is stored in the solid waste stores at solid waste management building.

Solid radioactive wastes are collected in special protective containers at the place of their formation.

Gradiation according to the levels of activity and the methods of further reprocessing is made at the place of their collection when they are loaded in the containers.

Solidified liquid waste concentrates which are fixed using concentration are collected in 200 litres stainless steel drums and stored in the intermediate storage area of solid waste management building.

The construction of the temporary solid radioactive waste store is provided at the site of NPP. This store is located in the special reinforced surface building. The thickness of walls and floors of storage sections ensures mechanical strength and biological protection. Storage sections of solid radioactive wastes belong to II category seismic resistance according to PN AE G-5-006-87.

The storage technology and storage structures and equipment permit to extract the wastes loaded and transport them for further reprocessing and storage in permanent storage yard in the future.

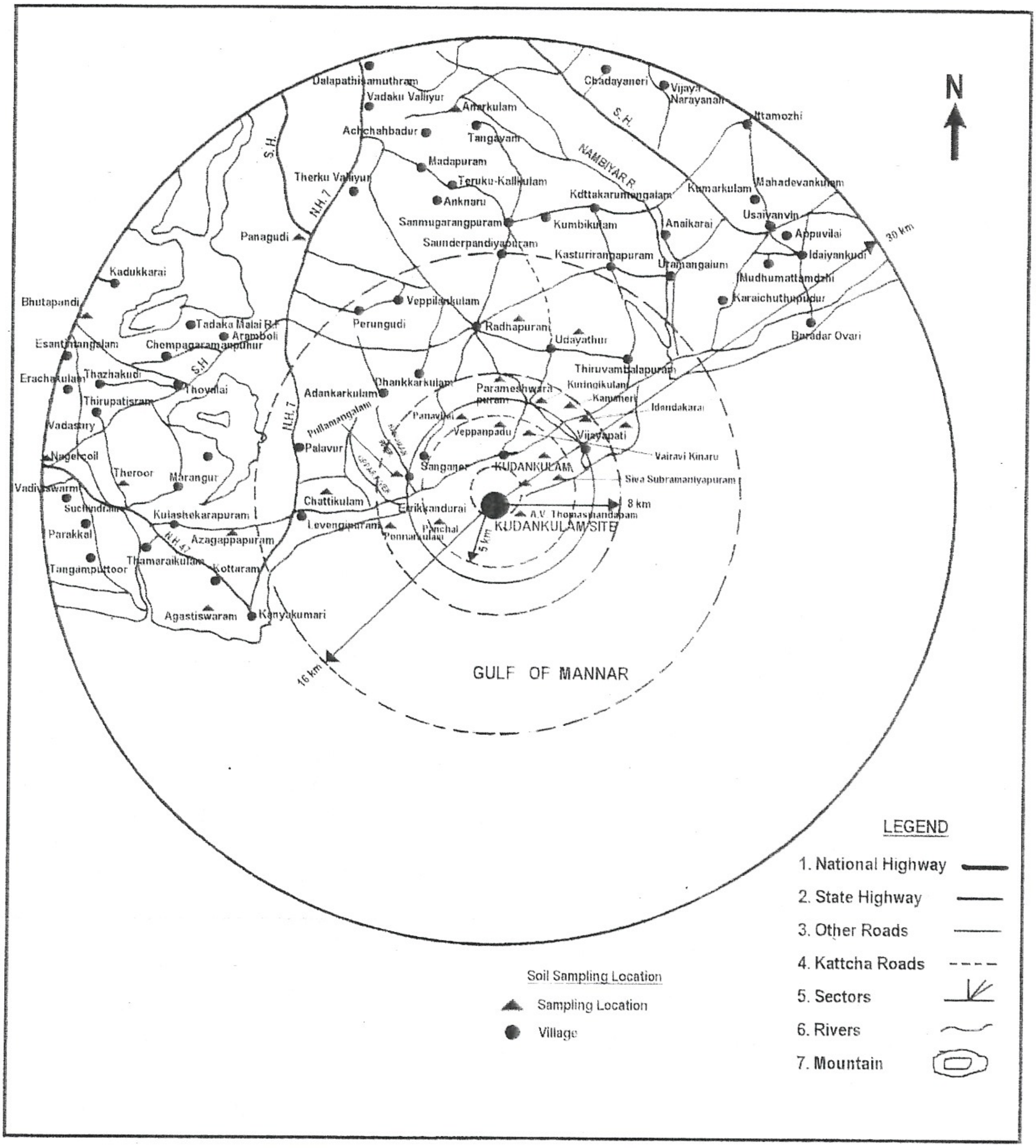


Fig. 2.4.1 : Locations for Collection of Soil Samples within the Study Area

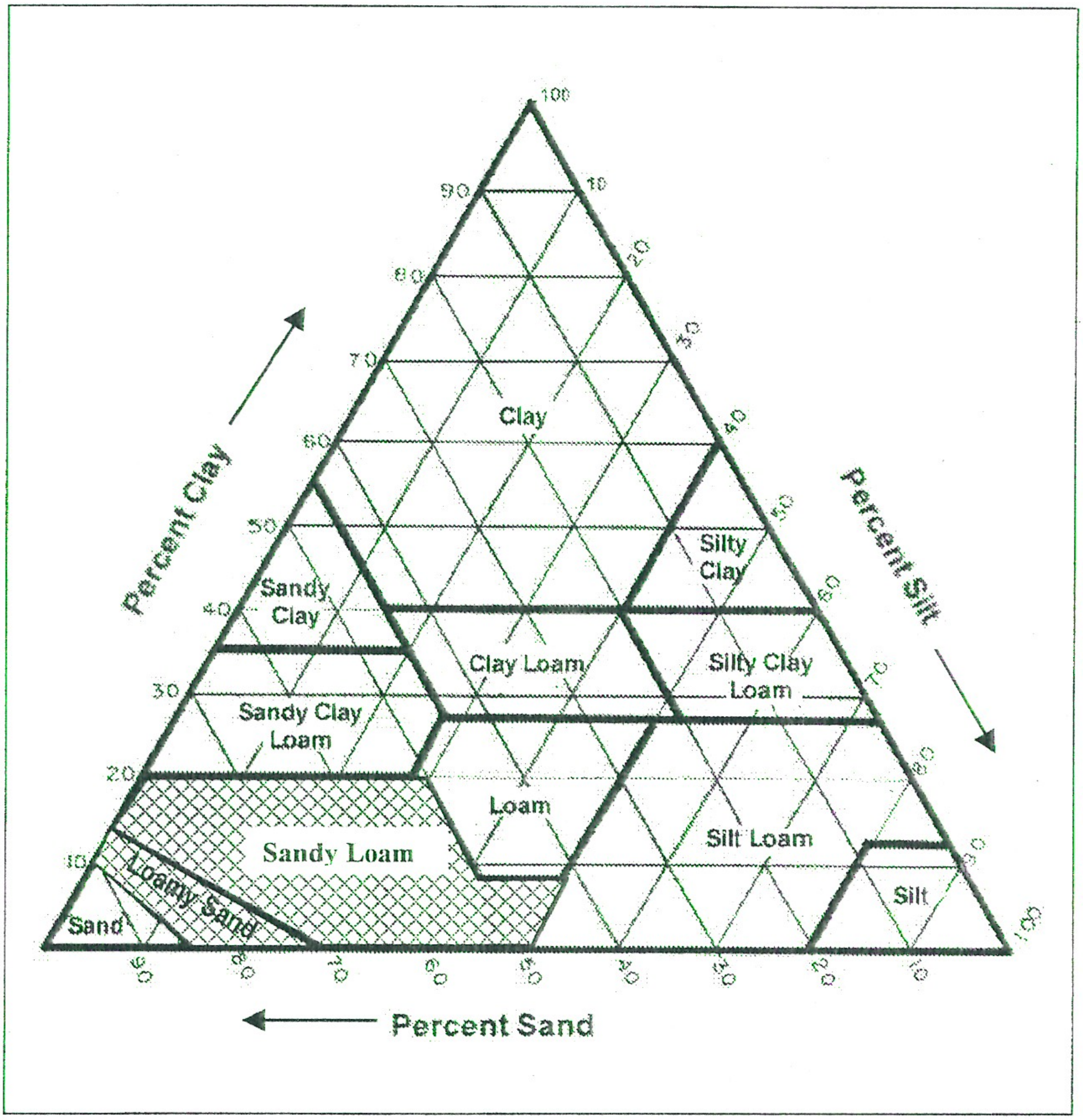


Fig. 2.4.2 : Soil Textural Diagram

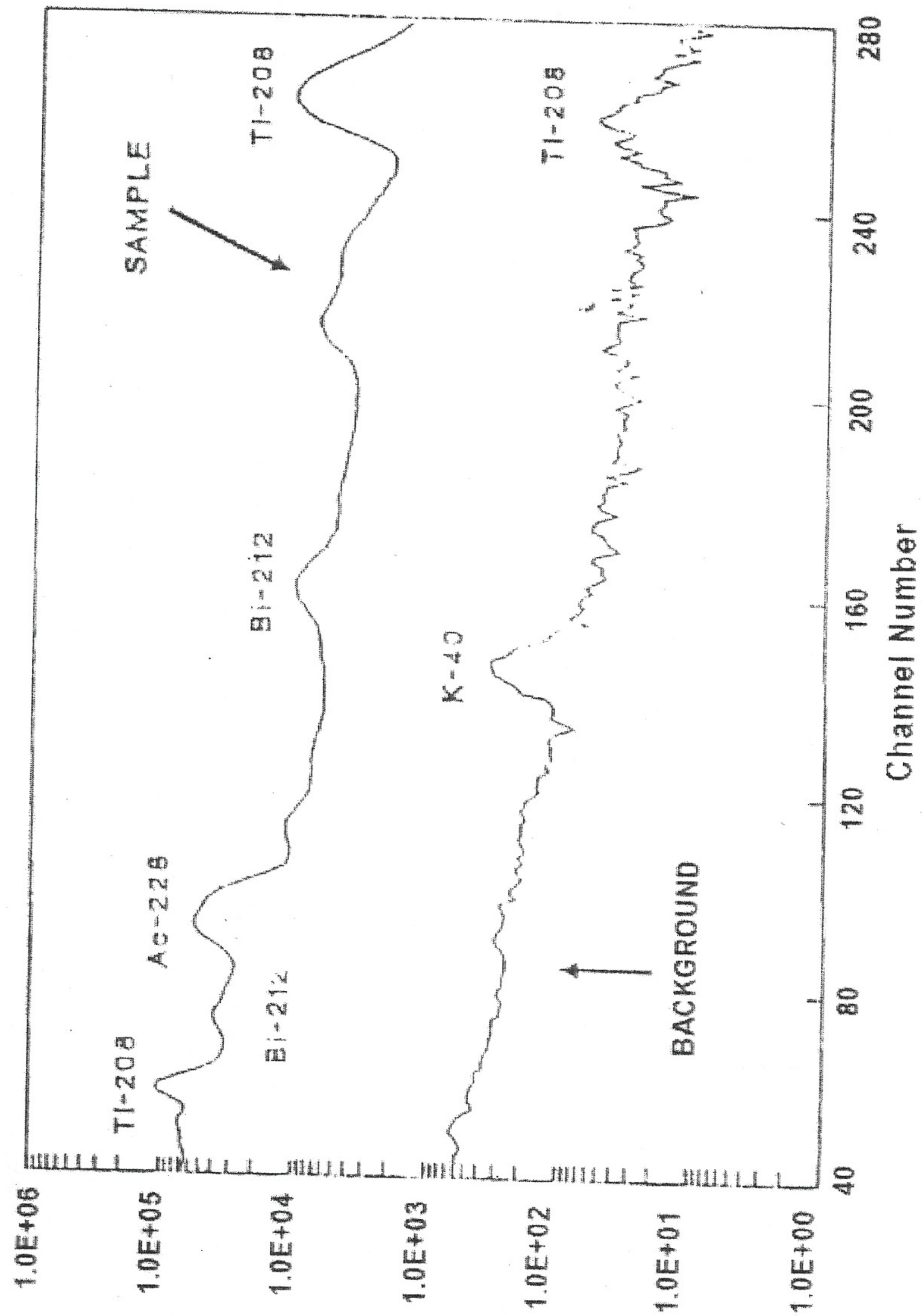


Fig. 2.4.3 : Gamma Spectrum of Soil Sample-Kudankulam Beach (310 μR/h) NaI(Tl) 3 x 3 10 keV/ch

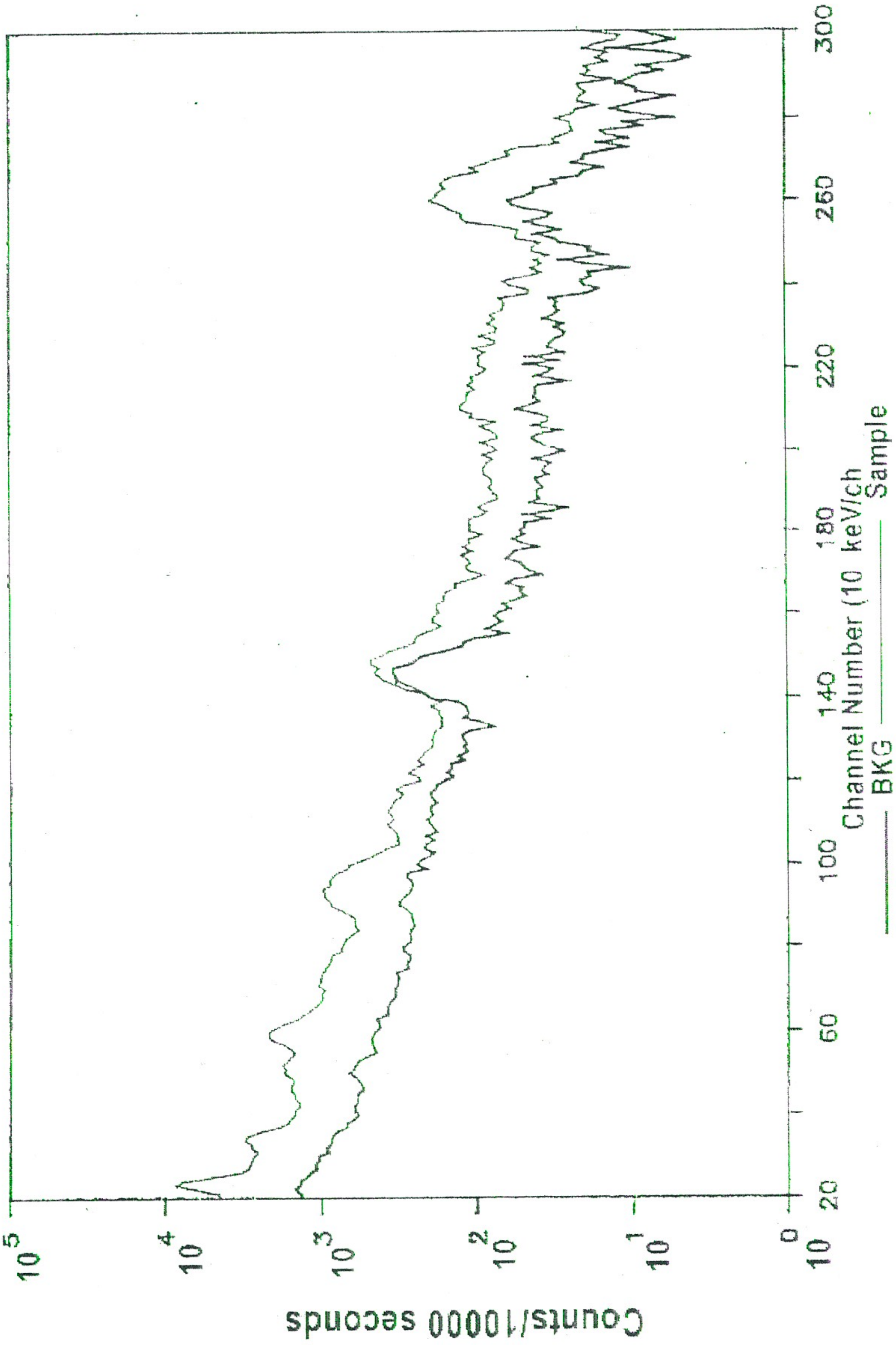


Fig 2.4.4 : Gamma Spectrum of Soil Sample - Panchal (15 µr/hr)

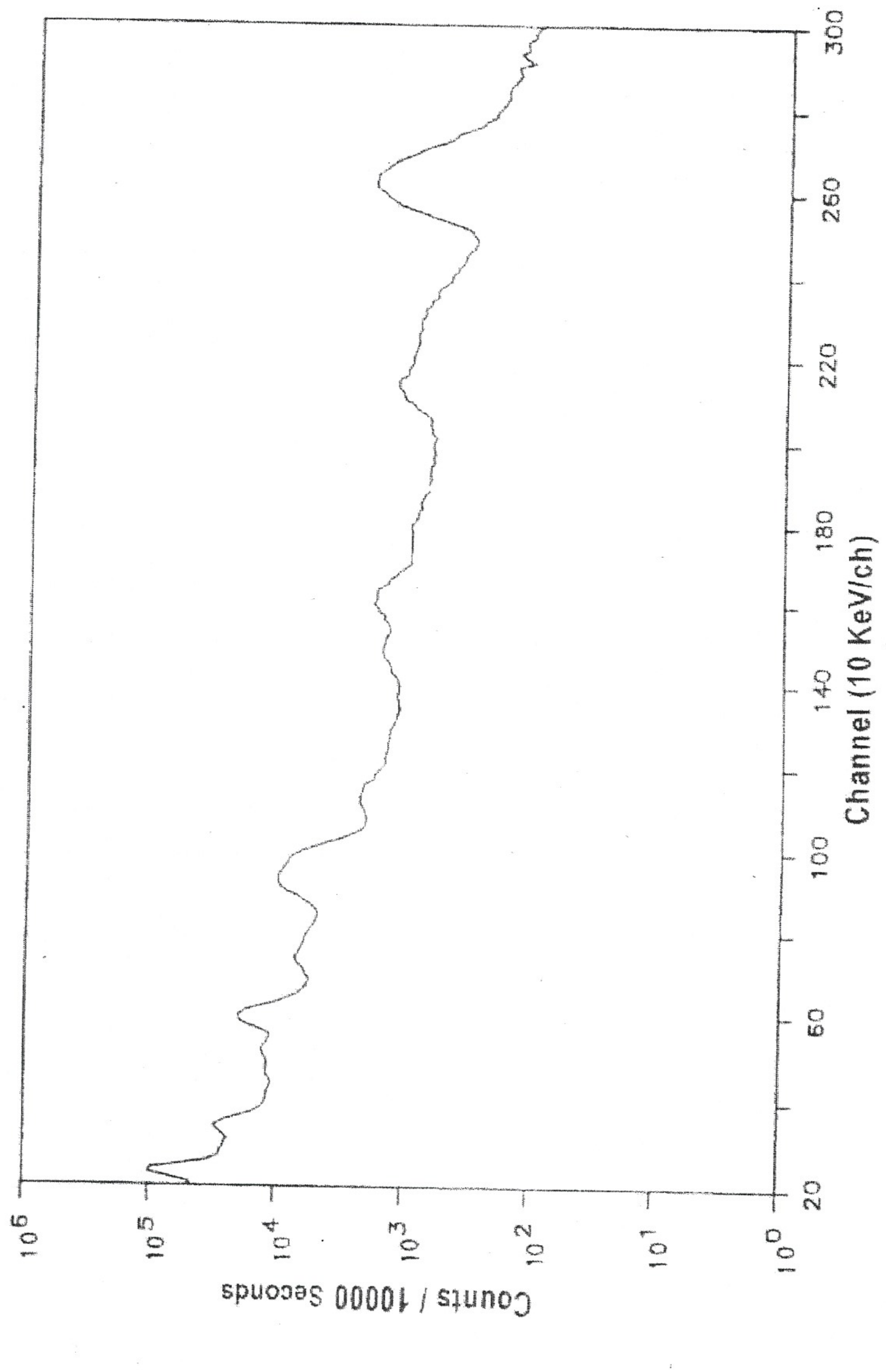


Fig. 2.4.5 : Gamma Spectrum of Soil Sample Kudankulam (50 μr/hr)

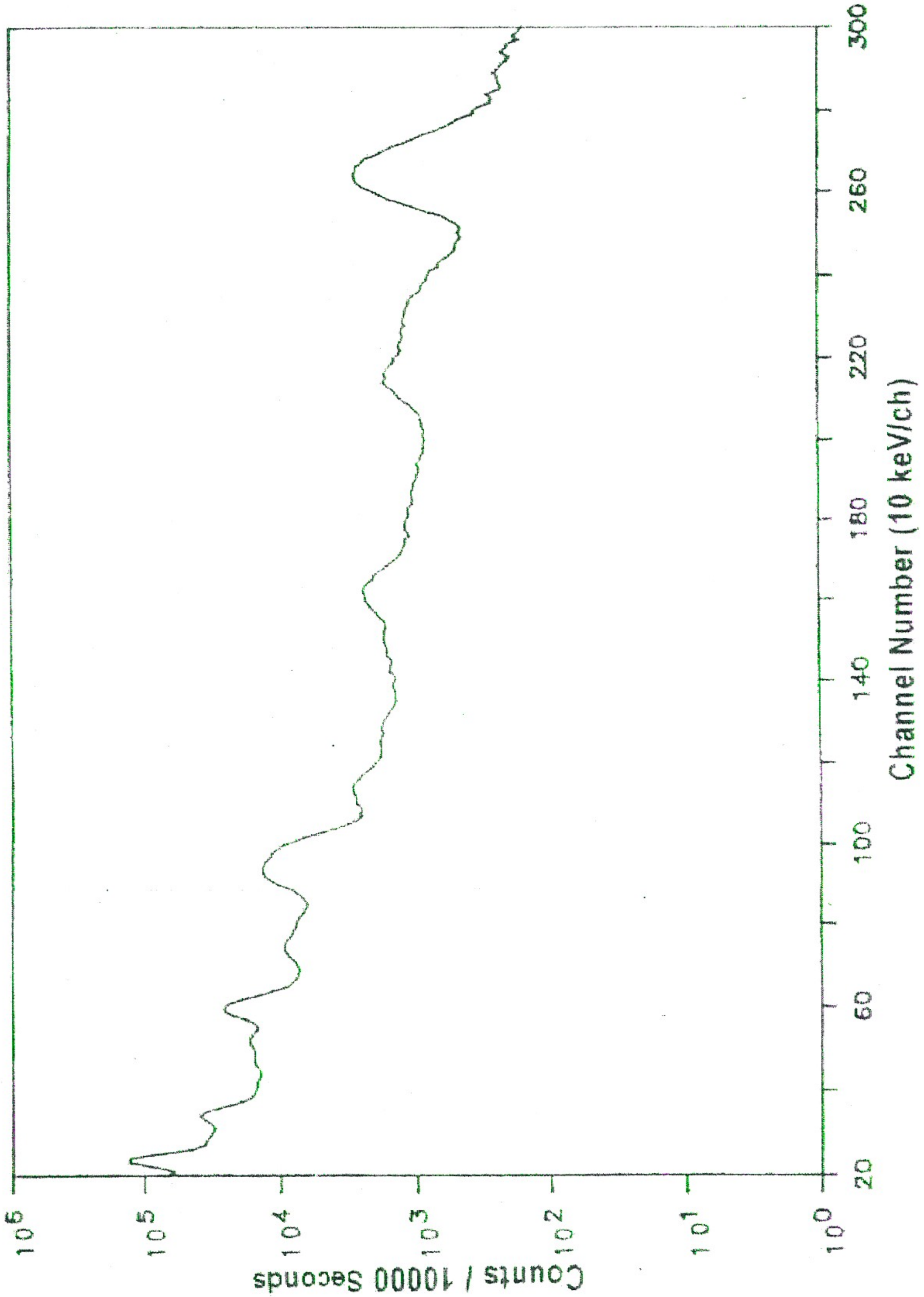


Fig. 2.4.6 : Gamma Spectrum of Soil Sample-Kudankulam (160 μr/hr)

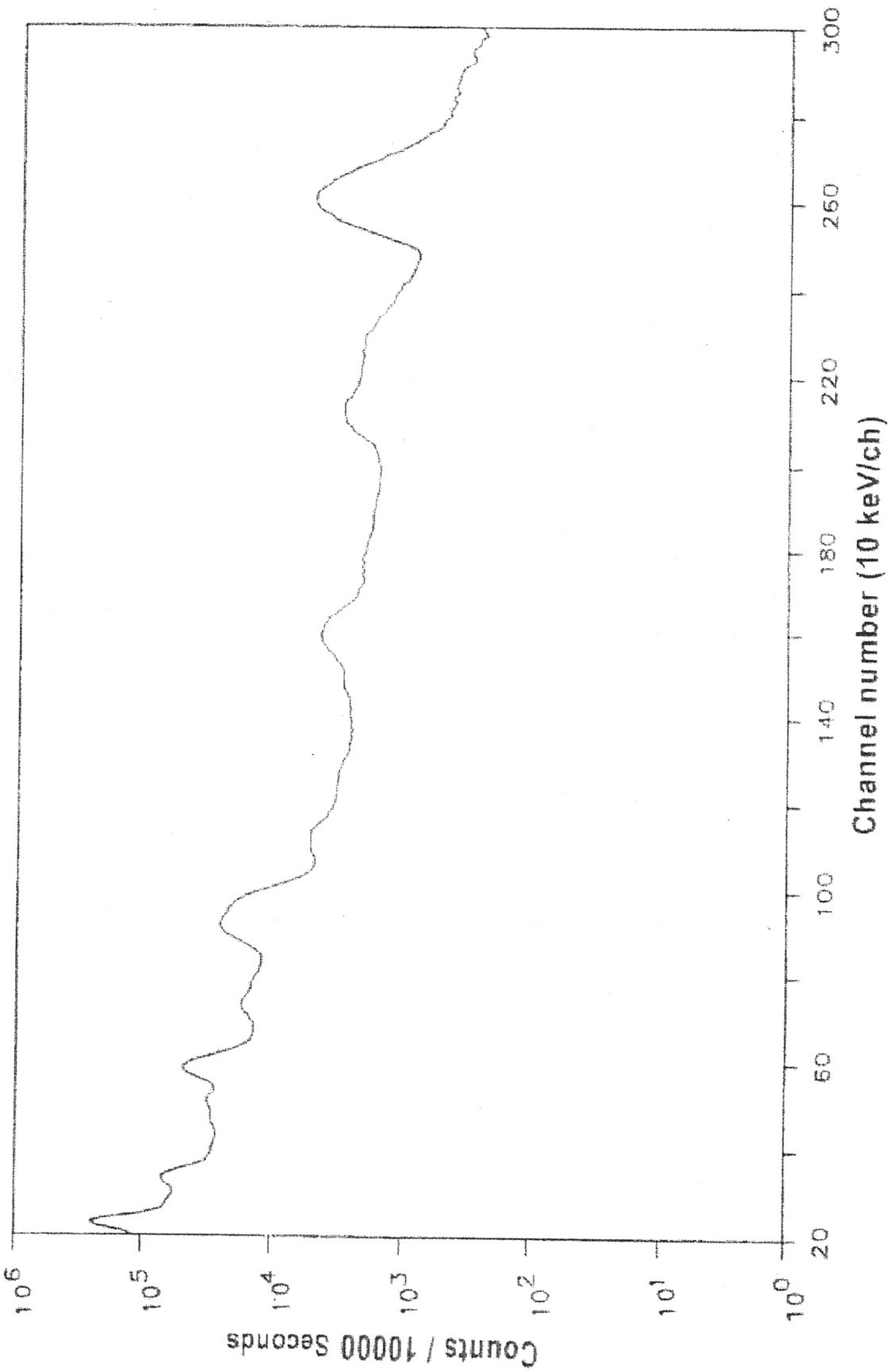


Fig. 2.4.7 : Gamma Spectrum of Soil Sample-Idindakarai (200 µr/hr)

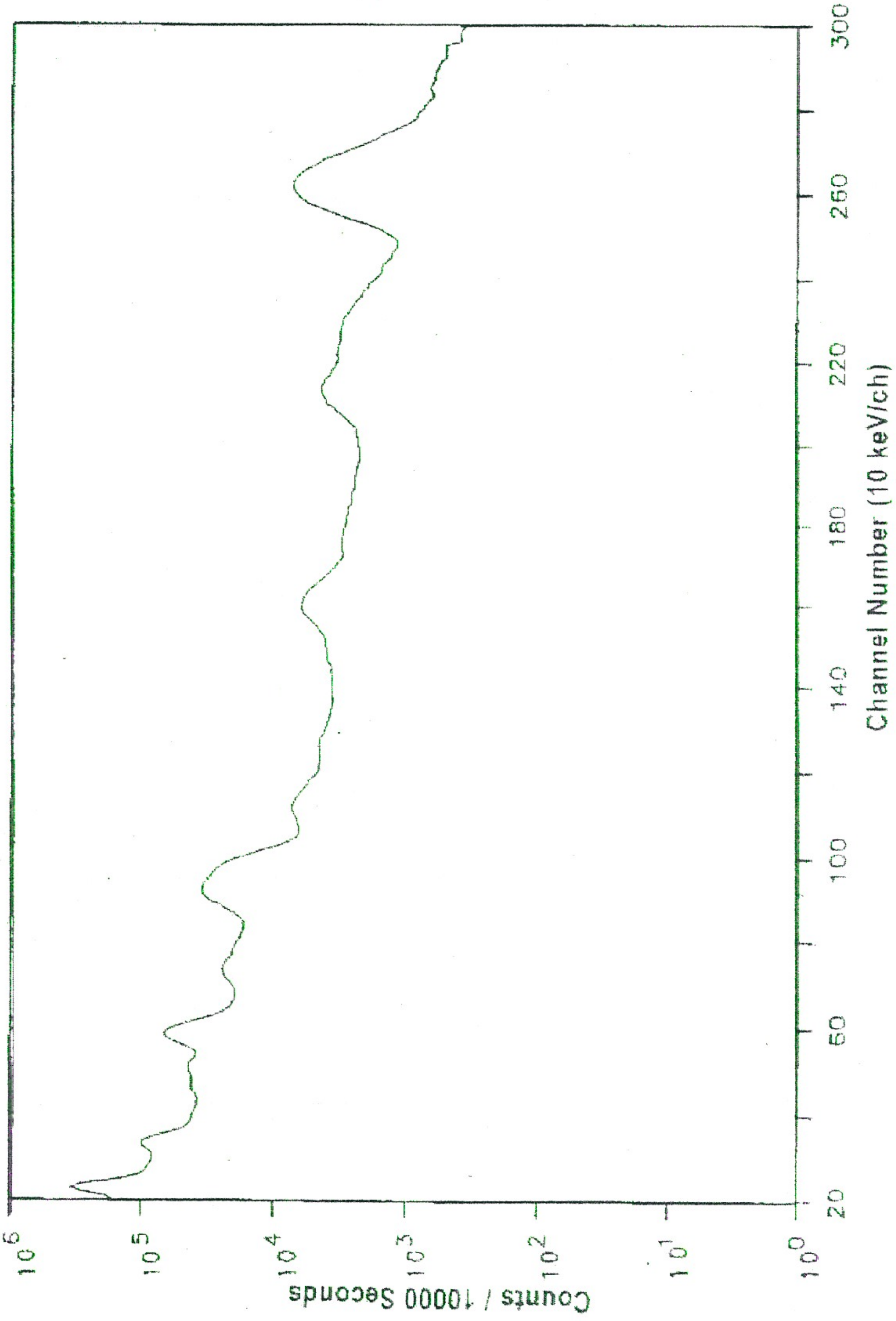


Fig. 2.4.8 : Gamma Spectrum of Soil Sample-Idindakarai (270 μr/hr)

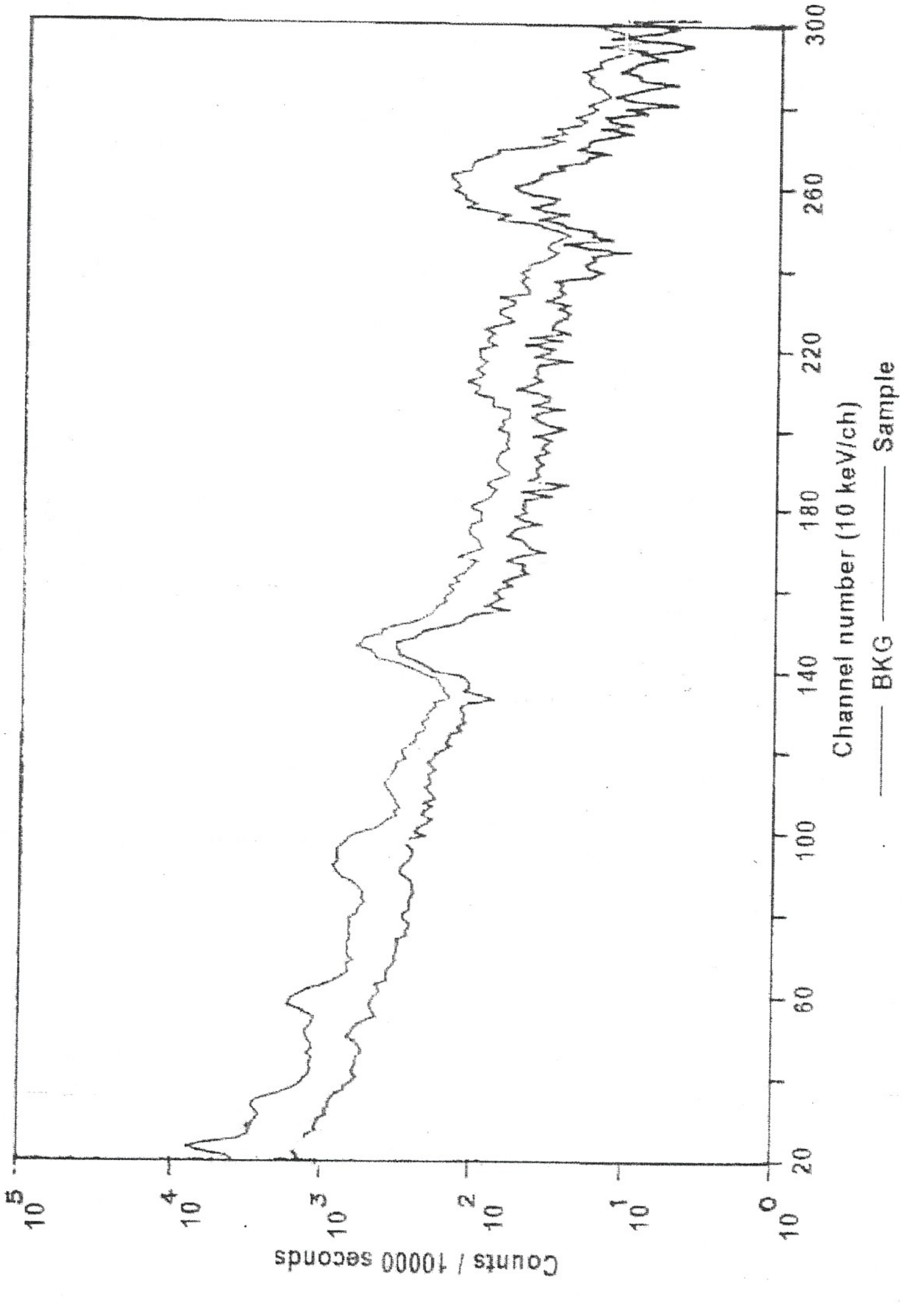


Fig 2.4.9 : Gamma Spectrum of Soil Sample-Arasarkulam (10 μr/hr)

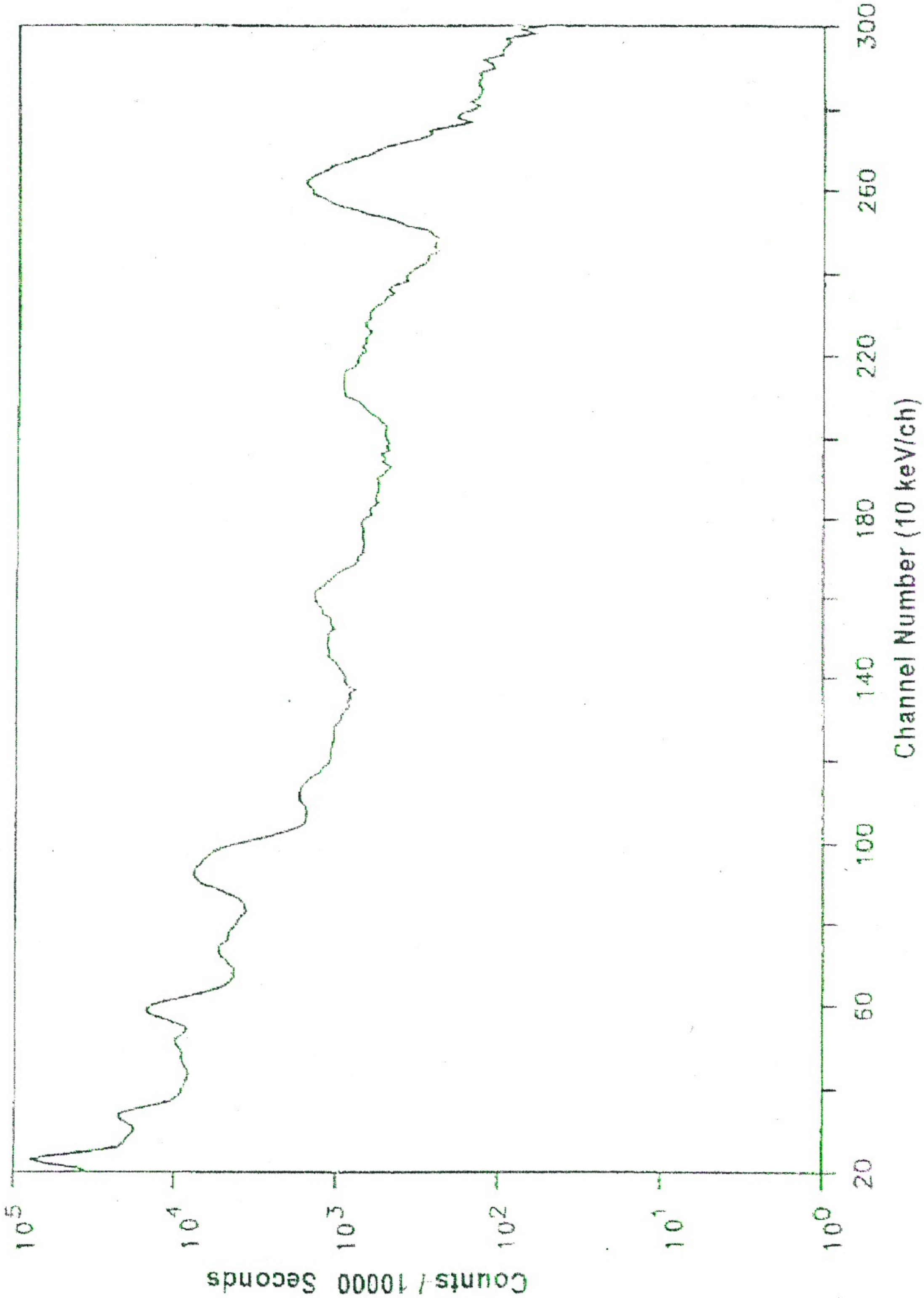


Fig. 2.4.10 : Gamma Spectrum of Soil Sample-Perumanal (40 µr/hr)

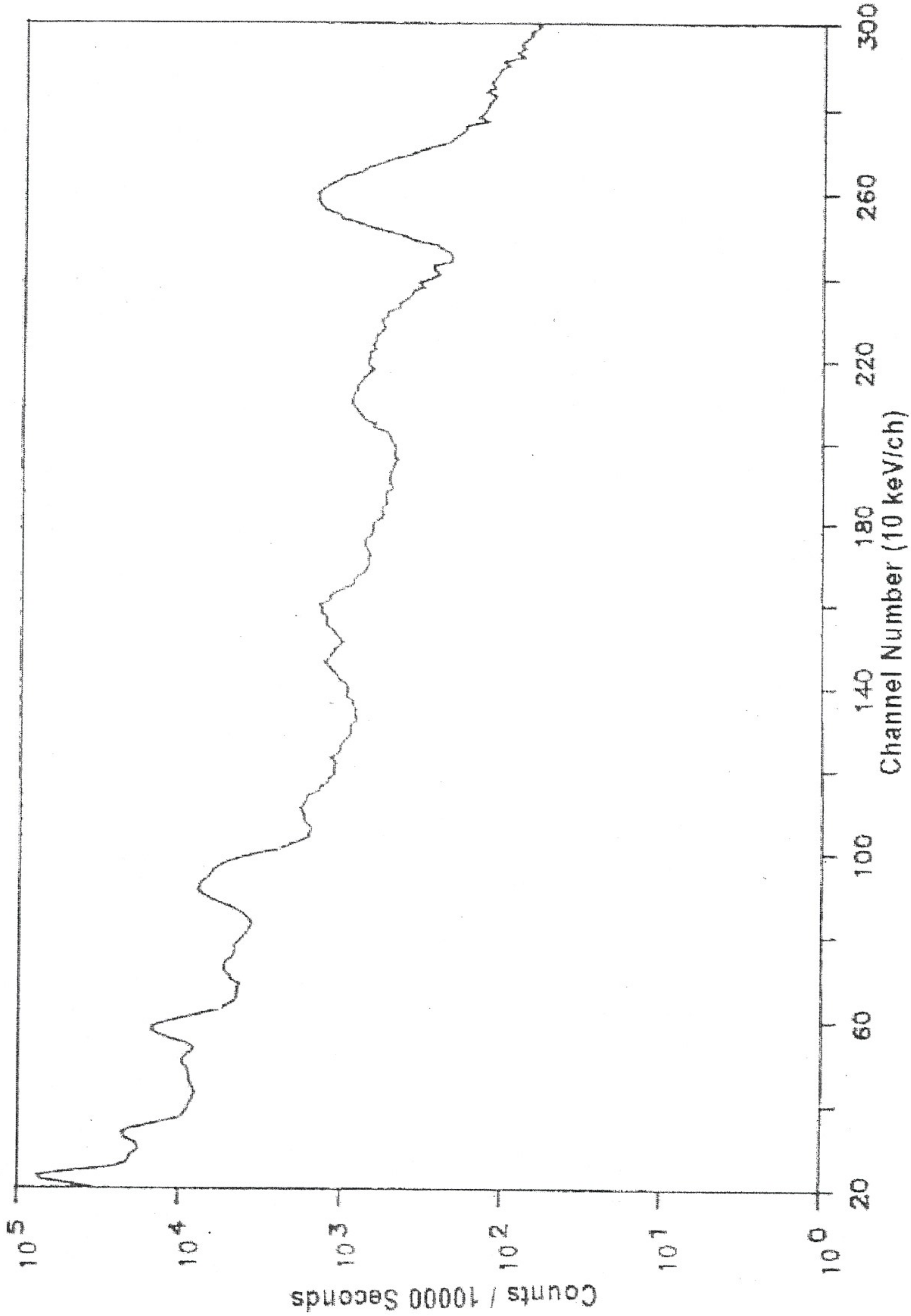


Fig. 2.4.11 : Gamma Spectrum of Soil Sample-Vismamitrar Thapas Temple (75 μr/hr)

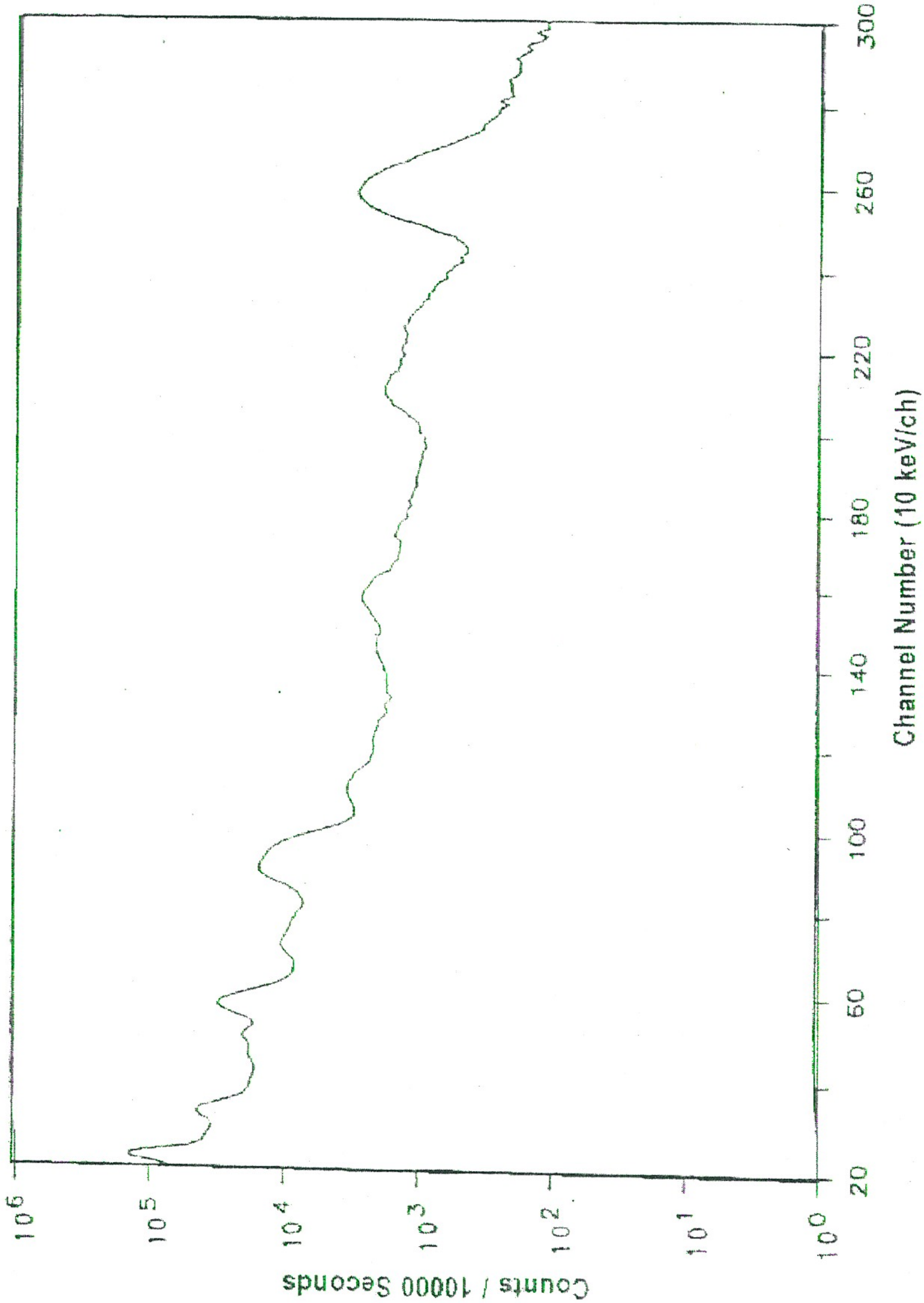


Fig. 2.4.12 : Gamma Spectrum of Soil Sample - Nadar Koothangudi (225 μr/hr)

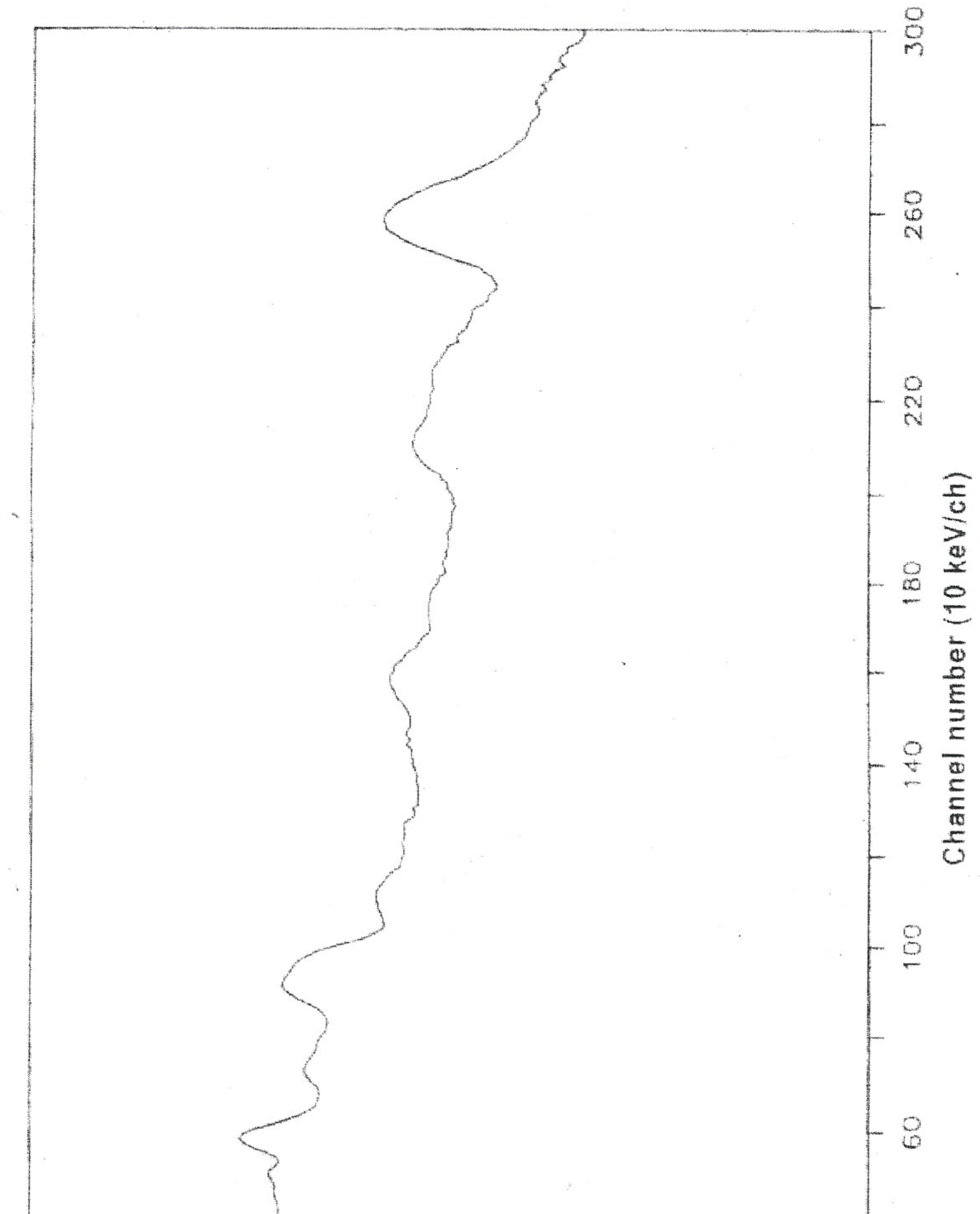


Fig. 2.4.13 : Gamma Spectrum of Soil Sample-Alagar Koothangudi (250 μr/hr)

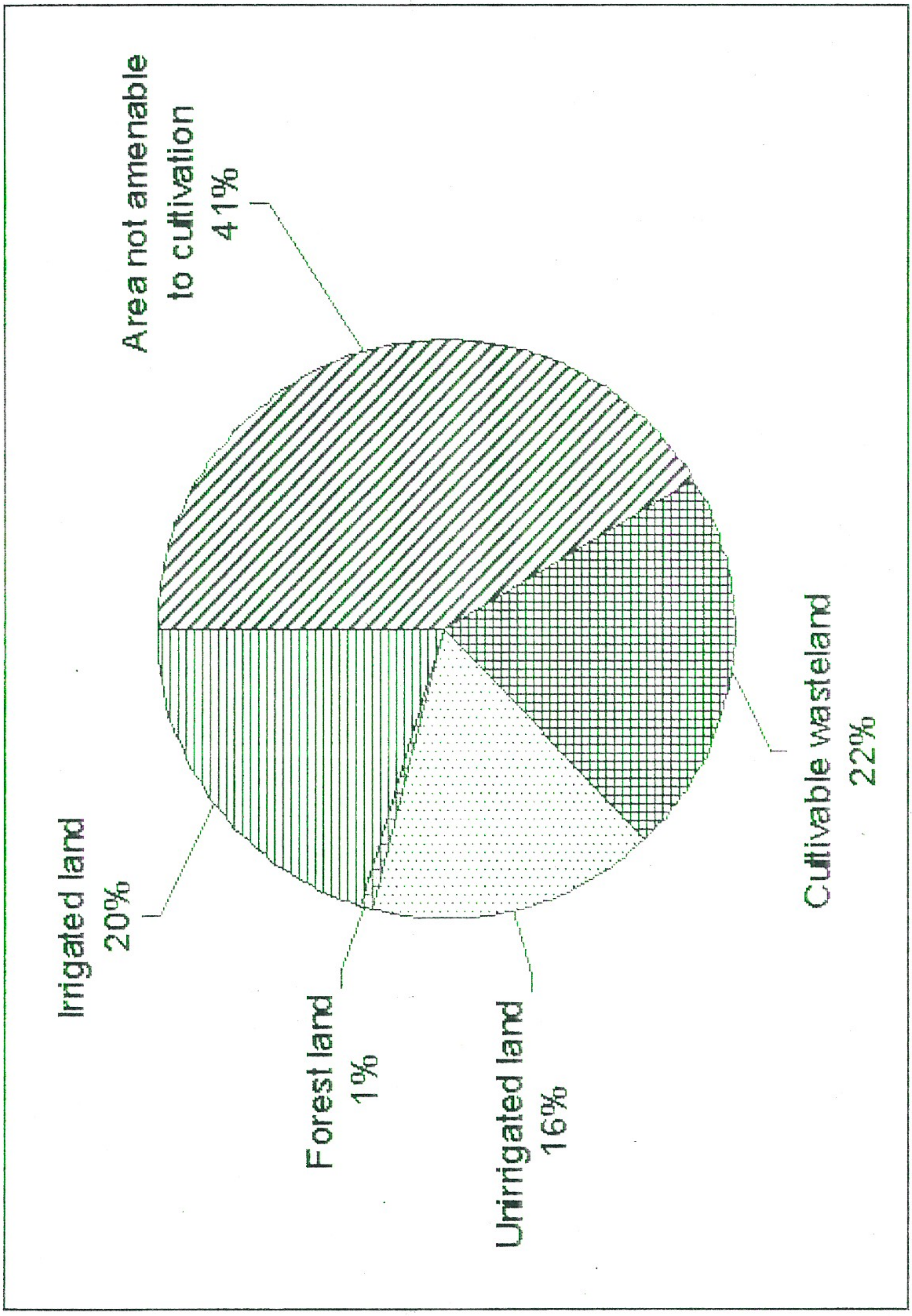


Fig. 2.4.14: Landuse Pattern

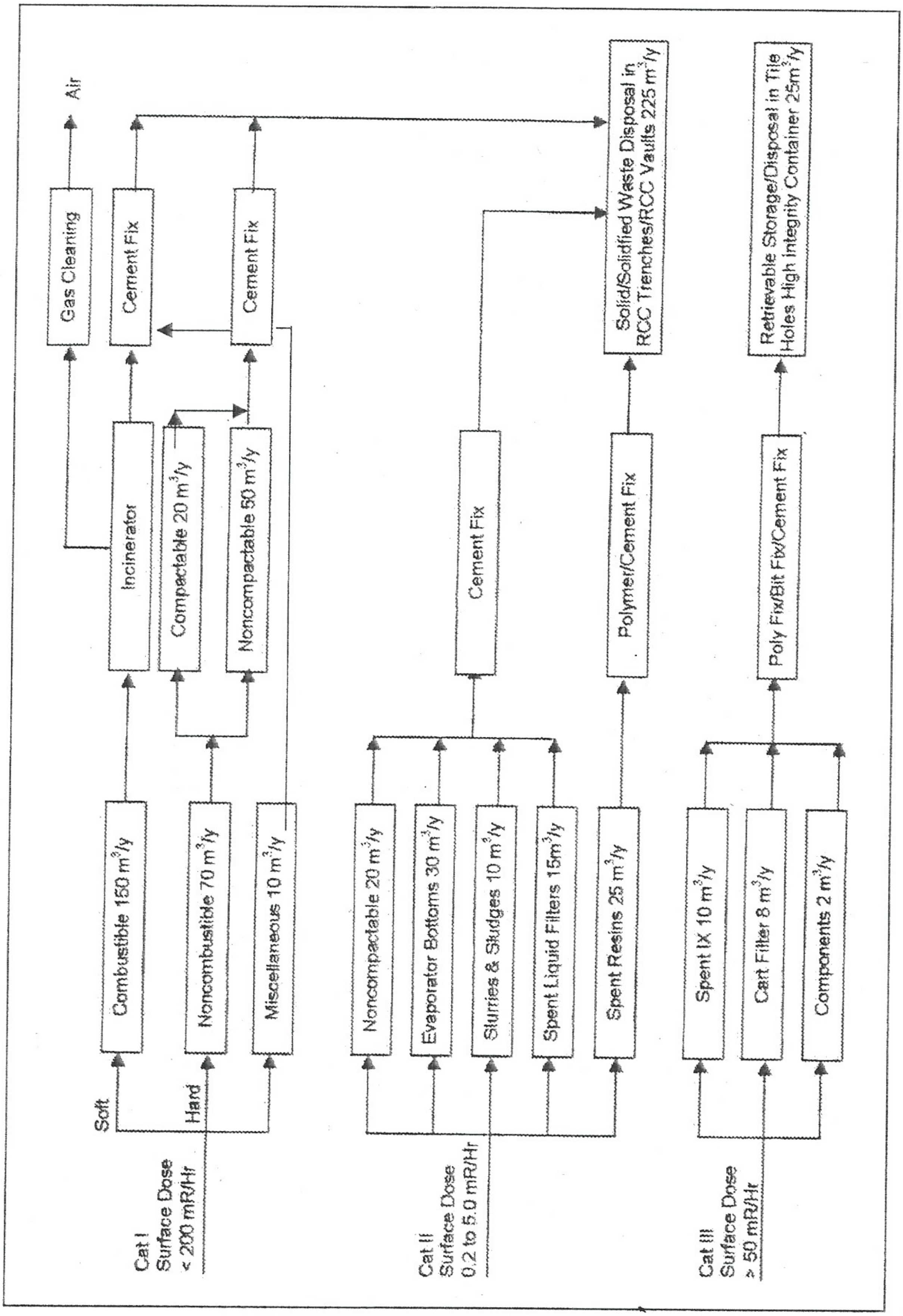


Fig. 2.4.15: Prpoosed Schematic Flowchart of Radioactive Solid Management of Nuclear Power Plant, Kudankulam

Table 2.4.1

Details of Soil Sampling Locations within the Study Area

Sr. No.	Sampling Location	Approximate Distance from Plant Site (km)
1.	Agasteswaram	20.0
2.	Azakappapuram	17.5
3.	Chettikulam	10.8
4.	Kudankulam	4.6
5.	Vijayapathi	10.0
6.	Idinthakarai	8.3
7.	Kurinji Kullam	7.5
8.	Kamaneri	8.3
9.	Panagudi	21.7
10.	Dalapathisamuthram	29.6
11.	Annakulam	25.8
12.	Radhapuram	12.1
13.	Udayathur	12.5
14.	Parameswarapuram	7.9
15.	Veppanpadu	5.0
16.	Panavilai	6.3
17.	Songaneri	5.4
18.	Ponnarkulam	6.7
19.	Panchal	3.8
20.	Siva Subramaniyapuram	5.0
21.	Kudankulam (Agri Field)	4.6
22.	A.V. Thomasmandapam	1.7
23.	Vairavi Kinaru	5.0
24.	Pullamongalam (Nakkaneri)	6.7
25.	Boothapandy	29.2
26.	Theroor	24.2
27.	Nagarcoil	30.0

Table 2.4.2

Physical Characteristics of Soils within the Study Area (Summer, 2001)

Sr. No.	Sampling location	Partical size distribution				Textural class	Bulk density (gm/cc)	Porosity (%)	Water holding capacity (%)
		Coarse sand	Fine sand	Silt	Clay				
1.	Agasteswaram	57	28	05	10	Loamy sand	1.41	46	40
2.	Azakappapuram	55	24	10	11	Sandy loam	1.37	47	41
3.	Chettikulam	51	38	6	5	Sand	1.28	44	36
4.	Kudankulam	33	48	13	6	Sandy loam	1.22	48	44
5.	Vijayapathi	40	48	8	4	Sand	1.39	43	36
6.	Idinthakarai	42	49	4	5	Sand	1.85	47	44
7.	Kurinji Kullam	48	29	8	15	Sandy loam	1.48	40	32
8.	Kamaneri	39	36	09	16	Sandy loam	1.52	41	37
9.	Panagudi	58	24	05	14	Sandy loam	1.20	47	40
10.	Dalapathisamuthram	43	43	5	9	Loamy sand	1.62	45	36
11.	Annakulam	33	36	11	20	Sandy loam	1.39	46	35
12.	Radhapuram	42	39	07	12	Sandy loam	1.32	46	37
13.	Udayathur	38	40	12	10	Sandy loam	1.53	39	30
14.	Parameswarapuram	42	31	13	14	Loamy sand	1.46	42	29
15.	Veppanpadu	37	31	8	24	Sandy clay loam	1.41	41	29
16.	Panavilai	42	36	16	6	Sandy loam	1.37	35	25
17.	Songaneri	34	23	30	13	Sandy clay loam	1.34	45	34
18.	Ponnarkulam	30	48	8	14	Loamy sand	1.45	39	26
19.	Panchal	24	45	14	17	Sandy loam	1.24	46	36
20.	Siva Subramaniyapuram	55	27	3	15	Loamy sand	1.49	35	23
21.	Kudankulam	68	17	4	11	Loamy sand	1.59	34	21
22.	A.V. Thomasmandapam	28	18	18	36	Sandy clay	1.59	37	23
23.	Vairavi Kinaru	77	12	3	6	Sand	1.59	37	23
24.	Pullamongalam (Nakkaneri)	42	29	7	22	Sandy clay loam	1.34	42	31
25.	Boothapandy	62	19	6	13	Loamy sand	1.27	48	41
26.	Theroor	49	28	8	15	Sandy loam	1.35	48	39
27.	Nagarcoil	42	41	5	12	Loamy sand	1.36	41	41

Table 2.4.3

Chemical Characteristics of Soil-Water (1:1) Extract (Summer, 2001)

Sr. No.	Sampling location	pH	EC mS/cm	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}
				meq/l					
1.	Agasteswaram	7.60	0.87	0.84	0.43	3.96	0.09	0.45	3.26
2.	Azakappapuram	8.19	0.40	1.20	0.96	8.80	0.23	4.94	6.24
3.	Chettikulam	7.37	0.18	0.72	0.96	1.08	0.28	1.16	2.32
4.	Kudankulam	8.20	0.25	1.64	1.42	1.30	0.12	1.92	3.44
5.	Vijayapathi	8.16	0.30	1.04	1.90	1.74	0.46	2.18	3.68
6.	Idinthakarai	7.30	0.28	1.28	1.88	1.52	0.43	1.71	2.60
7.	Kurinji Kullam	8.10	0.31	1.02	2.08	2.17	0.53	1.74	3.96
8.	Kamaneri	8.25	5.00	7.52	5.56	10.22	0.79	27.63	4.64
9.	Panagudi	8.09	0.25	1.26	1.94	1.63	0.38	1.82	4.04
10.	Dalapathisamuthram	7.63	0.20	0.48	1.10	1.52	0.53	1.66	2.64
11.	Annakulam	7.20	0.30	1.36	0.27	1.05	0.18	0.49	1.94
12.	Radhapuram	7.40	1.30	4.67	1.86	5.65	0.43	8.02	1.34
13.	Udayathur	6.90	0.18	1.04	0.59	0.23	0.21	0.13	1.68
14.	Parameswarapuram	7.15	0.19	1.52	0.19	0.26	0.20	0.05	1.54
15.	Veppanpadu	6.80	0.46	1.39	0.43	1.95	0.20	1.75	0.67
16.	Panavilai	6.85	0.17	-	0.35	0.60	0.50	0.67	0.64
17.	Songaneri	7.78	0.55	1.44	1.07	3.09	0.21	0.73	3.06
18.	Ponnarkulam	6.87	0.25	0.72	0.04	0.41	0.12	0.27	0.71
19.	Panchal	7.98	0.22	0.87	0.75	0.79	0.12	0.22	1.78
20.	Siva Subramaniyapuram	5.28	0.18	0.52	0.04	0.25	0.25	0.22	0.24
21.	Kudankulam	5.86	0.24	0.28	0.08	0.18	0.12	0.22	0.37
22.	A.V. Thomasmandapam	7.25	0.18	0.84	0.47	0.40	0.13	0.16	1.81
23.	Vairavi Kinaru	7.05	0.22	0.84	0.36	0.57	0.24	0.67	1.04
24.	Pullamongalam (Nakkaneri)	6.05	0.18	0.39	0.04	0.29	0.89	0.13	0.34
25.	Boothapandy	7.15	0.55	1.84	0.71	2.91	0.13	0.62	1.08
26.	Theroor	6.00	1.50	1.59	0.28	4.56	3.84	1.89	4.97
27.	Nagarcoil	6.55	3.00	2.16	2.29	25.01	1.03	15.28	4.87

Table 2.4.4

Cation Exchange Status of Soils within the Study Area (Summer, 2001)

Sr. No.	Sampling location	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CEC	ESP
		meq/100gm					(%)
1.	Agasteswaram	1.00	1.20	0.19	0.007	38	0.50
2.	Azakappapuram	2.10	0.30	0.19	0.040	24	0.79
3.	Chettikulam	1.00	3.85	0.19	0.010	24	0.79
4.	Kudankulam	3.06	0.84	0.19	0.003	15	1.27
5.	Vijayapathi	2.16	2.19	0.21	0.017	24	0.88
6.	Idinthakarai	0.82	1.03	0.19	0.006	14	1.36
7.	Kurinji Kullam	0.62	1.43	0.17	0.009	41	0.41
8.	Kamaneri	2.34	1.71	0.19	0.013	33	0.58
9.	Panagudi	1.30	0.30	0.07	0.004	5	1.41
10.	Dalapathisamuthram	0.52	0.33	0.10	0.008	7	1.43
11.	Annakulam	1.30	3.20	0.09	0.014	25	0.36
12.	Radhapuram	1.36	3.24	0.08	0.013	24	0.38
13.	Udayathur	1.44	3.86	0.07	0.011	13	0.54
14.	Parameswarapuram	2.52	4.88	0.10	0.014	9	1.11
15.	Veppanpadu	1.46	3.19	0.05	0.010	6	0.83
16.	Panavilai	0.32	1.68	0.03	0.013	3	1.00
17.	Songaneri	1.78	2.42	0.05	0.012	6	0.83
18.	Ponnarkulam	1.64	2.66	0.04	0.005	2	1.50
19.	Panchal	1.18	3.07	0.03	0.007	11	0.27
20.	Siva Subramaniyapuram	1.54	0.81	0.02	0.004	5	0.40
21.	Kudankulam	2.16	2.19	0.13	0.004	4	3.25
22.	A.V. Thomasmandapam	1.56	2.04	0.06	0.002	7	1.00
23.	Vairavi Kinaru	1.96	2.19	0.12	0.003	4	3.00
24.	Pullamongalam (Nakkaneri)	1.94	7.61	0.15	0.013	7	2.14
25.	Boothapandy	1.40	3.00	0.14	0.003	16	0.88
26.	Theroor	0.80	4.25	0.15	0.064	9	1.67
27.	Nagarcoil	0.92	1.38	0.24	0.024	38	0.63

CEC : Cation Exchange Capacity
ESP : Exchangeable Sodium Percentage

Table 2.4.5

Relationship of CEC with Productivity of Soils (Summer, 2001)

CEC Value	Range of meq/100g	Productivity of Soil	Soils at Locations (Sr. No.)
Very low	<10	Very low	9,10,14,15,16,17,18, 20,21,22,23,24,26
Low	10-20	Low	4,6,13,19,25
Moderate	21-50	Moderate	1,2,3,5,7,8,11,12,27
High	>50	High	None

Table 2.4.6

Relationship of CEC with Absorptivity of Soils (Summer, 2001)

CEC Value	Range of meq/100g	Absorptivity	Soils at Locations (Sr. No.)
Very low	<10	Very low	9, 10, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24, 26
Low	10-20	Low	4, 6, 13, 19, 25
Moderate	21-30	Moderate	2, 3, 5, 11, 12
High	>30	High	1, 7, 8, 27

Table 2.4.7

Nutrient and Organic Contents of Soils within the Study Area (Summer, 2001)

Sr. No.	Sampling location	Organic Carbon	Organic Matter	Available Nitrogen	Available Phosphorous
		(%)		mg/100 gm	
1.	Agasteswaram	0.62	1.07	0.98	0.010
2.	Azakappapuram	0.70	1.21	1.68	0.035
3.	Chettikulam	0.47	0.80	2.10	0.045
4.	Kudankulam	1.09	1.88	1.81	0.005
5.	Vijayapathi	0.70	1.21	1.78	0.005
6.	Idinthakarai	0.15	0.27	1.94	0.045
7.	Kurinji Kullam	0.62	1.07	3.25	0.035
8.	Kamaneri	0.86	1.47	2.55	0.050
9.	Panagudi	0.54	0.94	1.57	0.045
10.	Dalapathisamuthram	0.54	0.94	1.76	0.045
11.	Annakulam	0.54	0.94	1.86	0.005
12.	Radhapuram	1.01	1.74	2.74	0.045
13.	Udayathur	0.08	0.13	2.39	0.01
14.	Parameswarapuram	0.54	0.94	2.10	ND
15.	Veppanpadu	0.94	1.61	2.37	0.045
16.	Panavilai	0.39	0.67	3.24	0.010
17.	Songaneri	0.78	1.34	1.70	0.015
18.	Ponnarkulam	0.16	0.27	2.05	0.015
19.	Panchal	1.95	3.35	3.03	0.035
20.	Siva Subramaniyapuram	0.16	0.27	2.26	0.045
21.	Kudankulam	0.62	1.07	2.49	0.010
22.	A.V. Thomasmandapam	1.01	1.74	2.64	0.045
23.	Vairavi Kinaru	0.47	0.80	2.32	0.005
24.	Pullamongalam (Nakkaneri)	0.54	0.94	2.21	0.010
25.	Boothapandy	0.39	0.67	3.18	0.005
26.	Theroor	0.94	1.61	2.55	0.035
27.	Nagarcoil	0.15	0.27	1.78	0.005

Table 2.4.8

Fertility Status of the Soils within the Study Area (Summer, 2001)

Sr. No.	Location	Organic matter (%)	N	P_2O_5	K_2O
			(kg/ha)		
1.	Agasteswaram	1.07	2.55	0.06	11
2.	Azakappapuram	1.21	4.37	0.21	28
3.	Chettikulam	0.80	5.46	0.27	34
4.	Kudankulam	1.88	4.71	0.03	15
5.	Vijayapathi	1.21	4.63	0.03	56
6.	Idinthakarai	0.27	5.04	0.27	52
7.	Kurinji Kullam	1.07	8.45	0.01	64
8.	Kamaneri	1.47	6.63	0.30	96
9.	Panagudi	0.94	4.08	0.27	46
10.	Dalapathisamuthram	0.94	4.58	0.27	64
11.	Annakulam	0.94	4.84	0.03	22
12.	Radhapuram	1.74	7.12	0.27	52
13.	Udayathur	0.13	6.21	0.06	26
14.	Parameswarapuram	0.94	5.46	ND	24
15.	Veppanpadu	1.61	6.16	0.27	24
16.	Panavilai	0.67	8.42	0.06	61
17.	Songaneri	1.34	4.42	0.09	24
18.	Ponnarkulam	0.27	5.33	0.09	15
19.	Panchal	3.35	7.88	0.21	15
20.	Siva Subramaniyapuram	0.27	5.88	0.27	30
21.	Kudankulam	1.07	6.47	0.06	15
22.	A.V. Thomasmandapam	1.74	6.86	0.27	16
23.	Vairavi Kinaru	0.80	6.03	0.03	29
24.	Pullamongalam (Nakkaneri)	0.94	5.75	0.06	108
25.	Boothapandy	0.67	8.27	0.03	16
26.	Theroor	1.61	6.63	0.21	467
27.	Nagarcoil	0.27	4.63	0.21	125
	Level in poor soil	< 0.5	< 280	< 23	< 133
	Level in medium soil	0.5 – 0.75	280 – 560	23 – 57	133 – 337
	Level in fertile soil	> 0.75	> 560.0	> 57.0	> 337.0

Table 2.4.9

Heavy Metals in Soils within the Study Area

Sr. No.	Sampling location	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
		(mg/100 gm)								
1.	Agasteswaram	0.31	1.11	ND	ND	67.30	ND	1.23	ND	0.04
2.	Azakappapuram	0.25	1.33	3.23	2.09	2053.25	17.86	2.66	1.07	5.12
3.	Chettikulam	0.15	1.16	1.78	0.61	2162.25	12.26	2.28	0.25	0.49
4.	Kudankulam	0.15	1.32	1.17	0.22	1564.20	18.37	1.16	0.05	6.85
5.	Vijayapathi	0.13	0.83	1.65	0.38	896.75	9.74	1.62	0.25	0.59
6.	Idinthakarai	0.18	0.84	1.01	ND	1699.75	10.98	1.17	0.19	ND
7.	Kurinji Kullam	0.14	1.39	2.54	1.10	1028.25	21.92	2.87	0.17	2.10
8.	Kamaneri	0.17	1.35	2.61	1.16	2505.3	9.98	3.03	0.25	2.07
9.	Panagudi	0.11	0.66	2.80	0.37	818.00	6.48	1.66	0.17	2.49
10.	Dalapathisamuthram	0.17	1.16	2.06	0.52	1714.75	20.72	2.02	0.25	ND
11.	Annakulam	0.10	1.21	2.36	1.23	1853.00	11.74	2.58	0.29	1.94
12.	Radhapuram	0.19	1.42	3.15	1.80	1506.05	5.97	2.95	0.30	3.90
13.	Udayathur	0.12	0.58	2.02	0.41	747.50	8.17	1.29	0.42	6.41
14.	Parameswarapuram	0.17	1.26	3.59	0.63	1555.50	11.83	2.53	2.20	0.10
15.	Veppanpadu	0.14	1.19	2.37	0.66	1577.75	4.28	2.54	0.25	0.79
16.	Panavilai	0.17	1.27	3.62	1.77	1296.75	7.65	4.35	0.17	1.89
17.	Songaneri	0.11	0.97	2.55	1.40	1649.70	7.98	2.54	0.25	3.41
18.	Ponnarkulam	0.12	0.69	0.32	0.01	935.75	7.99	0.84	0.25	8.43
19.	Panchal	0.16	1.15	0.71	0.26	1714.75	12.35	1.01	0.25	1.91
20.	Siva Subramaniyapuram	0.10	0.49	ND	0.08	658.50	0.76	1.18	0.17	2.11
21.	Kudankulam	0.10	0.40	1.12	ND	592.50	0.80	0.65	0.17	1.72
22.	A.V. Thomasmandapam	0.12	0.69	3.00	0.36	969.50	3.65	1.91	2.06	4.35
23.	Vairavi Kinaru	0.15	0.95	1.24	ND	645.00	2.03	1.00	0.15	ND
24.	Pullamongalam (Nakkaneri)	0.15	1.21	3.30	0.81	1872.00	13.30	3.04	0.12	5.50
25.	Boothapandy	0.50	1.90	0.48	1.28	674.75	12.46	3.38	0.34	4.54
26.	Theroor	0.35	1.12	3.31	0.82	718.50	14.60	1.43	0.17	2.04
27.	Nagarcoil	0.14	1.77	2.35	1.20	1726.50	23.40	2.58	0.17	5.09

Table 2.4.10

^{137}Cs and ^{90}Sr Activity Levels in Soils, Sand and Sediment (October, 2000)

Sampling Locations	Nature of Sample	^{137}Cs (mBq/kg drywt.)	^{90}Sr (mBq/kg drywt.)
KK Site	Soil	1390+420	1210+610
Vijayapathi	Soil	6700+550	BDL
Chettikulam	Sand	3250+750	1250+490
Chettikulam	Sediment	8330+890	1380+490

Source : Report (2001) of Health Physics Division, BARC, Mumbai

Table 2.4.11

^{137}Cs and ^{90}Sr Activity Levels in Soil and Sand Samples (May, 2001)

Sampling Locations	Nature of Sample	^{137}Cs (Bq/kg drywt.)	^{90}Sr (Bq/kg drywt.)
Thovally	Soil	4.6+0.5	BDL
Kavalkinaru	Soil	3.8+0.5	BDL
Vadakankulam	Soil	7.3+0.6	BDL
KK Site	Black Sand	BDL	BDL
KK Site	White Sand	BDL	BDL
Idinthakarai	Soil	2.2+0.2	BDL
Vatakotai	Sand	BDL	BDL
Kanyakumari (Upperside)	Sand	BDL	BDL
Valliyur Farm	Soil	6.1+0.6	BDL
Kuttam Farm	Soil	0.9+0.4	BDL
Novari	Soil	BDL	1.3+0.5
KK Site/MSSRF	Soil	2.9+0.5	BDL

BDL : 0.9 Bq/kg dry wt.

Source : Report (2001) of Health Physics Division, BARC, Mumbai

Table 2.4.12

Natural Radioactivity Levels in Soil, Sand and Sediment Samples (October, 2000)

Sampling Locations	^{232}Th Activity	^{238}U Activity	^{40}K Activity
	(Bq/kg dry wt.)		
KK Site	83.1+1.9	13.9+0.6	690.7+15.5
KK township	316.3+3.1	60.2+1.0	515.5+11.2
Vijayapatti	2596.7+8.7	336.0+2.3	700.8+12.8
KK Site (sand)	130.1+2.1	33.5+0.8	52.9+2.3
Kanyakumari (sand)	13.7+0.6	3.3+0.3	494.0+10.7
Chettikulam (sand)	68.3+1.6	23.5+0.7	18.3+4.1
Chettikulam (sediment)	224.9+3.5	50.8+1.2	503.4+15.2

Source : Report (2001) of Health Physics Division, BARC, Mumbai

Table 2.4.13

Natural Radioactivity Levels in Soils (Kudankulam Site) (May, 2001)

Sampling Locations	^{232}Th Activity (Bq/kg dry wt.)	^{238}U Activity (Bq/kg dry wt.)	^{40}K Activity (Bq/kg dry wt.)
Thovalai	43.7±0.9	6.2±0.2	350.6±5.7
Vadakkankulam	212.2±3.5	27.9±0.8	742.7±14.4
KK Site (Black sand)	1857.0±6.1	149.4±1.3	152.9±3.9
KK Site (White sand)	340.3±4.2	60.1±1.3	28.9±4.1
Idinthakarai soil	4364.0±15.2	427.8±8.5	474.6±11.4
Vattakkottai sand	1185.9±4.5	213.7±1.4	118.6±3.2
Kanyakumari (Upper side)	33.9±1.1	5.6±0.3	178.7±5.7
Valliur farm soil	156.4±2.8	25.8±0.7	521.1±11.4
Kuttam farm soil	1341.0±5.7	223.5±1.9	140.8±4.5
N.Ovari soil	1223.0±8.6	164.9±2.4	206.4±8.4
KK Site (MSSRF)	248.1±4.8	39.8±1.2	114.8±9.6

Source : Report (2001) of Health Physics Division, BARC, Mumbai

Table 2.4.14

Natural Radioactivity at Different Depths of Borehole at Kudankulam Site (October 2000)

Locations and Depth	$^{228}Ra/^{232}Th$ Activity	$^{226}Ra/^{238}U$ Activity	^{40}K Activity
		(Bq/kg dry wt.)	
Bore hole No. 4 – 5 mtr	265.0+4.0	33.2+1.2	447.7+14.3
Bore hole No. 4 – 10 mtr	70.7+1.2	8.7+0.7	405.0+12.5
Bore hole No. 4 – 15 mtr	14.2+1.4	BDL	421.4+17.7
Bore hole No. 4 – 20 mtr	5.9+0.8	BDL	479.5+12.3
Bore hole No. 4 – 30 mtr	26.5+1.1	BDL	499.1+11.5
Bore hole No. 4 – 40 mtr	9.6+0.7	4.6+0.9	423.4+10.3
Bore hole No. 4 – 50 mtr	2.7+0.8	BDL	782.7+25.2
Bore hole No. 4 – 60 mtr	2.4+0.5	BDL	733.9+13.7
Bore hole No. 4 – 70 mtr	11.5+2.3	BDL	964.5+39.2
Bore hole No. 4 – 80 mtr	148.9+3.4	6.5+1.1	956.6+21.0
Bore hole No. 4 – 90 mtr	33.0+1.5	5.8+1.2	781.7+14.2
Bore hole No. 4 – 100 mtr	40.2+1.3	1.1+0.5	559.1+12.2
Bore hole No. 4 – 110 mtr	16.6+2.1	BDL	1066.3+36.4
Bore hole No. 4 – 130 mtr	5.0+1.5	BDL	598.2+28.6
Bore hole No. 4 – 140 mtr	2.3+0.7	BDL	567.3+19.3
Bore hole No. 4 – 150 mtr	37.6+2.1	2.4+0.7	584.1+19.4
Bore hole No. 4 – 160 mtr	2.4+0.5	BDL	560.4+12.7
Bore hole No. 4 – 180 mtr	29.8+1.2	BDL	531.4+12.9
Bore hole No. 4 – 190 mtr	11.5+1.4	BDL	643.2+20.5
Bore hole No. 4 – 200 mtr	24.9+1.6	BDL	545.8+18.6

Source : Report (2001) of Health Physics Division, BARC, Mumbai

Table 2.4.15

Microbiological Characteristics of Soils (Summer, 2001)

Sr. No.	Sampling location	TVC	Fungi	Actinomycetes	Rhizobium	Azotobacter
				CFU/g of Soil		
1.	Agasteswaram	278×10^5	17×10^3	19×10^3	52×10^3	48×10^3
2.	Azakappapuram	197×10^5	26×10^3	18×10^3	32×10^3	56×10^3
3.	Chettikulam	67×10^5	6×10^3	4×10^3	8×10^3	12×10^3
4.	Kudankulam	$127 X 10^5$	14×10^3	6×10^3	ND	14×10^3
5.	Vijayapathi	80×10^5	8×10^3	3×10^3	ND	4×10^3
6.	Idinthakarai	91×10^5	18×10^3	1×10^3	4×10^3	13×10^3
7.	Kurinji Kullam	168×10^5	22×10^3	14×10^3	38×10^3	61×10^3
8.	Kamaneri	291×10^5	24×10^3	19×10^3	47×10^3	53×10^3
9.	Panagudi	61×10^5	11×10^3	6×10^3	5×10^3	8×10^3
10.	Dalapathisamuthram	198×10^5	39×10^3	4×10^3	8×10^3	15×10^3
11.	Annakulam	289×10^5	28×10^3	21×10^3	69×10^3	58×10^3
12.	Radhapuram	41×10^5	26×10^3	9×10^3	ND	2×10^3
13.	Udayathur	28×10^5	23×10^3	ND	3×10^3	7×10^3
14.	Parameswarapuram	39×10^5	18×10^3	5×10^3	ND	14×10^3
15.	Veppanpadu	286×10^5	24×10^3	24×10^3	54×10^3	76×10^3
16.	Panavilai	43×10^5	15×10^3	8×10^3	ND	12×10^3
17.	Songaneri	38×10^5	25×10^3	14×10^3	35×10^3	83×10^3
18.	Ponnarkulam	98×10^5	34×10^3	5×10^3	7×10^3	14×10^3
19.	Panchal	191×10^5	21×10^3	17×10^3	46×10^3	57×10^3
20.	Siva Subramaniyapuram	48×10^5	16×10^3	4×10^3	14×10^3	11×10^3
21.	Kudankulam	256×10^5	21×10^3	18×10^3	54×10^3	95×10^3
22.	A.V. Thomasmandapam	263×10^5	28×10^3	15×10^3	84×10^3	73×10^3
23.	Vairavi Kinaru	48×10^5	15×10^3	2×10^3	ND	16×10^3
24.	Pullamongalam (Nakkaneri)	61×10^5	21×10^3	6×10^3	ND	9×10^3
25.	Boothapandy	237×10^5	30×10^3	11×10^3	44×10^3	61×10^3
26.	Theroor	204×10^5	18×10^3	22×10^3	49×10^3	71×10^3
27.	Nagarcoil	117×10^5	44×10^3	3×10^3	4×10^3	32×10^3

TVC : Total Viable Count

CFU : Colony Forming Unit

Table 2.4.16
Land Use Pattern Within the Study Area

Sr. No.	Name of village	Total area (Ha)	Forest Land (Ha)	Irrigated Land (Ha)		Unirrigated land		Cultivable Waste Land		Area Not Amenable cultivation	
				Hector	%	Hector	%	Hector	%	Hector	%
	Radhapuram C.D. Block										
1	Appuvilai	276.41	-	69.21	25	5.78	2	13.01	5	188.41	68
2	Karaichchuthupudur	2297.07	-	189.49	8	280.00	12	412.84	18	1414.74	61
3	Kasthurirangavari	4147.36	-	794.06	19	21.55	0.5	1288.75	31	2043.00	49
4	Kottaikarungulam	4341.10	-	287.39	6.62	546.89	12	2372.10	54.6	1134.72	26
5	Kumarapuram	1664.12	-	229.36	14	165.92	10	204.00	12	1064.84	64
6	Kumbikulam	1539.88	-	522.36	44	91.27	6	67.00	4	859.25	56
7	Kundankulam	2696.92	-	94.87	3	193.63	7	1028.00	38	1380.42	51
8	Kuttam	2554.06	-	126.66	5	211.62	8	402.00	16	1813.78	71
9	Muthumottamozhi	1652.92	-	385.29	23	166.25	10	679.81	41	421.57	25
10	Parameswarapuram	685.56	-	352.11	51	55.41	8	115.30	17	162.74	24
11	Radhapuram	3173.25	-	789.00	25	1864.8 5	59	154.50	5	364.90	11
12	Samugarangapuram	3079.76	-	381.62	12	29.26	1	2049.03	66	619.85	20
13	Soundarapandiapuram	1268.80	-	110.09	8.6	102.69	8	818.84	64	237.18	18.6
14	Terkukallikulam	668.56	-	54.76	8	-	-	-	-	613.80	-

Sr. No.	Name of village	Total area (Ha)	Forest Land (Ha)	Irrigated Land (Ha)		Unirrigated land		Cultivable Waste Land		Area Not Amenable cultivation	
				Hector	%	Hector	%	Hector	%	Hector	%
15	Tiruvambalapuram	2637.83	-	333.00	12.6	96.00	3.6	103.57	4	2105.26	80
16	Tisaiyanvilai	299.34	-	109.00	36	-	-	-	-	190.34	-
17	Udayattur	3713.12	-	411.00	11	659.00	18	-	-	2643.12	71
18	Urumangulam	2169.33	-	298.55	14	42.49	2	986.27	45	842.02	39
19	Vijayapathi	2595.15	-	233.51	9	800.59	31	96.98	4	1464.07	56
	Valliyoor Taluka										
1	Achchampadu	1096.73	-	265.79	24	240.59	22	341.46	31	248.89	22.6
2	Adangarkulam	972.06	-	169.20	17	26.37	3	200.00	20	576.49	59
3	Anaikkulam	1416.85	-	566.94	40	11.38	1	240.60	17	597.93	42
4	Chettikulam	728.46	-	115.99	16	232.70	40	268.82	37	110.95	15
5	Danakkandurai	3027.96	-	192.00	6	2541.00	84	2.96	0.97	292.00	9.6
6	Erukkandurai	4075.53	-	620.96	15	974.12	24	1720.11	42	760.34	18.6
7	Levinjipuram	1900.47	-	415.87	22	397.29	21	750.36	39	336.95	0.17
8	Palavur	3885.11	-	1099.64	28	810.34	21	932.16	24	1042.97	27
9	Perungudi	3680.34	-	462.90	12	282.62	7.6	2593.03	70	341.79	9
10	Terkn valliyur	2603.43	-	485.64	18.6	121.41	4.6	60.71	2	1935.67	74
11	Vadakku valliyur	4550.04	-	364.39	8	1577.51	34.6	258.04	5.6	2350.10	51.6

Sr. No.	Name of village	Total area (Ha)	Forest Land (Ha)	Irrigated Land (Ha)		Unirrigated land		Cultivable Waste Land		Area Not Amenable cultivation	
				Hector	%	Hector	%	Hector	%	Hector	%
12	Veppilangulam	2498.21	-	5.95	0.23	-	-	47.53	2	2444.73	98
	Nanguneri Taluka										
1	Dalapathi samudram	1659.15	-	70.75	4	96.04	6	182.16	11	1310.20	79
2	Ittamoli	1400.74	-	250.97	18	259.75	18	381.05	27	508.97	36
3	Vijayanarayanam	5919.71	-	728.75	12	2045.04	34	680.26	11	2465.66	41.6
	Agastiswaram Taluka										
1	Agastiswaram	948.12	-	87.74	9	-	-	448.77	47	411.61	43
2	Azagappapuram	1738.42	-	1044.28	60	-	-	530.00	30	164.14	9
3	Eraviputhoor	782.19	-	521.62	66.6	-	-	11.73	1	248.84	32
4	Kanniyakumari	656.97	-	336.40	51	298.41	45	-	-	22.16	3
5	Kottaram	1164.87	-	537.35	46	-	-	189.34	16	438.18	37.6
6	Kulasekarapuram	1411.29	-	697.04	49	165.23	12	150.49	10.6	398.53	28
7	Marangoor	1550.77	-	739.00	47.6	-	-	239.00	15	572.77	37
8	Nagercoil	383.54	-	257.00	67	3.00	0.78	-	-	123.54	32
9	Suchindram	538.60	-	283.36	52.6	-	-	76.00	14	179.24	33
10	Thamaraikulam	1604.03	-	264.03	16	-	-	741.00	46	599.00	37

Sr. No.	Name of village	Total area (Ha)	Forest Land (Ha)		Irrigated Land (Ha)		Unirrigated land		Cultivable Waste Land		Area Not Amenable cultivation	
					Hector	%	Hector	%	Hector	%	Hector	%
11	Thekkumalai R.F. (West and East)	805.00	-		Un-inhabitated							
12	Theroor	2153.08	-		1388	64	-	-	21.15	1	793.93	37
	Thovala Taluka		(Ha)	%								
1	Aramboly	1850.86	5.77	0.3	91.66	5	815.39	44	-	-	938.04	50.6
2	Boothapandy	293.68	-	-	190 23	65	-	-	-	-	103.45	35
3	Chenbagaramanputhoor	1529.58	-	-	626 80	41	113.20	7.4	-	-	789.58	51.6
4	Erachakulam	1339.76	565.65	42	517.92	38.6	-	-	-	-	256.19	19
5	Esanthimangalam	964.13	-	-	517.46	53.6	-	-	173.15	18	273.52	28
6	Thadagamalai R.F.	674.63	-		Un-inhabitated							
7	Thekkumalai west	1429.54	-		Un-inhabitated							
8	Thekkumalai East	N.A.	-		Un-inhabitated							
9	Thirupathisaram	623.00	-	-	449.65	73	64.00	10	-	-	109.35	17
10	Thovala	1738.96	-	-	546.60	31	85.00	5	--	-	1107	63.6
	Total	102147.18	571.42		20633.21		16493.59		22031.88		42417.08	
	Percentage of Total Area	100		0.55		20.2		16.15		21.60		41.50

Table 2.4.17

Characteristics of Solid Radioactive Wastes from Proposed NPP

Sr. No.	Type of Waste	Specific activity Bq/kg	Radionuclide composition %	Dose rate at surface mSv/h	Total activity during a year Bq/yr
1.	Category I	$2.8.10^{4}$ … $8.4.10^{6}$	^{137}CS 80; ^{60}Co 20	1.10^{-3}…3.10^{-1}	$3.3.10^{9}$…$9.9.10^{11}$
	Including solidified liquid radwaste	Up to $6.9.10^{6}$	^{137}Cs80; ^{134}Cs 10; ^{60}Co 5; ^{58}Co 5	Up to 3.10^{-1}	Up to $1.7.10^{11}$
2.	Category II	$8.4.10^{6}$…$2.8.10^{8}$	^{137}CS 80; ^{60}Co 20	3.10^{-1}…10	$1.8.10^{12}$…$5.8.10^{13}$
	including solidified liquid radwaste	Up to $2.3.10^{8}$	^{137}Cs80; ^{134}Cs10; ^{60}Co 5; ^{58}Co 5	Up to 10	Up to $8.0.10^{13}$
3.	Ventilation system filters (without treatment)	$8.4.10^{6}$…$2.8.10^{8}$	^{137}CS 80; ^{60}Co20	3.10^{-1}…10	$4.9.10^{13}$…$1.6.10^{13}$
4.	Category III	$7.7.10^{9}$…$9.75.10^{13}$	$^{51-50}$Cr; $^{54-20}$Mn; $^{58-20}$Co; $^{59-2}$ ^{4}Fe; $^{60-5;}$ ^{95}Co	10^{2}…10^{6}	$1.2.10^{14}$…$1.5.10^{18}$

Source : NPCIL, Mumbai

2.5 Biological Environment

Biological species viz. phytoplankton and zooplankton specific for a particular environmental quality studies on biological aspects of the ecosystem are important in environmental impact assessment in view of the conservation of environmental quality and safety of natural flora and fauna. Information about the impact on the biological species serves as inexpensive and efficient early warning and control system to check the effectiveness of control measures to prevent damage to a particular ecosystem. Keeping this in view, planktons (phytoplankton and zooplankton) being good indicators of environmental stress, were included in the study.

2.5.6 Surface Water

2.5.6.1 Phytoplankton

In the samples collected (sampling locations are shown in **Fig. 2.3.1**) at 50 m distance from the shore the phytoplankton count varied from 14 to 49/ml and the Shannon Wiener Index varied from 2.328 to 2.740 indicating semi-productive nature of water body. It is also seen from **Table2.5.1** that the phytoplankton count at 100 m distance varied from 27 to 54/ml and the Shannon Wiener Index varied from 2.16 to 2.712 indicating semi-productive nature of the marine water.

Shannon Wiener Index is a measure of diversity of plankton which takes into account the total count and individual species count in a water sample collected from a particular source.

The Shannon Wiener Index is calculated from the equation :

$$D = -\sum_{i=1}^{N} (ni/n)\ \log_2 (ni/n)$$

Where,

ni	=	Number of individuals of each species in the sample
n	=	Total number of individuals of all species in sample
N	=	Total number of species recorded in the sample

2.5.6.2 Zooplankton

Zooplankton organisms at 50 m distance from the shore varied from 35000 to 41500/m^3 and the Shannon Wiener Index varied from 2.39 to 2.74 indicating medium productive nature of the marine water, whereas at 100 m distance the zooplankton organisms count varied from 38400 to 42300/m^3 and the Shannon Wiener Index varied from 2.299 to 2.712, again indicating medium productivity of the marine water as seen from **Table 2.5.2**.

2.5.7 Ground Water

2.5.7.1 Phytoplankton

Summer Season

The open wells at locations 1 and 2 have indicated absence of phytoplanktons while the other four samples indicated presence of Cocconeis, Diatoms, Ulothrix, Merismopedia, Chlorophyta and Xanthophyta. The Shannon Wiener Index varied from 1.0 to 2.422 indicating medium to low productivity as seen from **Table 2.5.3**.

Post-monsoon Season

The open wells at Kudankulam and Kamaneri exhibited absence of phytoplankton population. Other four samples i.e. KK Project site, Erukkanthorai, Sri Ranganarayana Puram and Chettikulam indicated presence of cocconeis and diatoms. Ulothrix species were present in the samples collected from Erukkamthorai, KK project site and Chettikulam. Chlorophyta spècies were present in 3 ground water samples namely KK Project site, Erukkanthorai and Sri Ranganarayana Puram. The Shannon Wiener Diversity Index (SWDI) varied from 1.445 to 2.114 indicating medium productivity (**Table 2.5.4**)

Winter Season

All the ground water samples except sample at Kamaneri, exhibited presence of cocconeis. Presence of Diatoms, Ulothrix and Chlorophyta was detected in all the five samples collected from different sources as can be seen from **Table 2.5.5**. In terms of percentage of organisons, the percentage of Diatoms varied in the range of 29 to 64 percent which is maximum amongst all the species detected. Presence of Diatoms at more than 50 percent value indicate clean water condition. The values of Shannon Wiener Diversity Index (SWDI) was in the range of 1.302 to 1.937 indicating semi-productive nature of the water of wells.

2.5.2.2 Zooplankton

Ground water samples in all the three seasons did not exhibit presence of zooplankton due to the fact that they can not survive in underground environment for longer period.

2.5.8 Radionuclides in Biological Samples

Preliminary pre-operational survey for establishing the baseline radioactivity levels in aquatic and terrestrial environment of Kudankulam site have been carried out by Environmental Studies Section of Health Physics Division, BARC. A number of different types of environmental samples were collected in October 2000 and May 2001. Background radiation levels were measured using highly sensitive low range μSv survey meter. Aquatic samples such as fresh and sea water, sediment, fish, weed and aquatic plant were collected. Terrestrial samples such as soil, leaf, vegetables, tubers, fruits, crops and nuts were collected. The analysis of these samples for radioactivity content was carried out at Environmental Survey Laboratory, KGS, Kaiga. Samples were analyzed by standard analytical techniques such as gamma spectrometry and radiochemical analysis followed by beta counting. The procedures followed were as per ESL procedure manual, Health Physics Division, BARC (1998).

2.5.8.1 Aquatic Biological Samples

The aquatic samples such as plant leaf, weeds and fish were collected and analyzed for natural and fall out activity. From Gamma ray spectrometric analysis, ^{40}K were identified as the major component of natural radionuclides. The results of analysis of samples collected are shown in **Table 2.5.6.** ^{40}K activity in fish samples was found to vary from 74.8 to 202.1 Bq/kg dry wt. The activity levels of fallout radionuclides namely ^{137}Cs and ^{90}Sr, are reported in **Table 2.5.7**. It is observed that algae and weeds in the marine environment showed highest ^{40}K and ^{127} Cs activity. In the fresh water environment, leaves of lotus plant showed higher ^{40}K and ^{137}Cs activity.

2.5.8.2 Biological Samples

Major component of natural radioactivity in biological samples is ^{40}K. The ^{40}K activity levels in biological samples collected during October 2000 and May 2001 are presented in **Table 2.5.8** and **Table 2.5.9** respectively. Among fruits, watermelon showed maximum ^{40}K activity. Among vegetables, white pumpkin shows maximum activity of ^{40}K. Among cereals, Jowar showed a higher concentration than that of Rice. The ^{40}K activity levels in biological samples are comparable with those observed at other Power Plant sites. ^{137}Cs and ^{90}Sr activity observed in biological samples collected in October 2000 and May 2001 have been presented in **Table 2.5.10** and **Table 2.5.11** respectively. Among leaf samples, the leafy vegetable Mullukiray (local name) showed maximum ^{137} Cs and ^{40}K activity.

Fallout radioactivity levels observed in soil and biological samples at Kudankulam site are comparatively lower than those observed at Kaiga site. It is known that the fall out radioactivity in soil and terrestrial biota is directly related to the rainfall. Kudankulam, being a scanty rainfall area, is expected to have less fallout radioactivity.

2.5.9 Terrestrial Characteristics

2.5.9.1 Radioecology

The operations of nuclear power plant always result in releases of radioactivity to the environment either through air or water route. In the event of an accident in the reactors, it may cause instantaneous release. The released radioactive materials may get dispersed in the environment depending on prevailing meteorological conditions. Therefore, for collection of such information it is required to depend on the past experiences of release of radioactive materials from the existing Nuclear Power Plants. To assess the dose commitment to members of public from nuclear power plant operations, the dose received by individuals and population for each stage of the operation needs to be assessed. At the design stage, such assessment is necessary for determining the adequacy of design provisions. During operational phase, the assessment is necessary to establish compliance with the standards and limits laid down by AERB and ICRP for the plant and site.

Radioactive materials once released in the atmosphere are dispersed based on the regional meteriological conditions. There are three routes through which radioactive materials are dispersed as follows:

- Atmosphere
- Aquatic
- Terrestrial

Radioactive materials find their pathway through each of these compartments. These compartments are interconnected through natural process such as rain, wind pickup, evaporation etc. These radioactive materials reach different organisms through food chains or by direct contact at different trophic levels. In living organisms, biomagnification of some of these radionuclides through food chains is very common. It has been observed that the important pathway from these compartments to man is the food chain pathway.

The Environmental Radiological Laboratory, Kaiga has collected samples (in October 2000) of fruits, seeds, nuts, fish, cereals, vegetation, tapioca, common salt, seaweed and algae at and near the proposed nuclear power plant site. The details of samples alongwith their radiation field in µSv/hr are reported in **Table 2.3.26** under water environment.

2.5.9.2 Pathways for Atmospheric Releases

The released material gets dispersed in the atmosphere by winds and turbulence.

This leads to
- Inhalation dose
- External beta - gamma dose

The activity in air can be due to dry deposition on soil, water, vegetation and other living forms

This leads to
- Direct beta - gamma dose
- Internal dose due to direct consumption of vegetation
- Internal dose through cow-milk route

Soil contamination leads to contamination of agricultural products through biological intake by plants. This leads to internal dose due to ingestion. Rainfall can deposit the radio activity on soil and contaminate water leading to:

- Internal dose by drinking water
- Doses through different routes as reported above

Wind may pickup contaminated particles from land and make them airborne. This then adds to the source. However, physical characteristics of these particles may be different.

2.5.9.3 Terrestrial and Aquatic Pathways

Contamination of land and water can occur either from deposition of radioactive material originally introduced into the atmosphere, or from waste products discharged directly into surface or subsurface waters or disposed off on the land from which they are eventually mobilized by ground water or erosion. The primary reason for concern about the radioactive contamination of the environment is that it results in exposure of members of public. The dose to plants and lower animals is not an important consideration as they are comparatively more resistant to the effects of radiation than the members of public.

Pathways are more complex for aquatic releases. The processes like transport, mixing, sedimentation, biological uptake etc. make up the pathway complicated and site-specific. The aquatic environment will be contaminated with radioactive materials due to the release of radioactive substances in air and water. The groundwater resources and marine waters in Gulf of Mannar can get contaminated with the radioactive materials which may reach to higher organisms through different trophic levels. Good knowledge and understanding of the environmental processes is needed and the same may be used to eliminate prior unimportant pathways and select the more significant pathways for making dose assessment.

2.5.4.4 The Food Chain from Soil to Humans

Radionuclides get released in the atmosphere and in water. From both the routes, it reaches land environment by settling down from the atmosphere, rain and from water by irrigation on agriculture land. During settling down of radionuclides, some of these materials get deposited on grasses, crops, on leaves, etc. Herbivores consume these grasses, herbs, leaves etc. As a result of which in the first trophic level, these radionuclides may get accumulated in the different organs of the body of animals through herbivory strategies. Carnivores consume such herbivores and as a result of which radioactive materials can get accumulated in the carnivores at the second trophic level. Finally it reaches top carnivores through successive trophic levels. Omnivores like members of public get radioactive exposure through atmospheric releases and also through food chains. So it is necessary to study in details, the type of food consumed and radioactive materials accumulated in these food chain routes. Some of the analytical results of soils, food items, etc. are shown in **Tables 2.5.6 to 2.5.11**.

At the proposed NPP regular collection of different types of samples need be carried out and the samples should be brought to laboratory for regular monitoring of radioactive materials. Monitoring of different samples has to be done at the laboratory for establishing the status of food chains, and also the biomagnification levels due to the release of radioactive materials in the atmosphere, hydrosphere and pedosphere are required to be established.

2.5.5 Terrestrial Environment

2.5.5.1 Vegetation

Kanyakumari District (Nagarcoil Revenue Division)

The district is having favourable agroclimatic conditions for vegetation and crops. The rainfall is generally high in the northern part of the district. The average rainfall of the district is 1400 mm per year. The study area includes Agasteeswaram taluka and part of Thovalai Taluka. Most of Agasteeswaram taluka has sloping plain land (0.50 m above msl in south and 50 - 300 m above msl in the north). Thovalai taluka has mountainous terrain (600 - 900 m above msl) having a vast plateau land in the middle of elevated slopes. The differences in the altitude and climate of the hilly tract of the district have made the vegetation of this area greatly varied with characteristic representation of different types of land. Land use pattern (**Table 2.5.12**) shows large land area under agriculture and 5.74% and 7.74% of total geographical area under forest in Agasteeswaram and Thovalai taluka.

Tirunelveli District

Tirunelveli District (Radhapuram block, Valliyoor block and Nanguneri block) is more or less plain in the study area having agricultural fields and scrub vegetation. The density of vegetation is less on southern and eastern side of the district. *Prosopis* sp. (Kikar) is commonly observed throughout the tract. *Euphorbia* and *Opuntia* are widely distributed showing dry climatic conditions. *Borassus sp.* (fan palm) and coconut are found everywhere. *Casuarina* plantations are scattered throughout the study area. Land use pattern is shown in **Table 2.5.13**. A small forest area is present in Valliyoor. Nanguneri and Radhapuram Blocks have no forest. In all Blocks, waste land and fallow lands are larger in areas.

2.5.5.2 Forest

Thovalai taluka of Kanyakumari district has following Reserve Forests (R. F.) in the study area :

1. Thadakmalai R. F.
2. Poigaimalai R. F.
3. Mahendragiri R. F.

Thadakmalai R. F. covers 675 ha of area and lies adjacent to Poigaimalai R. F. This forest is classified under the type 3B/CI (e): slightly moist teak forest having top canopy of *Tectona grandis* with associated species viz. *Anogeissus latifolia, Terminalia paniculata, Pterocarpus marsupian* and *Grewia tilaefolia*.

Poigaimalai R. F. is spread over an area of 775 ha bounded by Mahendragiri R. F. on the North - East, Thadakamalai R. F. on the South-East and the Assambu R. F. on the South - West. It consists of slightly moist teak forests (3B/CI(e)) having teak mixed with

Grewia tiliaefolia, Terminalia chebula, Lagerstroemia lanceolata, Petrocarpus marsupian and *Terminalia paniculata*, and southern moist mixed deciduous forest (3B/C2) having *Terminalia paniculata* as a common species mixed with *Grewia tiliaefolia, Terminalia chebula, Lagerstroemia lanceolata, Dalbergia latifolia, Albizzia odoratissima* etc.

Mahendragiri R. F. occupies an area of 437 ha and has different forest types namely Southern thorn forest (6A/CI) dominated by *Zizyphus xylocarpus* and *Albizzia amara*), Carnatic umbrella thorn forest (6A/C2) (dominated by *Acacia planifrons*), and Southern dry mixed deciduous forest (5-A/C3) in small area consisting mainly of *Anogeissus latifolia, Pterocarpus marsupian* and *Albizzia amara*.

2.5.5.3 Agriculture

Kanyakumari District

The main occupation of population in the district is agriculture and its economy solely depends on agriculture. In Agasteeswaram, the total cropped area is 12,224 ha out of total geographical area of 13,802 ha, while it is only 13139 ha out of total geographical area of 36907 ha in Thovalai taluka. The area sown more than once is only 4032 ha in Agasteswaram taluka and 4289 ha in Thovalai taluka (**Table 2.5.12**).

In the hilly areas of Western Ghats, plantation crops like rubber, coffee, tea, spices, coconut, tapioca and horticultural crops like mango, pineapple, and jack fruits are raised, whereas in the plains, paddy, banana, coconut and vegetables are grown (**Table 2.5.14**).

Paddy is the most important crop of these areas and it is extensively cultivated in 17064 ha area. Rubber crop stands next covering an area of 9759 ha but is only in Thovalai taluka. In Agasteeswaram taluka, other crops are banana, coconut, gram/pulses, fruits, vegetables and cashew in decreasing order while in Thovalai taluka, other crops are tapioca, banana, gram/pulses, coconut, oil seeds, flowers, nut meg, arecanut etc. (**Table 2.5.14**). Varied soil conditions and higher rainfall is responsible for the variety of crops being taken there.

Irrigation

Pazhayar is a small river, which starts at Shorlacode, a place at a distance of about 18 km North-West of Nagarcoil. This is mainly a drainage river mostly collecting drainages of Thovalai, Ananthanar and N.P. channels. The main irrigation channels under the Pazhayar are the Nanhil and Puthanar channel taking off at Chattuputhoor Anaicut near

Bhutapandi. Agasteeswaram has got 16 canals with a total of 26 km length while Thovalai has 6 canals with a total of 96.8 km length. Apart from this, 622 and 285 wells are used in Agasteeswaram and Thovalai taluka respectively for irrigation purpose only. There are no tube wells. The wells used for domestic purposes are 1400 in Agasteeswaram and 245 wells in Thovalai taluka. There are 122 water tanks in Agasteswaram and 272 in Thovalai block (**Table 2.5.15**).

Tirunelveli District

The district has got dry climate, however, the main occupation is agriculture. The relevant particulars are furnished in **Table 2.5.16**. Around 1,57,482 ha of net area is under cultivation, out of which 8,321 ha is under irrigation. The method of irrigation is by canal, tank, well and other sources of water. No reservoirs are existing in the study area. Tanks and wells are rainfed (**Tables 2.5.17 & 2.5.18**). Paddy, millet, pulses, cotton, sugarcane, groundnut, chillies, banana, vegetables, tobacco, gingelly are the crops taken in Radhapuram and Nanguneri taluka (**Table 2.5.19**).

2.5.5.4 Fauna

In Thovalai taluka, the forests support the wildlife viz. Sambhur, Black Monkeys, Jackal, Fox, Moongoose, Hare etc. In Tirunelveli District, wildlife is extremely less due to plain terrain without any forest cover. Different types of birds are observed in the study area. Some of the prominent birds such as House Crow, Jungle Crow, Sparrows are common in the inhabited locality. The Treepies are common in the plains. Other common birds are Lablers, Wood Shrike, Cuckoo Shrike, Tailor Bird, Myna, Indian Skylark and Parrots.

There are four main species of turtles observed here, of which two species viz. the great turtles or the edible turtle and longer head turtle are very common here. Two species of land tortoises and three species of fresh water tortoises are also observed here.

2.5.5.5 Fishery

No major fish landing sites are present in Tirunelveli and Kanyakumari District. The details of mechanical boats, crafts and fishermen population in Kanyakumari District are furnished in **Table 2.5.20**. In Tirunelveli District, no trawlers or mechanical boats are used. Fishermen collect fish using country boats and return to their villages on the coast.

The marine fish species obtained near Kanyakumari are Rock Perches, Seccanids, Bavvacuda, Ribbon Fish, Red Murrets, Cavanx, Rays, Leather Jackets, Silver Bellies, Mackarels, Sardines, Prawns, Lobsters, Cuttle Fish etc.

2.5.5.6 Livestock Population in Kanyakumari District

Cattle population is more in Kanyakumari district with around 150 milk societies. Fowls and ducks are reared in poultry stock. Apart from these animals, other domestic animals are sheep, goat, pigs, donkeys and dogs. No veternery hospitals are existing in Thovalai and Agasteeswaram blocks.

Table 2.5.1

Phytoplankton Counts in Marine Water Samples

Sr. No.	Location	Organisms per ml	% of Organisms						Shannon Wiener Index
			Cocconeis	*Diatoma*	*Flragillaria*	*Asterionella*	*Chlorophyta*	*Xanthophyta*	
At 50 m distance from the Sea – shore									
1	M-1	22	36.4	18.2	13.6	9.1	13.6	9.10	2.390
2	M-2	22	27.2	18.2	18.2	9.1	18.2	9.1	2.482
3	M-3	14	25.0	25.0	10.0	10.0	20.0	10.0	2.487
4	M-4	20	30.0	35.30	6.0	5.0	14	15.0	2.328
5	M-5	49	30.6	16.3	16.3	10.2	12.2	14.4	2.740
At 100 m distance from the Sea - shore									
6	M-1	38	34.3	26.3	15.7	7.9	10.5	5.3	2.509
7	M-2	27	20.5	22.2	18.5	14.4	12.2	12.2	2.508
8	M-3	34	29.4	35.3	10.5	13.0	5.0	6.8	2.264
9	M-4	38	47	15.5	5.3	5.2	15	12.0	2.160
10	M-5	54	22.2	29.6	7.4	18.5	14.8	7.5	2.712

Table 2.5.2

Zooplankton Counts in Marine Water Samples

Sr. No.	Location	Organisms per m^3	% of Organisms						Shannon Wiener Index
			Rotifera	*Cladocera*	*Gastropoda*	*Copepoda*	*Isopoda*	*Amphipoda*	
At 50 m distance from the Sea – shore									
1	M-1	35000	32.3	17.9	10.7	14.3	14.2	10.7	2.604
2	M-2	37500	22.4	24.5	12.2	14.3	16.3	10.3	2.740
3	M-3	38700	13.6	13.6	18.2	36.4	9.1	9.1	2.390
4	M-4	40900	26.3	21.1	7.9	26.2	13.2	5.3	2.641
5	M-5	41500	31.4	15.1	8.2	15.7	20.5	9.1	2.438
At 100 m distance from the Sea - shore									
6	M-1	38400	33.3	14.6	10.4	8.3	31.3	2.1	2.299
7	M-2	39100	18.2	27.2	18.2	9.1	18.2	9.1	2.712
8	M-3	---	---	---	---	---	---	---	---
9	M-4	41700	27.2	18.2	15.7	14.8	18.8	5.3	2.458
10	M-5	42300	24.4	14.6	9.8	22.0	19.5	9.7	2.673

Table 2.5.3

Phytoplankton Counts in Ground Water Sample (Summer Season)

Sr. No.	Location	Organisms per ml	% of Organisms						Shannon Wiener Index
			Cocconeis	*Diatoms*	*Ulothrix*	*Merismopedia*	*Chlorophyta*	*Xanthophyta*	
1	Kudankulam Outer	NIL	NIL	NIL	NIL	NIL	NIL	NIL	---
2	Kamaneri	NIL	NIL	NIL	NIL	NIL	NIL	NIL	---
3	Kudankulam (Near Project Site)	20	20	20	10	5	30	15	2.422
4	Erukkanthorai Farm House	10	50	20	10	NIL	10	10	1.983
5	Sri Ranganarayana Puram	12	40	40	10	NIL	10	---	1.375
6	Chettikulam (near Aqua Park)	10	50	50	NIL	NIL	NIL	NIL	1.000

* *Zooplankton - Nil for all samples*

Table 2.5.4

Phytoplankton Counts in Ground Water Samples (Post-monsoon Season)

Sr. No.	Location	Organisms per ml	% of Organisms						Shannon Wiener Index
			Cocconeis	*Diatoms*	*Ulothrix*	*Merismopedia*	*Chlorophyta*	*Xanthophyta*	
1	Kudankulam Outer	NIL	NIL	NIL	NIL	NIL	NIL	NIL	---
2	Kamaneri	NIL	NIL	NIL	NIL	NIL	NIL	NIL	---
3	Kudankulam (Near Project Site)	25	30	40	10	-	10	10	2.064
4	Erukkanthorai Farm House	22	40	25	15	-	10	10	2.114
5	Sri Ranganarayana Puram	20	50	40	-	-	10	-	1.445
6	Chettikulam (near Aqua Park)	15	40	50	10	-	-	-	1.445

* Zooplankton - Nil for all samples

Table 2.5.5

Phytoplankton Counts in Ground Water Samples (Winter Season)

Sr. No.	Location	Organisms per ml	% of Organizms				Shannon Wiener Index
			Cocconeis	*Diatoms*	*Ulothrix*	*Chlorophyta*	
1	Kamaneri	14	Nil	50	21	29	1.491
2	Kudankulam (Near Project Site)	21	24	29	14	33	1.937
3	Erukkanthorai Farm House	15	13	53	20	14	1.715
4	Sri Ranganarayana Puram	20	15	50	15	20	1.786
5	Chettikulam (near Aqua Park)	11	18	64	18	Nil	1.302

* Zooplankton - Nil for all samples

Table 2.5.6

^{40}K Activity Levels in Aquatic Samples Collected from Kudankulam Site (October 2000 & May 2001)

Type of Sample	Location	Date of Collection	^{40}K Activity (Bq/kg dry wt)
Sea weed (Sarghasm)	Chettikulam	21 - 10 - 00	2005.5 ± 28.1
Sea weed (Sarghasm)	Kanyakumari	22 - 10 - 00	2326.8 ± 20.4
Green Algae	Kanyakumari	22 - 10 - 00	1374.5 ± 35.3
Sea weed	Vattakotai	30 - 05 - 01	637.6 ± 29.2
Lotus Leaf	Vallamadom	29 - 05 - 01	1018.3 ± 101.8
Vale Meen (Seafish)	Idinthakrai	29 - 05 - 01	131 .9 ± 11.9
Seafish	Idinthakarai	29 - 05 - 01	202.1 ± 17.1
Fish	KK Village	23 - 10 - 00	74.8 ± 10.0
Fish	KK Village	23 - 10 - 00	113.1 ± 6.9
Fish	KK Village	23 - 10 - 00	143.1 ± 14.3

Source :- BARC, Mumbai

Table 2.5.7

^{137}Cs and ^{90}Sr Levels in Aquatic Samples Collected from Kudankulam Site (October 2000 & May 2001)

Type of Sample	Date of Collection	Location	^{137}Cs	^{90}Sr
Valemeen Sea fish (mBq/kg ed wt)	29-05-01	Idinthakarai	BDL	BDL
Sea fish (mBq/kg ed wt)	29-05-01	Idinthakarai	BDL	491.4 ± 108.8
Fish (mBq/kg ed wt)	23-10-00	KK village	188 ± 59	BDL
Fish (mBq/kg ed wt)	23-10-00	KK village	<134	BDL
Fish (mBq/kg ed wt)	23-10-00	KK village	250 ± 86	BDL
MDL = 170 mBq/kg edible wt				
Sea Weed (mBq/kg dry wt)	21-10-00	Chettikulam	809 + 437	BDL
Sarghasm (mBq/kg dry wt)	22-10-00	Kanyakumari	4250 ± 1369	3958 ± 1928
Green Algae (mBq/kg dry wt)	22-10-00	Kanyakumari	7753 ± 2637	BDL
Seaweed (mBq/kg dry wt)	30-05-01	Vattakotai	2900 + 1300	BDL
MDL = 3500 mBq/kg dry wt				
Lotus Leaf (mBq/kg dry wt)	29-05-01	Vallamadom	7000 ± 2300	BDL
MDL = < 4500 mBq/kg dry wt				

Source: - BARC, Mumbai

Table 2.5.8

^{40}K Activity In Biological Samples Collected from Kudankulam Site (October 2000)

Type of Sample	Sampling location	Date of Collection	^{40}K (bq/kg dry wt)
Fruits / Nuts / Seeds/ Tubers			
Castor	KK Site (MSSRF)	20/10/00	138.5 + 6.1
Banana	KK Village	21/10/00	406.2 ± 12.2
Ground Nut	Vijayapathi	23/10/01	245.8 ± 7.3
Tapioca	Idinthakarai	23/10/01	378.2 ± 8.5
Leaf / Grass			
Cactus	KK Site	20/10/00	1519.8 ± 29.3
Perendai	KK Site	20/10/00	887.3 + 37.2
Eakki	KK Site	20/10/00	1161.9 ± 55.8
Babool	KK Site	20/10/00	616.6 ± 36.0
Agappe	KK Site /MSSRF	20/10/00	964.2 ± 29.7
Agathi	KK Site /MSSRF	20/10/00	175.9 + 28.1
Mango	KK Village	2110/00	480.7 + 37.0
Bananna	KK Village	21/10/00	702.6 + 26.0
Grass	KK Village	21/10/00	772.8 ± 51.5
Cereals			
Rice	KK Village	21/10/00	76.1± 3.8
Jowar	KK Village	21/10/00	131.8 ± 5.1
Vegetabales			
Whitepumpkin	KK village	23/10/00	1263.9 ± 42.1
Tomato	KK Village	23/10/00	162.2 + 16.2

Source :- BARC, Mumbai

Table 2.5.9

^{40}K Levels in Biological Samples Collected From Kudankulam Site (May 2001)

Type of Sample	Sampling Location	Date of Collection	^{40}K (Bq/kg dry wt)
Fruits / Seeds			
Watermelon	KK Site	29/05/01	828.1 ± 34.1
Mango	KK Village	29/05/01	591.5 ± 24.4
Banana	KK Village	29/05/01	587.5 ± 16.0
Tamarind	KK Village	29/05/01	249.4 ± 8.7
Castor	KK Site	29/05/01	78.0 ± 6.4
Leaf / Grass			
Grass	Vadakankulam	29/05/01	735.7 ± 50.9
Golden Arvi	Thovally	29/05/01	780.4 ± 26.7
Mullukiray	Thovally	29/05/01	1856.1 ± 48.4
Perandai	KK Site	29/05/01	642.6 ± 32.1
Cactus	KK Site	29/05/01	702.2 ± 32.8
Avarambu	Idinthakarai	29/05/01	540.7 ± 54.1
Banana	Valliyur Farm	31/05/01	596.1 ± 31.0
Elumpotti	Edyangudi	31/05/01	273.3 ± 22.4
Kolanchi	Kuttam Farm	31/05/01	399.4 ± 26.6
Cereals			
Paddy	KK Village	29/05/01	76.8 ± 8.8
Vegetables			
Pumpkin	KK Site /MSSRF	29/05/01	841.1 ± 28.0
White Pumpkin	KK Site /MSSRF	29/05/01	867.4 ± 57.8
Banana	Valliyur Farm	31/05/01	397.1 ± 18.3
Kothamarai	Radhapuram	01/06/01	468.6 ± 21.5
Miscellaneous			
Banana Stem	Valliyur Farm	31/05/01	1481.4 ± 98.8
Banana Root	Valliyur Farm	31/05/01	1059.4 ± 30.0
Kolanchi Stem & Root	Kuttam Farm	31/05/01	229.0 ± 19.1

Source :- BARC, Mumbai

Table 2.5.10

^{137}Cs and ^{90}Sr Levels in Biological Samples from Kudankulam Site (October 2000)

Sample	Date of Collection	Location	^{137}Cs	^{90}Sr
Fruits/Nuts/ Tubers				
Castor (mBq/kg dry wt)	20/10/00	KK Site (MSSRF)	985±107	554±161
Banana (mBq/kg dry wt)	21/10/00	KK Village	291±46	BDL
Ground Nut (mBq/kg Edible wt)	23/10/00	Vijayapathi	424+174	BDL
Tapioca (mBq/kg Edible wt)	23/10/00	Idinthakarai	497±105	BDL
Milk (mBq/l)	23/10/00	KK Village	92±22	123+26
MDL : 60 mBq/kg Edible wt				
Vegetables (mBq/kg Edible wt)				
White Pumpkin	23/10/00	KK Village	97+15	BDL
Tomato	23/10/00	KK Village	104+28	NA
MDL : 75 mBq.kg Edible wt				
Leaf/Grass (mBq.kg dry wt)				
Cactus 1	20/10/00	KK Site	BDL	BDL
Perendai	20/10/00	KK Site	3890+972	BDL
Eakky	20/10/00	KK Site	BDL	BDL
Babool	20/10/00	KK Site	BDL	BDL
Agappe	20/10/00	KK Site (MSSRF)	6113±915	1377±444
Agathi	20/10/00	KK Site(MSSRF)	1258±122	295±87
Mango	21/10/00	KK Village	2470±630	BDL
Banana	21/10/00	KK Village	BDL	BDL
Grass	21/10/00	KK Village	BDL	BDL
MDL : 1200 mBq/kg Edible wt				

Source :- BARC, Mumbai

Table 2.5 11

^{137}Cs and ^{90}Sr Activity Levels in Biological Samples Collected from Kudankulam (May 2001)

Sample	Date of Collection	Location	^{137}Cs	^{90}Sr
Fruits /Seeds (mBq/kg ed. Wt)				
Watermelon	29/05/01	KK Site	232.7±18.6	141.7±14.6
Mango	29/05/01	KK Village	460.4±34.4	BDL
Banana	29/05/01	KK Village	BDL	BDL
Tamarind	29/05/01	KK Village	478.4±91.7	539.5±80.6
Castor	29/05/01	KK Site	238.8±81.7	BDL
MDL = 60 mBq/kg ed. Wt				
Leaf/Grass(Bq/kg dry Wt)				
Golden Arvi	29/05/01	Thovally	1.8±0.7	1.7±0.3
Mullukiray	29/05/01	Thovally	2.9±1.0	BDL
Perandai	29/05/01	KK Site	BDL	BDL
Cactus	29/05/01	KK Site	1.4±0.5	2.8±0.7
Avarambi	29/05/01	Idinthakarai	BDL	1.8±0.4
Banana	31/05/01	Valliyur Farm	BDL	BDL
Elumpotti	31/05/01	Edyangudi	BDL	BDL
Kolanchi	31/05/01	Kuttam Farm	2.3±0.5	2.5±0.4
Grass	29/05/01	Kavalkinaru	1.1±0.5	BDL
Grass	29/05/01	Vadakankulam	2.0±0.8	BDL
MDL = 1 Bq/kg dry wt				
Vegetables (mBq/kg ed. Wt)				
Pumpkin	29/05/01	KK Site MSSRF	BDL	BDL
White Pumpkin	29/05/01	KK Site MSSRF	BDL	BDL
Banana	31/05/01	Valliyur Farm	129.0±56.5	116.5±40.5
Kathamarai	01/06/01	Radhapuram	183.5±55.8	BDL
MDL = 75 (mBq/kg ed. Wt)				
Cereals (mBq/kg dry Wt)				
Paddy	29/05/01	KK Village	BDL	BDL
MDL 140 mBq/kg dry wt.				
Vegetables mBq/kg dry wt)				
Milk (mBq/l)	30/05/01	KK Village	66.5±22.5	BDL
MDL = 40 mBq/L				
Miscellaneous (mBq/kg fresh wt)				
Banana Stem	31/05/01	Valliyur Farm	78.4±22.4	BDL
Banana Root	31/05/01	Valliyur Farm	139.4±38.3	BDL
MDL = 75 mBq/Kg fresh wt				

Source :- BARC, Mumbai

Table 2.5.12

Land Use Data for Kanyakumari District, (1999 - 2000)

Sr. No.	Classification	Agasteeswaram (ha)	Thovalai (ha)
1	Forest	795	2856
2	Barren and uncultivated land	583	820
3	Land put to non-agricultural uses	4214	3819
4	Cultivable waste land	6	99
5	Permanent pastures and grazing land	-	72
6	Land under miscellaneous use trees, crops and grass not included in net areas sown	-	74
7	Current fallow land	-	1262
8	Other fallow land	12	1055
9	Net area sown	8192	8850
10	Geographical area according to villages papers	13862	36907
11	Total cropped area	12224	13139
12	Area sown more than once	4032	4289

Table 2.5.13

Blockwise Land Use Data for Tirunelveli District, 1997
(Area in Ha)

Sr. No.	Name of Block	Forest	Barren & uncultivable land	Land put to non-agri. Use	Cultivable waste land	Permanent pastures and other grazing land	Land under misc land uses	Current fallow land	Other fallow land	Net area sown	Geographical area according to village paper
1.	Nanguneri	-	4750	8676	22890	1973	474	2045	2294	7157	50259
2.	Radhapuram	-	2760	5651	12121	299	1971	109	17868	3815	44614
3.	Valliyoor	290	5777	6499	3060	1851	2197	160	17477	5281	42592

Source : Assistant Director Dept., Agriculture Dept., Tirunelveli

Table 2.5.14

Blockwise Profile of Agriculture Area (in ha) for Kanyakumari District

Particulars	Agasteswaram	Thovalai	Total Area
Gross cropped area	11995	11419	26414
Irrigated area	9062	9629	18691
Area Covered under Major Crops			
Paddy	8311	8753	17064
Fruit and Vegetables	289	14	303
Grams / Pulses	421	605	1026
Cashew	134	-	134
Banana	477	855	1332
Coconut	456	385	841
Rubber	-	9759	9759
Tapioca	-	1460	1460
Flowers	-	216	216
Oil seeds	-	341	341
Pepper	-	8	8
Cloves	-	36	36
Nut meg	-	185	185
Cardamom	-	-	-
Arecanut	-	113	113
Normal Rainfall (mm)/year	694	1015	-

Table 2.5.15

Blockwise Sources of Water Supply for Irrigation in Kanyakumari District

Sr. No.	Name of block	Canals		Wells used for irrigation purpose only	Tube wells	Wells used for domestic water supply purpose only	Reservoirs	Tanks
		Number	Length (km)					
1.	Agasteeswaram	16	26	622	-	1400	-	122
2	Thovalai	6	96.8	285	-	245	-	272

Table 2.5.16

General Particulars of Agriculture in Tirunelveli District

1	Geographical area	6823 sq. km or 682308 ha
2	Net area under cultivation	157482 ha
3	Gross area under cultivation	190608 ha
4	Net area under irrigation	8321 ha
5	Gross area under irrigation	109845 ha

Table 2.5.17

Types of Irrigation Facilities and Areas (in hectares) Covered under Irrigation in Tirunelveli District

1	Canal irrigation	15591
2	Tank irrigation	32467
3	Well irrigation	34908
4	Other sources	244
	Total	**83210**

Sources of Irrigation:

- In Radhapuram taluka, Canal irrigates 680 ha area
- No reservoirs are present in the study area
- Rainfed tanks and wells are major sources of irrigation water

Table 2.5.18

Blockwise Sources of Water Supply in Tirunelveli District (1999 - 2000)

Sr. No.	Name of Block	Canals		Wells used for irrigation purpose only	Tube wells	Wells used for domestic water supply purpose only	Reservoirs	Tanks
		Nos	Length (km)					
1	Nanguneri	1	30	3231	-	168	-	17
2	Radhapuram	1	56	1584	19	553	-	126
3	Valliyoor	1	25	6231	22	602	-	143

Source : Directorate of Economics and Statistics, Chennai – 6

Table 2.5.19

Talukawise Areas Under Different Crops in Tirunelveli District (Area in Hectares)

Sr. No.	Taluka	Total Paddy	Cholam (Sorghum)	Kurumb (Bajra)	Ragi	Maize	Other millets	Total millets	Total pulses	Cotton	Sugarcane	Oil seeds (total)	Banana
1	Naguneri	6000	-	-	50	-	50	100	809	500	25	750	2300
2	Radhapuram	26000	100	-	150	-	50	300	1100	300	-	1735	1100

Table 2.5.20

Crafts, Boats and Fishermen Population in Kanyakumari and Tirunelveli Districts

Place	Mechanical Boats	Traditional Crafts	Fishermen Population	Active Fishermen
Arobiapuram	1	165	2299	650
Chinnamittam	17	121	1944	510
Kanyakumari	72	685	7229	2900

Source : State Fisheries Department

2.6 Socio-economic Environment

2.6.1 Reconnaissance

Nuclear Power Corporation (I) Limited (NPCIL), proposes to install a nuclear power plant near Kudankulam village on the eastern sea coast area, north east of Kanyakumari in Radhapuram taluk of Tirunelveli Kattaboman district in Tamil Nadu state.

The ecological settling near proposed site involves Gulf of Mannar, tourist places and salt pans. These places, besides being aesthetically important, provide employment for number of people involving them in salt production, shell art and fishing. As such it becomes imperative to predict the impacts of the proposed power plant on the socio-economic environment. This is so, because the project of such a magnitude would trigger off multiple impacts hampering as well as benefiting the environment at local and regional level and the likely impacts would relate to physical, biological, and socio-economic environment. Such an exercise of impact assessment would help in formulating an effective Environmental Management Plan which, if properly implemented would help mitigating adverse impacts on the socio-economic environment.

Keeping Kudankulam (NPP) site as a focal point, a 30 km radius area was delineated as the study area which incorporates mainly two districts, viz. Kanyakumari and Tirunelveli Kattabomman. A little part of Tuticorin district also falls in the study area towards North East (NE) side. The study area has four rivers, namely - Pazhayar, Upper, Hanuman and Nambiyar. Significantly NH-7 and NH-47 pass through the study area. The baseline status refers to the following elements :

- Demographic structure
- Infrastructure resource base in study area
- Economic attributes
- Aesthetic & cultural attributes
- Health status
- Socio-economic survey

Baseline data has been collected from several primary and secondary sources, viz. census record, statistical handbook, village administrative office, primary health centres, office of the District medial officer etc.

The information regarding awareness about project activity among the people and their opinion about the impacts arising out of the activities has been collected with the help of socio-economic survey incorporating interviews using predesigned set of questionnaires among the respondents on random basis.

2.6.2 Baseline Status

Study area comprises mainly two districts, viz. Kanyakumari and Tirunelveli and four talukas viz.

• Agasteswaram • Thovalai	**Kanyakumari district**
• Radhapuram • Nanguneri	**Tirunelveli district**

For administrative purpose, Radhapuram tehsil is divided into two C.D. blocks namely Radhapuram, C.D. block & Valliyoor, C.D. block. Kanyakumari is smallest district in Tamilnadu. Even though it is a smallest district, the density of population per sq. km is 957, whereas population density per sq. km for Tirunelvelli district is 367 as against 429 persons/sq. km for the Tamilnadu state.

2.6.2.1 Demographic Structure

The demographic structure of the study area is presented in **Table 2.6.1** which gives information on population, employment, house holds, literacy and community structure. The salient features of the area studied are as follows :

- The entire study area covers 1035.63 sq.km. area from Tirunelveli Kattabomman and Kanyakumari district

- The proportion of the area from Tirunelvelli Kattabomman and Kanyakumari district is 79.47% and 20.53 % respectively

- The total population of study area is 366690, with a population density of 354 persons per km^2 as against the density of 429 persons per sq. km. for Tamilnadu state

- Kanyakumari district is a densely populated district. The density of population for Kanyakumari district under the study area is 788 persons per km^2 as against the density of population of 241 persons per km^2 for Tirunelveli Kattabamman district, though it contributes a larger area in the study area

- Sex ratio (no. of females per thousand males) is 1072.6, which indicates that females are more in number than their males counterpart in the study area

- The overall literacy rate in the study area is 69%. District Kanyakumari in the study area shows a good literacy rate of 73% as against the literacy rate of 68% for Tiruneveli Kattabamman district

- The employment rate in the study area is 35.23%.

2.6.2.2 Infrastructure Resource Base

The infrastructure resource base of the villages in the study area with reference to education, medical, water resource, post and telegraph, transportation and power supply based on census data, 1991 is presented in **Table 2.6.2**.

The significant features are :

- All the villages have primary schools. There are 40 middle schools and 11 pre university/junior colleges. The education facilities are good in the study area, this is reflected in a very good literacy rate of 70.47%

- Medical facilities in terms of community health workers and registered medical practitioners are available in almost all the villages. The villages which are devoid of medical facilities avail them from the villages located at distance of 1-5 km. There are 29 hospitals in the study area, whereas, Samugarangapuram, Urumangalam, Perungudi, Vadakku Valliyoor and Agasteswaram villages have primary health centers

- Water supply facilities are available in all the villages which include bore wells, tube wells, tank etc.

- Post and telecommunication facilities are good. In some of the villages, this facility is available at 1-5 km distance

- Transport facilities are satisfactory. Bus stop is available in every village and the approach route is either kuchha or pucca road

- All the villages are electrified. Power supply for domestic as well as agriculture purposes is available

2.6.2.3 Economic Attributes

- The economy of the area is mainly based on agriculture with 63% of main workers engaged in agricultural and allied activities
- The important food crops grown are paddy, cholam, ragi in Tirunevili district, whereas plantation crops like rubber, coffee, tea, spices, coconut, tapioca are grown in Kanyakumari district
- Next to agriculture, people are engaged in fishing. Kanyakumari is the main fish landing centre
- At some places near coast, salt pan works are practiced generating income for the population thereby
- Kanyakumari is a very famous tourist centre as southern tip of India and is famous for shell art
- The forest based resources in the study area are very meagre with a small portion of Thadakmalai Reserve Forest coming within the study area
- Rolling of beedies and brick making is the occupation of some of the people in study area
- There are no major industries in the study area, whereas rice milling, paper making, saw milling, brick making are some of the important village industries.

2.6.2.4 Cultural and Aesthetic Attributes

- The southern most tip of India, where the Arabian sea, the Indian Ocean & the Bay of Bengal meets, is at Kanyakumari which is an important pilgrim centre. Kanyakumari attracts tourists belonging to both India and foreign countries
- Gandhi Mandapam, Vivekananda Rock Memorial, Thiruvalluvar statue in the sea, Bhagavati Temple, Suchindrum temple, Vattakotai Padmanabhapuram palace with an archaeological Museum and Pechiparai Dam are the major places in the district attracting both inland and Foreign tourists. Most of these places are approachable by road from the site and are located at a distance of more than 20 kms from the site
- Kodyar hydro project is a power generation scheme. It is supplemented by a number of wind mills in this district

- There are some important pilgrimage centres like Sankarnainar, Krishnapuram in Tiruvelveli district. Nanguneri is famous for Thadadri temple.

  The main festivals celebrated in the region are :

  i) Chaitra pournima festival : April/May

  ii) Navratri festival : September/October

  iii) Cape festival

  iv) Car festival of the Kanthimalai Nellaiapper temple is celebrated

  v) Kale Shastri festival at Tiruchendur Murugan Temple

Health Status

Government Hospital at Radhapuram & Deputy Director, Health Services, were contacted for obtaining the data to assess the morbidity status in the area along with the Primary Health Centers in Kudankulam, Azagappapuram, Agasteswaram and Chenpagaramanputur. The data for the months from July 2000 to June 2001 is presented in **Tables 2.6.3 to 2.6.7**. It was informed by the hospital staff that this hospital caters to population in the surrounding villages. It was informed by the hospital staff and medical officers at different PHCs that amongst the diseases recorded besides common fever, respiratory, diaorrhoea & dysentery are the most prevailing. Besides this, other diseases are dermatitis, anaemia and gastroenteritis. Other relevant information relating to morbidity status in the area refers to :

		Birth Rate (per 1000 population) 1999-2000	Infant Mortality Rate (per 1000 alive population) 1999-2000
1.	Kanyakumari District	17.3	22.9
2.	Tirunelveli Distt.	19.4	32.0
3.	Agasteswaram PHC	16.6	11.6
4.	Azagappapuram PHC	16.5	8.8
5.	Chenpagaraman puthur PHC	15.4	15.1

Source : Office of the Deputy Director Health & Medical Officer of the concerned PHC

- The birth rate in terms of no. of births/1000 population for Kanyakumari and Tirunelvelli districts are 17.3 and 19.4 respectively

- The reasons attributed for infant mortality rate (I.M.R.) could be due to the following:
- Diaorrhoea
- Malnutriation of mother
- Premature births
- Birth asphyxia

2.6.2.5 Land Acquisition and Rehabilitation and Resettlement (R & R)

The land requirement and rehabilitation of the villages if any, within the acquired land area are relevant aspects which are not new only to nuclear power stations but common to all major projects. However, in case of nuclear power stations, precaution is taken to ensure that public habitation in the vicinity is not to close to the plant and that in case of emergencies, the population upon which counter measures are taken are within manageable levels.

Regarding the site at Kudankulam, the population within the 1.6 km exclusion zone is nil and therefore, there will be no rehabilitation of people. The same is the case for colony. The details of land requirements for colony and plant are given below :

- An area of 2.0 km radius around the reactor is to be acquired. Within this zone, extent of land to be acquired is about 1050 Ha
- An area of about 165 ha. at a distance of about 6 to 7 km from the proposed plant is to be acquired for township.

Approximate Details of Nature and Ownership of land for Plant and for Colony

Particulars	Plant	Colony
• Patta unirrigated cultivable land	830 ha.	69.9 ha.
• Poramboku unirrigated cultivable land	62 ha.	-
• Patta agricultural land	15 ha.	93.0 ha.
• Poromboku agriculture land	0.2 ha.	-
• Patta barren land	129 ha.	-
• Poromboku barren land	13.8 ha.	1.8 ha.
	1050 ha.	**164.7 ha.**

As regards the land use pattern, nature of the land indicated above within an area of 2.0 km radius, about 34% of the area falls in the sea and remaining constitutes mostly unirrigated cultivable land (follow land). This land is mostly barren and unirrigated. Due to existence of limestone deposits, less rainfall and lack of irrigation, agricultural yields are poor.

No forest land needs to be acquired either for the plant, its exclusion zone and the township.

2.6.3 Information Collected from the Management of NPCIL

The following information has been received from the Management, the details of which are presented in **Annexures**. Salient features are as given below:

i) Total no. of persons proposed to be employed :

a) During construction	:	Around 5000 (including labour)
b) After construction	:	1500

ii) Employment likely to be generated in the proposed power plant for the welfare of affected families and local population.

a)	During Operation	:1.	Direct jobs	:	100 Unskilled
					200 Skilled
		2.	Indirect jobs	:	1500
b)	During Construction	:	By Contractors : 5000		

iii) Provisions for Industrial hygine, occupational health and safely Hazards in working environment of the industry (Please refer **Annexure-A**)

iv) Provisions made to meet requirements for health & safety (Please refer **Annexure-B**)

v) Welfare measures to be implemented for the people around the plant (Please refer **Annexure-C**).

2.6.4 Socio-economic Survey

2.6.4.1 Sampling Method

Socio-economic survey was carried out by using judgmental or purposive sampling method for collecting detailed information about prevailing socio-economic conditions in the study area and also to assess awareness, opinion and reaction of the respondents about the project.

Occupational stratification provides prime parameters for sampling because each strata of the sample unit possesses specific characteristics and their views and attributes would form the basis for predicting and evaluating the likely impacts due to the project on existing social and economic status and delineation of Environmental Management Plan for overall improvement in social and economic status.

Socio-economic Survey

The present socio-economic survey has been conducted in selected 11 villages located in all the directions with reference to project site. The villages were selected on random basis; it is assumed that these villages may be affected in future. Locations of these villages are shown in **Figure 2.6.1** and their distances and directions from the project site are presented in **Table 2.6.8**.

The salient observations are :

- The houses in the surveyed villages are both Kuccha & Pucca
- The villages are connected by means of either Kuccha or Pucca roads
- Educational facilities are good, this facility is available in all the villages mostly upto middle school. In some of the villages, it is extended upto high school. In Tiruvalambhapuram, Theroor and Vadakku valliyoor, higher educational institutes including polytechnic college are available. Teachers training Institute and Nursing colleges are also available
- Farming is the main occupation, mostly people are engaged in agricultural activities. The main crops grown are paddy, banana, coconut, pulses, chillies etc.
- The monthly income of the people ranges from Rs. 1,000/- to Rs. 5,000/- per month. Unemployment problem is most prevalent in the study area (**Figure 2.6.2**)
- All the villages have electric supply both for houses and agricultural fields
- Wells, borewells and hand pumps are most common sources of drinking water. Taps are being used by very few respondents and the water supply through taps is from overhead tanks

- Sanitation facilities are very poor. Open field defecation is a common practice in most of the villages. Drainage facilities are not satisfactory and there are many problems reported by respondents mainly due to poor drainage system and mosquito nuisance

- The medical facilities are satisfactory. The common prevailing diseases in the study area are dysentery, diaorrhoea, malaria and asthma. In some of the villages, medical facilities are not available and they have to go to the nearest place for medical aid

- Wood, Kerosene, and LPG are the fuels used for cooking purposes depending upon the income as reported by the respondents

- The mode of transport is Bus and Bus Stops are available in every villages. The respondents expressed their satisfaction with respect to transportation facility.

2.6.4.2 Quality of Life

Quality of life (QoL) is a term, which indicates overall status of socio-economic environment in a given area. Quality of life (QoL) is defined as a function between "objective conditions" and "subjective attitudes" involving a defined "area" of concern.

The "objective conditions" are defined as numerically measurable artifacts of a physical, sociological event or economic event. Objective conditions may be defined as any number which stands for a given quantity of a variable of interest so long as it is independent of subjective opinion.

Subjective attitude" is primarily concerned with affective and cognitive dimensions. It is specifically concerned with 'how aspects of cognition vary as objective conditions vary'.

Once objective measures are obtained for each factor they are transformed to a normal scale varying from 0 to 1 (value function curve) in which 0 corresponds to the lowest or least satisfactory measure, and 1 corresponds to the highest. The weights are assigned to each factor by ranked-pairwise technique, by the expert group based on the secondary data and general observations.

For each objective measure, a corresponding subjective measure is developed for each individual of the sample population by asking him to rate his satisfaction scale (value function curve) is used such that 0 corresponds to the lowest level of attitudinal satisfaction and 1 corresponds to the highest level of satisfaction. Weights are assigned to each factor using ranked - pairwise comparison techniques.

The Socio-economic Indicators for QoL Assessment are :

1. Income, Employment and Working Condition
2. Housing
3. Food
4. Clothing
5. Water Supply and Sanitation
6. Health
7. Energy
8. Transportation and Communication
9. Education
10. Environment and Pollution
11. Recreation
12. Social Security
13. Human Rights

I. Subjective quality of life

$$QoL_s = 1/p \sum_{i=1}^{m} \sum_{j=1}^{p} QI_{ij} \times W_i$$

Where,

QoL_s = Subjective quality of life index

p = No. of respondents, $j = 1, \ldots\ldots, p$

m = No. of factors, $i = 1, \ldots\ldots, m$

QI_{ij} = Subjective quality index for i^{th} factor assigned by j^{th} respondent

$\sum Qi_{ij}$ = Subjective quality index for i^{th} factor assigned by all respondents in an area

W_i = Relative weightage of the i^{th} factor

II. Objective quality of life

$$QoL_o = \sum_{i=1}^{i=n} QI_i \times W_i$$

Where,

QoL_o = Objective quality of life index

n = No. of QoL Factors

i = 1, ..., n

QI_i = Satisfaction level (assigned by the expert group) for the i^{th} objective indicator

W_i = Normalized weight for i^{th} factor

III. Quality of Life (Cumulative Index)

$$QoL_c = \frac{QoL_o + QoL_s}{2}$$

The subjective and objective QoL indices prior to commissioning of the project are presented in **Table 2.6.9**.

The average QoL index values are estimated as :

$QoL_{(S)}$ = 0.48

$QoL_{(O)}$ = 0.52

$QoL_{(C)}$ = 0.50

The average QoL index value for the study area is leaning towards satisfactory level due to good economic status like income, employment and also availability of basic needs, viz. food, clothing, housing. The area is provided with proper medical, educational facilities and social security. But due to water scarcity, inadequate irrigation, lack of sanitation which are subjective conditions and are not much satisfactory as compared to objective conditions.

2.6.5 Project Awareness and Opinion

An attempt has been made to make a comprehensive write-up on project awareness amongst the respondents and their opinion about project whether favorable or unfavorable.

Almost all the respondents showed awareness about the project. This awareness can be attributed to their having seen the project construction, having heard about it and also information obtained through media. However, person to person communication has played a good role in creating awareness amongst local people about the project.

Though an effort has been made to assess the opinion about the project, there appears to be a lot of confusion, due to the fact that the same people calling the project as "Good" as well as "Bad". However, the opinion pole can be analysed as follows:

- The respondents from Vijaypathi and Thiruvalambalpuram reported unfavorable opinion about the project. This can be attributed to the fact that these two villages are very close to the sea coast and project site, fishermen population are not happy as they think that due to this project, sea water may get polluted leading to low fish catch/yield
- The respondents from Kudankulam village where actual project site is located have indicated favourable opinion. They expressed that due to this project, there may be an overall development of the area. Also people whose land has been acquired for the project are happy due to the compensation provided to them. Some of the people whose land was acquired for the project could not get compensation as the records of the land, they hold, are not clear due to which they showed some dissatisfaction
- Educated respondents have given favourable comments about the project, they also added that due to this project their lifestyle may improve.
- A large number of respondents felt that the project would lead to more job opportunities, increase in business facilities which can lead to the improvement in community infrastructure, economic status, transportation facilities, educational facilities, medical and health facilities (**Figure 2.6.3**)
- As regards the adverse opinion about the project, people reported that for the project, water will be used from Pechiparai dam due to which there may be water scarcity in future for irrigation and domestic purpose. However, in view of the water

quantity to be drawn by NPCIL from the dam will be quite small as compared to the total capacity of the dam, the quantitative impacts are expected to be insignficant.

The people in the study area are happy with this project coming up in their area. However, they expect that it should provide employment to the affected people (atleast one person from the family whose land has been acquired for the project). People have expressed that infrastructure facilities should be improved and better water supply and sanitation including health and educational facility should be enhanced.

Annexure-A

Health & Safety at NPP

During the operation of the nuclear power plant, main health hazard that is encountered is radiation hazard apart from the any normal industrial hazard. This is a very clean industry chemically, as no chemical pollutants are released. In these plants, there are three sections to take care of all these problems. They are :-

1. Health Physics Division,
2. Industrial Safety Division,
3. Sanitary Division

The design of the station has been done to meet the international standards and are designed such that the exposure to the personnel working will receive a dose as low as reasonably achievable. Health Physics Division is an independent division directly working under BARC and are administratively reporting to Station Management. They are responsible for the radiation exposure control of the operating personnel. Activities of this section are entirely governed by the Atomic Energy Regulatory Board guidelines and International Commission for Radiation Protection codes and guides and are directly reportable to above agencies and BARC. They are responsible for the exposure control of individuals and are responsible for assessing the working condition and duration at any location within the power plant.

The design of the plant takes in to account all Industrial safety regulations presently in practice and in force. Industrial safety division is responsible for all the safety aspects of the power station. They are also responsible for training industrial workers in using safety appliances during the course of their work. They are responsible for the inspection and certification of any electrical installation in the plant and are responsible for qualifying and authorizing the operators for the operation of electrical installations.

Sanitary division is responsible for the hygiene part in the plant site areas. They are responsible for maintaining the stock of all sanitary requirements and materials and gadgets required and issue them to the employees. These people are responsible for the maintenance of all toilets, shower rooms, laundry, and supply of fresh clothes to the employees going for work inside the reactor building, they are also responsible for decontamination of contaminated areas.

Annexure-B

Health and Safety Provisions

Inside the Plant and Industrial Premises

The plant locations along with its auxiliary buildings are housed inside a fence known as operating island. And there is an area of 2 km radius around the plant in which no habitation is permitted which is known as Exclusion boundary.

Within the plant area just outside the operating island, a dispensary is setup, which is operational 24 hours with duty staff. During the day, a doctor will be available and at nights he will be available on call duty. Ambulance will be available throughout at the site itself. Any patient requiring medical attention immediately can be shifted to the main hospital at the township.

For nearby Industrial Area

For the staff of power station, a full-fledged hospital will be established at the township with all facilities. The hospital will have at least 30 beds, pathological laboratories; X-ray facility, ENT, Labor Ward and operation facilities with necessary number of doctors and staff. In case of necessity, the corporation doctors will refer cases to approved institutions for necessary treatment. It is also proposed to get specialists at least once in a week for referral cases.

For the population nearby industrial area, a base line data on the health of the population is taken. On a regular basis health surveys will be conducted. In addition, with the help of the State Authorities and Voluntary Organizations, health camps like eye camps, family planning camps, general checkup camps will be conducted. It is also proposed to augment some medical facilities available in the local Primary Health Centers.

Annexure-C

Welfare Measures

It is proposed to provide following welfare measures as a goodwill gesture to the members of the families surrounding the NPP, Kudankulam project site.

1. To train the family members in M/s M.S. Swaminathan Research Foundation which has set a demonstration farm in the plant site area. They are already training the local population about the type of crops that can be grown, irrigation methodology, type of manure to be used etc. They are also training them in methodologies of harvesting natural rainwater for the purposes of farming and also methodologies of aqua culture and ornamental fish breeding. They have been already utilizing these families for these purposes. They have also engaged the local public in plantation of 10,000 trees of different verities of Neem and Tamarind in an area of 100 acres. They are proposing to utilize the local families in Green Belt Development in the plant site.

2. It is proposed to select bright students from the local schools from classes 8^{th} to 10^{th} and provide them with scholarship facilities so that they can pursue their education to diploma/ITI/any graduation level so that they can compete in competitive examinations and secure a job in the project/elsewhere.

3. It is also proposed to provide drinking water to the village enroute from Pachiparai reservoir to Kundankulam site from where NPCIL authorities are proposing to bring water for the project. It is proposed to give water at one point for use by the Village Panchayat for the distribution work.

4. It is also proposed to fund some definite amount for the purpose of constructing bore wells for the purposes of drinking water supply to the villages around NPP Kudankulam site.

5. Seminars will be conducted around this area to give a clear picture of the plant and about the benefits the people may get from the proposed power plant.

6. Upgradation of educational institutions already existing will be taken up by NPCIL by providing some laboratory facilities, computers etc.

7. Upgradation of medical facilities in the Primary Health Centers already functioning in this area will also be taken up by NPCIL.

Fig. 2.6.1 : Locations of the Villages Surveyed

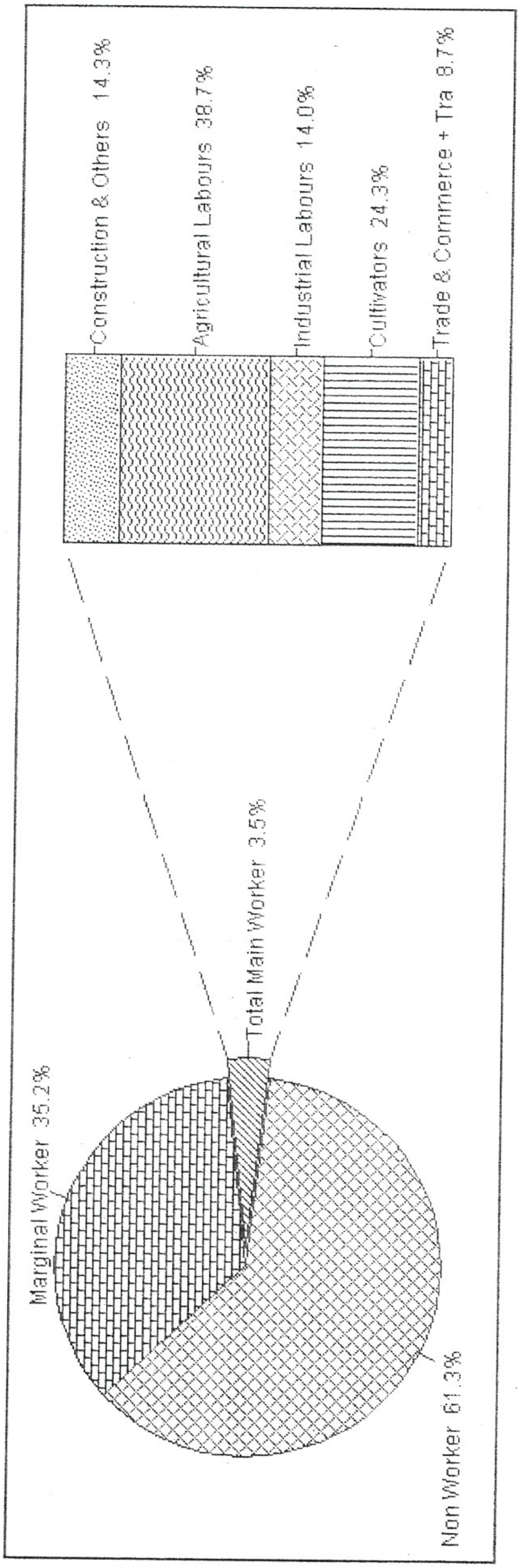


Fig. 2.6.2: Employment Pattern in the Study Area

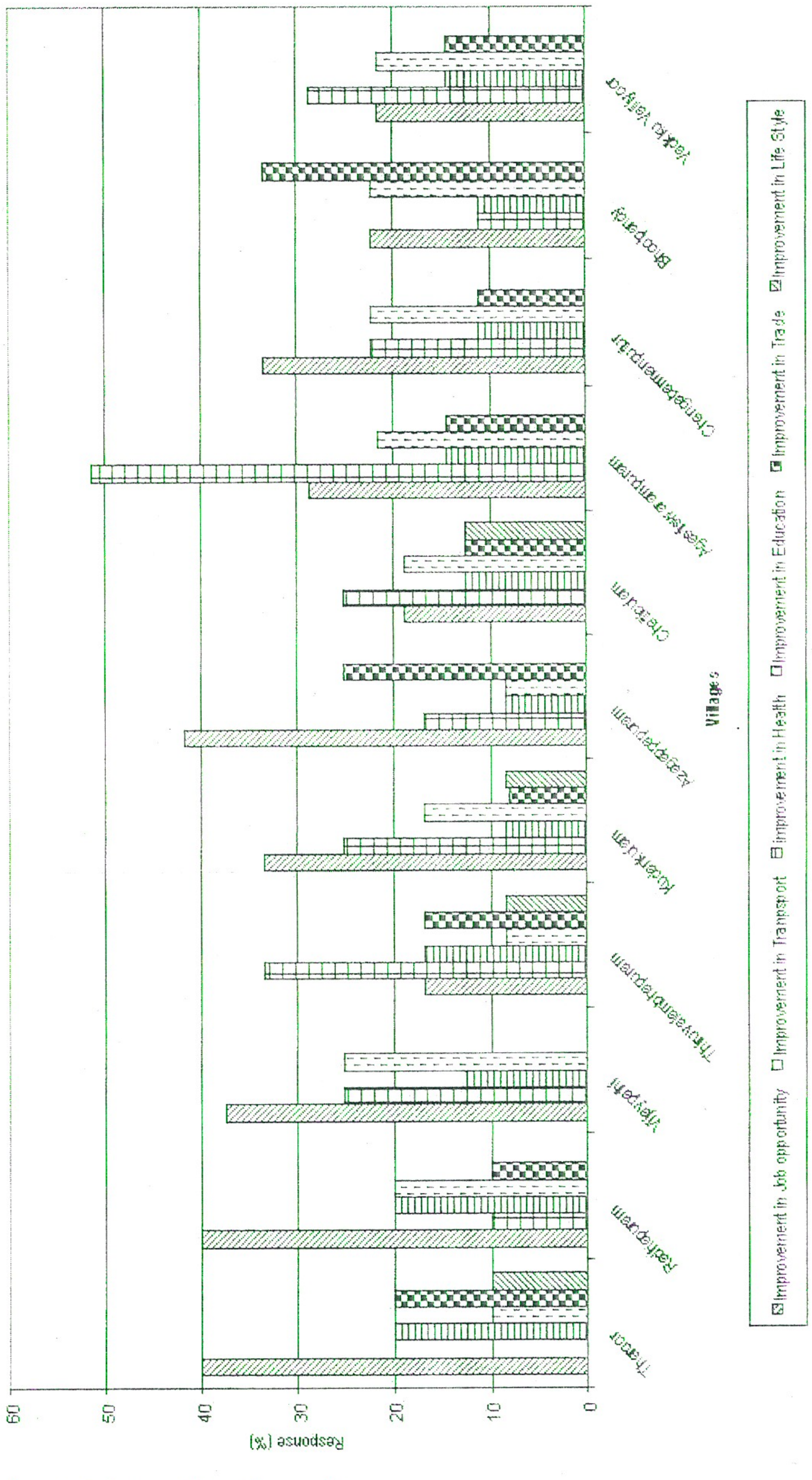


Fig. 2.6.3: Public Opinion about the Project

Table 2.6.1

Demographic Structure of the Villages Surveyed Within KK Project Study Area

Sr. No.	Villages	Area in Hectares	No. of Residential Houses	Total Population TP	Total Population M	Total Population F	Scheduled Caste	Scheduled Tribe	Literates	Main Workers	Marginal Workers	Non Workers
	Tirunlveli - Kattabomman District											
	Radhapuram Taluka											
	Radhapuram C.D. Block											
1.	Appuvilai	276.41	172	690	282	408	121	-	507	359	38	393
2.	Karaichuthuvari	1296.66	1598	7638	3828	3810	866	-	2710	2315	131	5192
3.	Kasturirangpuram	4147.36	679	2798	1341	1457	817	-	1369	1290	11	1497
4.	Kottai Karungulam	4341.10	649	2935	1391	1544	445	652	1631	1057	763	1115
5.	Kumarapuram	1664.12	849	3698	1742	1956	207	-	2359	1363	64	2271
6.	Kumbikulam	1539.88	623	2592	1275	1317	805	122	1271	1501	19	1072
7.	Kadankulam	2696.92	2009	9023	4462	4561	835	10	5414	3745	492	4786
8.	Kuttam	2554.06	890	4414	2130	2284	139	-	3096	1575	371	2468
9.	Mutnumottamozhi	1652.92	985	4438	2011	2427	173	-	3073	1698	185	2555
10.	Parameshwarapuram	685.56	398	1673	791	882	537	591	954	758	16	899
11.	Teruku Kallikulam	668.56	1126	4580	2044	2536	238	-	3469	1291	155.	3134
12.	Tisaiyanvilai	299.34	466	1839	848	991	5	-	1363	488	16	1335
13.	Anaikarai	1416.85	763	3263	1520	1743	326	7	2199	1228	424	1611
14.	Urumangulam	2169.33	1146	4897	2219	2678	470	-	3185	1866	156	2475
15.	Soundarapandiapuram	1268.80	402	1675	773	902	459	-	961	614	196	865
16.	Vijayapati	2595.15	1883	9307	4577	4730	866	-	6130	3266	499	5542
17.	Samugarangapuram	3079.76	1136	4926	2323	2603	1087	129	2872	2090	24	2812
18.	Thiruvambalapuram	2637.83	1377	6429	3134	3295	15	-	3864	2385	139	3905

Sr. No.	Villages	Area in Hectares	No. of Residential Houses	Total Population			Scheduled Caste	Scheduled Tribe	Literates	Main Workers	Marginal Workers	Non Workers
				TP	M	F						
19.	Udayattur	3713.12	906	3873	1807	2066	1170	240	1850	1660	180	2033
20.	Radhapuram	3173.25	1416	5860	2819	3041	2231	61	3568	2281	326	3253
	Valliyoor C.D. Block											
21.	Terku Valliyur	2603.43	1634	5042	1383	3659	929	23	4076	3424	184	3234
22.	Achchambadu	1096.73	666	2555	1078	1477	417	-	1738	821	80	1654
23.	Vadaku Valliyur	4550.04	4758	20879	10344	10535	2320	298	14864	7460	453	12966
24.	Anaikkulam	1416.85	763	3263	1520	1743	326	7	2199	1228	424	1611
25.	Erukkandurai	4075.53	792	3328	1595	1733	1423	-	1913	1640	123	1565
26.	Veppilangulam	2498.21	871	3564	1648	1916	590	-	2031	1636	105	1823
27.	Perungudi	3680.24	3464	14315	6360	7955	1734	137	10312	4951	316	9048
28.	Dhankkarkulam	3027.96	1091	4636	2200	2436	1173	-	2818	2013	72	2551
29.	Adangarkulam	972.06	563	2355	1097	1258	804	-	1153	829	15	1511
30.	Palavur	4885.11	2950	13338	6448	6890	2095	17	8637	5737	503	6824
31.	Chettikulam	728.26	1823	8635	4179	4456	201	-	4913	3243	535	4857
32.	Levingipuram	1900.47	2316	10544	5074	5470	444	4	7625	3822	279	6443
Kanyakumari District												
	Agasteswaram Taluka											
33.	Kanyakumari	656.97	1668	7362	3671	3691	415	-	5083	2354	163	4845
34.	Kottarm	1164.87	1827	8035	3968	4067	826	16	6383	2317	229	5489
35.	Thamaraikulam	1604.03	4172	18390	8961	9429	660	-	13737	5680	469	12241
36.	Suchindram	538.60	1660	7120	3532	3588	751	38	5927	1961	18	5141
37.	Azhagappapuram	1738.42	3699	16123	7761	8362	1782	-	12243	3454	328	10685
38.	Kulashekarapuram	1411.29	2171	10042	5051	4991	613	30	7523	3485	214	6343

Sr. No.	Villages	Area in Hectares	No. of Residential Houses	Total Population			Scheduled Caste	Scheduled Tribe	Literates	Main Workers	Marginal Workers	Non Workers
				TP	M	F						
39.	Eraviputhur	782.19	2024	8802	4414	4388	977	128	6282	2992	160	5650
40.	Marangoor	1550.77	2251	9677	4728	4949	1025	-	7115	3452	208	6017
41.	Theroor	2153.08	2583	10670	5311	5359	3169	101	8039	3886	194	6590
42.	Agasteeswaram	948.12	2651	12380	6093	6287	217	-	8827	3520	143	8717
43.	Nagercoil	383.54	649	2662	1334	1328	649	4	2003	952	-	1710
	Thovalai Taluka											
44.	Erachakulam	1339.76	1070	6009	2961	3048	1069	-	4274	1774	-	3001
45.	Thovalai	1738.96	1319	5504	2768	2736	362	48	4385	1619	86	3799
46.	Esanthimangalam	964.13	973	4274	2095	2179	214	-	3012	1277	52	2992
47.	Aramboli	1850.86	3765	16367	8397	7970	2685	62	10318	5685	265	10417
48.	Boothpandy	293.68	2583	11712	5908	5804	932	5	9349	3187	230	8295
49.	Chenbagaramanputhoor	1529.58	2316	10184	5064	5120	1919	-	7391	3413	436	6335
50.	Thirupathisaram	623.00	944	4056	1983	2073	921	20	3261	1308	29	2719
	Nanguneri Taluka											
51.	Vijayanarayanam	5919.71	1435	5366	2649	2717	554	-	3498	2269	121	2976
52.	Ittamoli	1400.74	1670	7475	3471	4004	565	-	5170	2767	272	4436
53.	Dalapathisamudram	1659.15	1298	5488	2561	2927	518	-	3490	2238	101	3149
	Total	103563.3	83892	366690	176923	189767	45091	2750	251434	129224	11012	224847

Source:- District Census Handbook, 1991 (Kanyakumari and Tirunelvelli Districts)

Table 2.6.2

Infrastructure Resource Base of the Study Area

Sr. No.	Villages	No. of Education Centers	Medical Facilities	Drinking Water facilities	Communication facilities	Transportation facilities	Approach Road	Power Supply
	Tirunelveli Kattabomman District							
	Radhapuram Taluka							
	Radhapuram C.D. Block							
1.	Appuvilai	P(1)	-(-5)	W,HP	PO	BS	PR	EA
2.	Karaichchuthuvari	P(5),M(2),H(1)	MCW(1)	W,HP	PO, Phone	BS	PR	EA
3.	Kasthurirangapuram	P(2),M(2)	-(5-10)	W,HP	PO	BS	PR	EA
4.	Kottaikarungulam	P(4),M(1)	MCW(1),MH(1),RP(2)	W,HP	PO	BS	PR	EA
5.	Kumarapuram	P(4),M(2)	D(1)	W,HP	PO	BS	PR	EA
6.	Kumbikulam	P(4),M(1)	-(-5)	W,HP	PO	BS	PR	EA
7.	Kudankulam	P(5),M(5),H(1)	MH(1),FPC(1),	W,HP	PTO, Phone	BS	PR	EA
8.	Kuttam	P(6),M(3),H(1)	MCW(1)	T,W,TW,HP	PTO, Phone	BS	PR	EA
9.	Muthumottamozhi	P(5)	-(-5)	W,HP	PO	BS	PR	EA
10.	Parameswarapuram	P(1),M(1)	RP(1)	W,HP	PO	BS	PR	EA
11.	Radhapuram	P(1),M(2),H(1),PUC(1)	H(1),MH(1),RP(3)	T,W,HP	PTO, Phone	BS	PR	EA
12.	Samugarangapuram	P(4),M(1),H(1),TR(1)	H(2),PHC(1)	W,HP	PTO, Phone	BS	PR	EA
13.	Soundarapandiapuram	P(2), M(1)	-(-5)	W,HP	PO	BS	PR	EA
14.	Terkukallikulam	P(3),M(1),H(1),PUC(1),C(1)	H(1)	W,HP	PTO, Phone	BS	PR	EA

Sr. No.	Villages	No. of Education Centers	Medical Facilities	Drinking Water facilities	Communication facilities	Transpor-tation facilities	Approach Road	Power Supply
15.	Tiruvambalapuram	P(9),M(2)	-(5-10)	W,HP	PO	BS	PR	EA
16.	Tisaiyanvilai	P(1),M(1),H(1)	O(1)	W,HP	PO, Phone	BS	PR	EA
17.	Udayattur	P(4),M(1)	O(2)	W,HP	PO	BS	PR	EA
18.	Urumangulam	P(7),M(4),H(1),O(1)	MCW(1),MH(1),PHC(1)	W,HP	PTO, Phone	BS	PR	EA
19.	Viayapathi	P(3),M(2),H(1)	-(-5)	W,HP	PO	BS	PR	EA
Valliyoor C.D. Block								
23.	Achchampadu	P(5),M(1)	-(-5)	W,HP	PO	-(-5)	PR	EA
24.	Adangarkulam	P(3)	RP(1)	HP	PO	-(-5)	PR	EA
25.	Anaikkulam	P(4), M(2)	MCW(1)	W,HP	PO, Phone	BS	PR	EA
26.	Chettikulam	P(4),M(1),H(1)	MCW(1),NH(1),O(1)	W,HP	PO	BS	PR	EA
27.	Danakkarkulam	P(3),M(2)	MCW(1)	W,HP	PO	BS	PR	EA
28.	Erukkandurai	P(4),M(1),O(1)	MH(1)	W,HP	PO	BS	PR	EA
29.	Levinjipuram	P(5),M(5)	H(1),RP(1)	W,HP	PTO	BS	PR	EA
30.	Palavur	P(7),M(3),H(1)	MCW(1),RP(4)	W,TW,HP	PTO	BS	PR	EA
31.	Perungudi	P(12),M(7),H(7),PUC(3)	MCW(1),PHC(1),FPC(1),RP(5)	W,HP	PTO, Phone	BS	PR	EA
32.	Terku valliyur	P(10),M(3)	MCW(1),HC(1)	W,HP	PO	BS	PR	EA
33.	Vadakku valliyur	P(11),M(5),H(1),PUC(2)	H(5),MH(3),PHC(1), PHS(1),O(2)	T.W,TK,TW,HP	PTO	BS,RS	PR	EA
34.	Veppilangulam	P(7),M(1)	MCW(1)	W,HP	PO	BS	PR	EA

Sr. No.	Villages	No. of Education Centers	Medical Facilities	Drinking Water facilities	Communication facilities	Transpor-tation facilities	Approach Road	Power Supply
	Nanguneri Taluka							
20.	Dalapathi samudram	P(8),M(1),H(1)	MCW(1),MH(1)	W	PO	BS,RS	PR	EA
21.	Ittamoli	P(9),M(3),H(2),PUC(1)	MH(1)	W,HP	PTO, Phone	BS	PR	EA
22.	Vijayanarayanam	P(6),M(1)	H(1),MCW(1),MH(1),FPC(1)	W,HP	PTO, Phone	BS	PR	EA
Kanyakumari District								
	Agastiswaram C.D. Block							
35.	Agastiswaram	P(4),M(1),H(1),PUC(1),C(1)	MCW(1),PHC(1),HC(1),D(1)	T,W,TK	PTO, Phone	BS, RS	PR, KR	EA
36.	Azhagappapuram	P(6),M(6),H(3)	MH(1),CWC(1),NH(2),RP(2)	T,W,TK,HP,C	PTO, Phone	BS	PR, KR	EA
37.	Eraviputhoor	P(1),M(1),H(1)	RP(1)	T.W,TK,HP,C	PO	BS	PR, KR	EA
38.	Kanniyakumari	P(7),M(4),H(1)	MH(1),RP(2)	T,W,TK,HP,C	PTO, Phone	BS,RS	PR, KR	EA
39.	Kottaram	P(3),M(2),H(1)	H(1), RP(1)	T,W,TK,HP	PTO, Phone	BS, RS	PR, KR	EA
40.	Kulasekarapuram	P(4),M(2),H(1),TR(1)	H(2),MH(1),RP(2)	T,W,TK,HP	PTO, Phone	BS	PR, KR	EA
41.	Marangoor	P(1),M(2),H(1)	MCW(1),HC(1),RP(6)	T,W,TK,HP,C	PTO	BS	PR, KR	EA
42.	Nagercoil	P(1),M(1)	-(-5)	T,W,R,C	-(5)	BS	PR, KR	EA
43.	Suchindram	P(4),M(1),H(1)	H(2),MCW(1),CHC(1),HC(1),NH (3),RP(1)	T,TK,R,C	PTO, Phone	BS, RS	PR, KR	EA
44.	Thamaraikulam	P(9),M(3),H(2)	MCW(1),MH(1),NH(1),RP(6)	T,TK,HP,R	PTO, Phone	BS, RS	PR, KR	EA
45.	Theroor	P(8),M(2),H(1),TR(1)	CHC(1),RP(1)	T,W,TK,C	PO	BS	PR, KR	EA

Sr. No.	Villages	No. of Education Centers	Medical Facilities	Drinking Water facilities	Communication facilities	Transpor-tation facilities	Approach Road	Power Supply
Thovalai Taluka								
46.	Aramboli	P(4),M(4),H(1),PUC(1),C(1)	H(5),RP(7)	T,W,HP	PTO, Phone	BS, RS	PR	ED,EAG
47.	Boothapandy	P(2),M(2),H(2),O(2)	H(5),CWC(1),HC(1),RP(4)	T,W,HP,R	PTO, Phone	BS	PR	EA,EAG
48.	Chenbagaramanputhoor	P(1),M(1),H(1),I(1)	H(1),PH(1)	T,W,HP,C	PO, Phone	BS	PR	EA, EAG
49.	Erachakulam	P(1),M(1),H(1)	H(1),MCW(1),RP(1),MH(1)	T,W	PO, Phone	BS	PR	ED, EAG
50.	Esanthimangalam	P(1), M(1)	MCW(1)	T,W,HP,R	-(-5)	BS	PR	ED, EAG
51.	Thirupathisaram	P(1),M(1),H(2),TR(1)	H(1),MCW(1)RP(1)	T,W,HP	PO, Phone	BS	PR	ED, EAG
52.	Thovalai	P(2),M(1),H(1),PUC(1)	MCW(1),MH(4),HC(1), D(3),RP(1)	T,W,TK,HP,C	PO, Phone	BS, RS	PR	ED, EAG

Source:- District Census Handbook, 1991 (Kanyakumari and Tirunelvelli Districts)

List of Abbraviations

Educational Institutions
P - Primary School
M - Middle School
H - High School
AC - Adult Literacy Centre
PUC - Pre university/Junior College
TR - Training School
IS - Industrial School
C - College

Transportation facilities
BS - Bus service
RS - Railway station

Power Supply
EA - Electricity for all purpose
ED - Electricity for domestic purpose
EAG - Electricity for agriculture purpose

Medical Facilities
PHC - Primary Health Centre
PHS - Primary Health Subcentre
CHW - Community Health Worker
CWC - Community Welfare Centre
FPC - Family Planning Centre
SMP - Subsidiary Medical Practitioner
RP - Registered Private Practitioner
MH - Maternity Home
D - Dispensary
H - Hospital
MCW - Maternity & Child Welfare Centre
CHC - Child Health Centre
O - Others
NH - Nursing Home

Communication facilities
PO - Post Office
PTO - Post & Telegraph office
Phone - Telephone connection

Drinking Water Sources
HP - Hand Pump
TK - Tank Water
TW - Tube Well Water
T - Tap Water
R - River
C - Canal
W - Well Water
N - Nallah
S - Spring

Approach Road
PR - Pucca Road
KR - Kuccha Road
NW - Navigable waterway

Table 2.6.3

Morbidity Pattern at PHC - Number of Patients at OPD (Village : Kudankulam) (June 2000 - May 2001)

Month	Malaria	Pneumonia	Respiratory Problem	Common Fever	Dysentery	Diaorrhoea	Gastro Enteritis	Digestive	Skin	Injury	Worms	Anaemia	Vision Problem	Snake/ Dog bite
2000														
June	-	-	80	76	23	27	4	20	142	16	9	-	146	1
July	-	-	103	103	29	31	3	17	180	25	13	-	144	1
August	-	-	113	105	32	27	5	14	196	27	15	-	180	1
September	-	-	104	120	23	28	3	12	177	20	13	-	217	-
October	-	-	106	108	31	24	2	16	174	19	11	-	212	-
November	-	-	99	6	24	33	4	15	159	17	6	-	153	2
December	-	-	91	103	26	21	2	14	168	21	4	-	158	-
2001														
January	-	-	150	234	34	27	3	16	217	53	6	-	268	2
February	-	-	149	173	27	32	4	17	286	48	4	-	178	3
March	-	-	135	97	23	27	5	14	262	43	3	-	156	4
April	-	-	130	87	21	31	2	15	185	19	2	-	144	2
May	-	-	117	147	27	26	4	13	203	36	4	-	175	3

Source :- Primary Health Center Kudankulam

Total villages which come under this PHC are 6

1. Kudankulam
2. S.S. Puram
3. Udayathoor
4. Tiruvampalapuram
5. Koothankuphi
6. Vijayapathi

Birth Rate % - NA
Infant mortality Rate % - NA

Table 2.6.4

Morbidity Pattern at PHC - Number of Patients at OPD
(Village : Azagappapuram)
(June 2000 - June 2001)

Month	Malaria	Pneumonia	Respiratory Problem	Common Fever	Dysentery	Diaorrhoea	Gastro Enteritis	Digestive	Skin	Injury	Worms	Anaemia	Vision Problem	General	Snake/ Dog bite
2000															
June	-	-	49	50	57	67	9	48	96	4	36	41	32	458	-
July	-	-	42	53	55	58	8	42	69	15	28	41	23	665	-
August	-	-	56	82	4	11	7	9	37	6	18	49	17	941	-
September	-	-	49	71	3	9	13	6	41	3	24	54	11	770	-
October	-	8	47	147	39	42	42	52	130	13	43	59	38	489	2
November	-	19	44	57	2	53	52	42	69	13	43	44	33	587	1
December	-	7	45	92	3	58	11	39	27	9	41	34	25	533	1
2001															
January	-	-	93	87	4	11	9	12	21	8	17	32	7	475	1
February	-	-	102	92	3	8	7	16	27	11	18	38	5	936	6
March	-	-	36	70	6	15	12	6	42	11	16	132	-	432	1
April	-	-	88	76	3	16	11	7	31	9	15	48	-	434	1
May	-	-	98	101	2	9	6	19	26	8	17	54	3	574	8
June	-	-	102	83	2	9	12	16	14	5	19	42	2	472	-

Source :- Primary Health Center Azagappapuram

No. of T.B. patients : 43

Total villages which come under this P.H.C are 10

Birth rate : 16.5 %
Infant mortality rate : 8.8 %

1. Naloor
2. Dhroor
3. Azhagppapum (S)
4. Dherekelputhur
5. Azhagppapum (N)
6. Rampuram
7. Mylady
8. Rajawas
9. Maungoor
10. Anjugramam

Table 2.6.5

Morbidity Pattern at PHC - Number of Patients at OPD
(Village : Agasteswaram)
(June 2000 - May 2001)

Month	Malaria	Pneumonia	Respiratory Problem	Common Fever	Dysentery	Diaorrhoea	Gastro Enteritis	Digestive	Skin	Injury	Worms	Anaemia	Vision Problem	General	Snake/ Dog bite
2000															
June	-	-	154	90	6	-	32	18	70	1	19	36	23	-	-
July	1	-	82	112	5	-	42	14	68	-	24	32	18	-	-
August	1	-	36	130	12	-	26	16	118	3	18	28	27	-	-
September	1	-	76	122	8	-	31	19	161	-	16	30	23	-	-
October	1	-	99	117	11	-	38	22	126	2	17	11	24	-	-
November	-	-	120	140	9	-	17	16	132	1	22	10	20	-	-
December	1	-	192	69	6	-	22	13	118	-	11	8	26	-	-
2001															
January	-	-	230	202	14	-	36	47	149	2	34	19	25	-	-
February	1	-	166	90	8	-	10	9	106	-	21	16	20	-	-
March	1	-	139	99	13	-	14	13	112	-	32	15	29	-	-
April	-	-	129	84	7	-	12	22	172	1	16	20	22	-	-
May	-	-	144	119	4	-	18	11	182	-	15	14	24	-	-

Source :- Primary Health Centre, Agasteswaram
No. of T.B. patients : 61

Total villages which come under this PHC are 9

1. Poojapuravilai
2. Pooviyoor
3. Santhaiyadi
4. Kovalam
5. North Thamakaikulam
6. South thamdraikolam
7. Swamy Thoppu
8. Jucheendram
9. Akkarai

Birth rate : 16.6%
Infant mortality rate : 11.6%

Table 2.6.6

Morbidity Pattern at PHC - Number of Patients at OPD
(Village : Chenpaga Ramanputhur)
(June 2000 - May 2001)

Month	Malaria	Pneumonia	Respiratory Problem	Common Fever	Dysentery	Diaorrhoea	Gastro Enteritis	Digestive	Skin	Injury	Worms	Anaemia	Vision Problem	General	Snake/ Dog bite
2000															
June	-	-	418	157	7	11	18	17	167	42	86	132	23	-	1
July	-	-	146	122	14	15	28	16	44	70	69	99	37	-	1
August	-	1	139	112	6	11	78	20	68	68	59	82	19	-	1
September	-	1	126	132	9	13	20	32	19	56	48	23	22	-	1
October	-	-	118	127	8	20	14	36	82	75	36	68	33	-	1
November	-	1	132	115	5	12	13	18	92	43	35	55	45	-	-
December	-	-	140	110	10	17	17	23	103	28	90	57	42	-	1
2001															
January	-	2	122	112	12	19	15	17	114	60	27	88	39	-	2
February	-	1	118	108	15	10	19	27	120	55	28	63	41	-	-
March	-	1	211	105	9	13	22	43	149	75	32	44	38	-	-
April	-	2	158	113	8	20	19	38	152	46	43	38	27	-	1
May	-	-	229	100	4	18	17	37	128	52	20	36	46	-	4

Source :- Primary Health Centre, Chenpaga Ramanputhur
No. of T.B. patients : 15

Total villages which come under this PHC are 8

1. Mathavalayam
2. Sautharilai
3. Erachakulam
4. Esanthimangalam
5. Boothapandy
6. Thashakudi
7. Thirupathisaram
8. Thittuvilai

Birth rate : 15.4%
Infant mortality rate : 15.1%

Table 2.6.7

Morbidity Pattern at PHC - Number of Patients at OPD (Govt. Hospital, Radhapuram) (July 2000 - June 2001)

Month	Malaria	Pneu-monia	Respiratory Problem	Common Fever	Dysentery	Diaorrhoea	Gastro Enteritis	Digestive	Skin	Injury	Worms	Anaemia	Vision Problem	General	New Patients		
															M	F	C
2000																	
July	-	10	340	150	25	29	118	22	34	38	108	160	12	302	544	631	273
August	-	12	288	154	18	31	194	18	32	25	120	148	10	284	541	265	184
September	-	8	315	148	16	27	198	20	38	26	115	170	5	324	588	677	145
October	-	18	341	154	12	34	159	12	42	34	113	138	11	342	577	564	169
November	-	13	295	164	21	39	161	30	25	42	95	154	6	339	525	596	253
December	-	65	345	172	78	75	160	48	83	52	121	106	8	256	574	841	254
2001																	
January	-	42	465	184	65	65	174	58	75	74	134	185	12	456	794	988	206
February	-	32	418	126	52	54	154	54	68	65	128	180	15	238	512	731	341
March	-	28	350	160	38	54	174	24	72	54	138	168	9	502	550	775	446
April	-	17	325	250	42	36	184	18	65	60	193	125	14	241	553	663	451
May	-	8	296	218	24	18	156	27	62	48	176	184	16	505	721	381	636
June	-	19	374	247	27	22	178	44	58	65	229	288	16	566	738	971	423

Source :- Govt. Hospital, Radhapuram

No. of T.B. patients : 134

Table 2.6.8

Distance and Direction of the Villages Surveyed

Sr. No.	Village	Aerial distance * (in km)	Direction
1.	Theroor	24	E
2.	Radhapuram	12	N
3.	Vijaypathi	7	W
4.	Thiruvalambhapuram	12	W
5.	Kudankulam	4	W
6.	Azagappapuram	18	E
7.	Chetticulam	12	E
8.	Agasteswarampuram	20	SE
9.	Chengabarmanputhur	24	NE
10.	Bhoolpandy	30	NE
11.	Vadakku valliyoor	26	N

* from the NPP site

Table 2.6.9

Quality of Life Indices for the Villages Within the Study Area of Proposed NPP, Kudankulam

Sr. No.	Village	$QoL_{(S)}$	$QoL_{(O)}$	$QoL_{(C)}$
1.	Theroor	0.47	0.51	0.49
2.	Radhapuram	0.49	0.54	0.51
3.	Vijaypathi	0.42	0.44	0.43
4.	Thiruvalambhapuram	0.43	0.48	0.45
5.	Kudankulam	0.45	0.50	0.48
6.	Azagappapuram	0.52	0.55	0.53
7.	Chetticulam	0.49	0.53	0.51
8.	Agasteswarampuram	0.54	0.59	0.56
9.	Chengabarmanputhur	0.47	0.50	0.48
10.	Bhoolpandy	0.51	0.54	0.42
11.	Vadakku vallioor	0.54	0.60	0.57
12.	Average Values	0.48	0.52	0.50

$QoL_{(S)}$ - Subjective Quality of Life
$QoL_{(O)}$ - Objective Quality of Life
$QoL_{(C)}$ - Cumulative Quality of Life

Chapter 3
Prediction of Impacts

Chapter 3

Prediction of Impacts

3.1 Air Environment

The impacts from nuclear power projects are of mainly radiological type because of the release of radioactive materials during normal operation as well as in emergencies. The effects of radioactive material on members of public and surrounding ecosystem differ from conventional chemical pollutants in the form of cumulative radiation doses over long periods, since some of the radio-nuclides have very long half life. Accordingly, the prediction models for radioactive pollution in air environment will be mainly concerned with computation of time integrated long term concentrations of individual radioactive isotopes and the resultant dose levels. In the present study, the mathematical model that has been used for predictions on air quality includes steady state Gaussian Plume Dispersion model designed for multiple point sources.

In the proposed nuclear power plant, major point sources emitting gaseous pollutants include two stacks from reactor auxiliary buildings of Unit#1 and Unit#2 and one stack from solid waste management facilities. The impacts of air pollutants were predicted in summer season using **Industrial Source Complex – Short Term (ISCST Version 3)** air quality model, which is selected keeping in view the plain terrain at the project site.

3.1.1 Radioactive Pollution

Some of the radioisotopes can enter the human body through different path ways (routes) as explained in previous sections. The radiation exposure received can be classified as external and internal according to the location of the radioactive material irradiating the tissue. External radiation is received from the irradiations from the isotopes in the radioactive cloud as it passes over the receptors, from the material deposited on surfaces around the receptors and on receptor body itself as the cloud passes. Internal exposure can result from inhaling the radioactive material in the air as the cloud passes or by ingesting contaminated food stuff and drinking contaminated water.

Release of radioactive material to atmosphere can occur almost instantaneously or on continuous basis from nuclear power plants. The resulting exposure of people downwind and objects, to the air borne radioactive material will be of short or long duration, depending upon the release time, the wind speed, the nature of the material, the geometry of the source and the dispersion of the cloud as it travels. The final effect of radioactive material on a receptor is a function of the total radiation received from different isotopes with variations in concentrations during exposure. In this circumstance the integral of the concentration vs. time curve at the point of receipt is a measure of the total dose.

3.1.2 Plant Emissions

The sources of gaseous radioactive waste produced during the operation of the reactor are as follows :

- Degassing of the primary coolant in the deaerator of volume control system
- Nitrogen blow offs from the equipments containing radioactive noble gases
- Bubbler tank, sumps for collection of leakages, nuclear sampling equipment, and equipments (tanks) located in reactor auxiliary building

Radioactive gas treatment facility has two systems:

- System for burning hydrogen from process blow offs
- Radioactive gas purification system

Radioactive gas purification system is designed to reduce the activity of process blow offs coming from hydrogen burning system and from other tanks containing radioactive media to admissible levels. After purifying through absorbing filters the gases are discharged to the atmosphere through 100 m tall ventilation stack.

Atmospheric Releases

Unlike in other nuclear power stations in India, there are three different stacks at Kudankulam site. Two stacks on the respective reactor auxiliary buildings of Unit #1 and 2. These stacks discharge ventilation air of respective reactor building and reactor auxiliary buildings. There is one stack on the solid waste management facility, which is common to both the units.

Stack details of the Stack on Reactor Auxiliary Building

Stack height	–	100 mts above ground level
Stack diameter at the top	–	3.2 mts
Exit velocity	–	15 m/sec
Exit temperature	–	Ambient

The emissions from the stack of reactor auxiliary building are presented in **Table 3.1.1**.

Gas-aerosol Release by Ventilation Systems through Solid Waste Management Building, Stack

During normal operation, from stack of solid waste management building, some releases of radioactive particulates are caused due to presence of particles of burned materials in effluent smoke gases. Smoke gases are removed from the incineration system through its own aerosol filter system featuring high purification degree. The quantitative analysis, based on radiation characteristics of processed wastes and capacity of the facility determines the following (evaluation is carried out by major dose-generating isotopes) :

At the highest specific activity of processed (burned) wastes of 9.10^7 Bq/kg with the following characteristics:

by Co^{-60}	–	3 Bq/m^3
by Cs^{-137}	–	7.5 Bq/m^3

The Stack on solid waste management building has following details :

Stack height	–	35 mts above ground level
Stack dia at the top	–	1.5 mts

Exit velocity – 10 m/sec

Exit Temperature – Ambient

In this prediction exercise, only two stacks from reactor auxiliary buildings have been considered as the emissions from the stack located at solid waste management facilities will be intermittent and only for a short duration.

3.1.3 Micro-Meteorology

The hourly wind speed, solar insolation and total cloudiness during day time and wind speed and total cloudiness during night time were used to determine the hourly atmospheric stability class (Pasquill and Gifford) viz., A to F. The hourly stabilities were determined based on the technique suggested by Turner.

Turner's system used for determining the stability classes is as follows:

- For day or night: If total cloud cover (TC) = 10/10 and ceiling <7000 ft (2134 m), NR=0
- For night-time (defined as period from one hour before sunset to one hour after sunrise):

  a) If TC<4/10, use NR = -2

  b) If TC>4/10, use NR = -1
- For day time: Determine insolation class number (IN)

  a) If TC<5/10, use NR=IN

  b) If TC>5/10, modify IN by the sum of the following applicable criteria

     If ceiling<7000 ft (2134m), modification = -2

     If ceiling>7000 ft but <16000 ft (4877 m), modification = -1

     If TC=10/10 and ceiling>7000 ft, modification = -1, and let modified value of IN=NR, except for day-time NR cannot be <+1

During study period in summer season the winds were recorded from SW-W-NW sector thereby projecting the impact zone in NE-E-SE sector with respect to the location of nuclear power plant as the zone of impacts. During post-monsoon season and winter season the winds were recorded from N-NE-E sector. The wind speed has been recorded high during most of the study period with no calm condition prevailing at the site. The diurnal variations in winds were insignificant at the project site. The high wind speed can be attributed to closeness to seashore.

The meteorological data used for air quality modelling for three seasons are presented in **Tables 3.1.2 to 3.1.4**.

3.1.4 Air Quality Model Description

The impact on air quality due to emissions from single source or group of sources is evaluated by use of mathematical models. When air pollutants including radionuclides are emitted into the atmosphere, they are immediately diffused into surrounding atmosphere, transported and diluted due to winds. The air quality models are designed to simulate these processes mathematically and to relate emissions of primary pollutants to the resulting downwind air quality. The inputs include emissions, meteorology and surrounding topographic details to predict the impacts of conservative pollutants.

The **Industrial Source Complex' – Short Term Version 3 (ISCST-3)** model has been developed to simulate the effect of emissions from the point sources on air quality. The **ISCST-3** model was adopted from the USEPA guideline models which is routinely used as a regulatory model to simulate plume dispersion and transport from and up to 100 point sources and 20000 receptors. **ISCST–3** is the state of the art model with USEPA which is extensively used for predicting the Ground Level Concentrations (GLCs) of conservative pollutants from point, area and volume sources. The impacts of radionuclides have been predicted using this air quality model keeping in view the plain terrain at the project site. The micrometeorological data monitored at project site as also data made available by NPCIL for the study period have been used in this model.

The **ISCST-3** model is, an hour-by-hour steady state Gaussian model which takes into account the following:

- Terrain adjustments
- Stack-tip downwash
- Gradual plume rise
- Buoyancy-induced dispersion, and

- Complex terrain treatment and consideration of partial reflection
- Plume reflection off elevated terrain
- Building downwash
- Partial penetration of elevated inversions is accounted for
- Hourly source emission rate, exit velocity, and stack gas temperature

The **ISCST-3** model, thus, provides estimates of pollutant concentrations at various receptor locations.

The ISC short term model for stacks uses the steady-state Gaussian plume equation for a continuous elevated source. For each source and each hour, the origin of the source's coordinate system is placed at the ground surface at the base of the stack. The x axis is positive in the downwind direction, the y axis is crosswind (normal) to the x axis and the z axis extends vertically. The fixed receptor locations are converted to each source's coordinate system for each hourly concentration calculation. The hourly concentrations calculated for each source at each receptor are summed to obtain the total concentration produced at each receptor by the combined source emissions.

For a steady-state Gaussian plume, the hourly concentration at downwind distance x (meters) and crosswind distance y (meters) is given by:

$$\text{Concentration} = \frac{QKVD}{2\pi U_S S_Y S_Z} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right]$$

where:

Q	= pollutant emission rate (mass per unit time)
K	= a scaling coefficient to convert calculated concentrations to desired units
V	= vertical term
D	= decay term
s_y, s_z	= standard deviation of lateral and vertical concentration distribution (m)
u_s	= mean wind speed (m/s) at release height

Above equation includes a Vertical Term (V), a Decay Term (D), and dispersion parameters (s_y and s_z) as defined by Pasquill and Gifford and varies with distance and stability. It should be noted that the Vertical Term includes the effects of source elevation, receptor elevation, plume rise, limited mixing in the vertical, and the gravitational settling and dry deposition of particulates (with diameters greater than about 0.1 microns).

The ISC model uses either a polar or a Cartesian receptor network as specified by the user. The model allows for the use of both types of receptors and for multiple networks in a single run. All receptor points are converted to Cartesian (X,Y) coordinates prior to performing the dispersion calculations. In the Cartesian coordinate system, the X axis is positive to the east of the user-specified origin and the Y axis is positive to the north.

The Vertical Term (V), which is included in Equation (1), accounts for the vertical distribution of the Gaussian plume. It includes the effects of source elevation, receptor elevation, plume rise, limited mixing in the vertical, and the gravitational settling and dry deposition of particulates. In addition to the plume height, receptor height and mixing height, the computation of the Vertical Term requires the vertical dispersion parameter (s_z).

3.1.5 Air Quality Modelling and Prediction

In the present case, prediction of impacts has been carried out for three seasons, i.e. summer, post-monsoon and winter on 24 hourly basis in a study area of 10 km radius using the mentioned **ISCST–3** model. In this case, short term concentrations of inert radioactive kinds of gas (any mixture), iodine and mixture of long-lived nuclides are predicted.

It is predicted that maximum concentration of noble gases, iodine and longlived nuclides in the form of particulates from the proposed nuclear power plant will be 0.84 microcurie /m^3 (at 1.5 km in E), 18 picocurie/^{3} (at 1.5 km in E) and 19 picocurie/m^3 (at 1.5 km in E) respectively in summer season (**Figures 3.1.1 - 3.1.3**). In post monsoon season, the maximum concentrations of noble gases, iodine and longlived nuclides in the form of particulates will be 2.1 microcurie/m^3 (at 1.8 km SW), 21 picocurie/m^3 (at 1.8 km SW) and 22 picocurie/m^3 (at 1.8 SW) respectively (**Figures 3.1.4 - 3.1.6**). In winter season, the maximum concentrations of noble gases, iodine and longlived nuclides in the form of particulates are predicted to be 1.7 microcurie/m^3 (at 1.6 km W), 22 picocurie/m^3 (at 1.6 km W) and 24 picocurie/m^3 (at 1.6 km W) respectively (**Figures 3.1.7 - 3.1.9**).

Isopleths showing GLCs of the radionuclides are presented in **Figures 3.1.1 - 3.1.9**. It is expected that annual dose of inert radioactive noble gases, iodine and long-lived nuclides in the from of particulates will be well below the stipulated standards.

3.1.6 Conventional Air Pollution

As such, there is no possibility of conventional air pollution emissions from nuclear power plants except during construction phase. Hence, the impacts of the proposed nuclear power plant on ambient air quality due to conventional air pollutants in that region will be insignificant. There will be marginal increase in conventional air pollutants levels due to increase in vehicular traffic and urbanization which can be attributed to indirect impacts of the project in that region. However, these concentrations shall be within the prescribed limits of CPCB as the proposed nuclear power project is not the source of conventional air pollution and present levels of conventional air pollutants are very low.

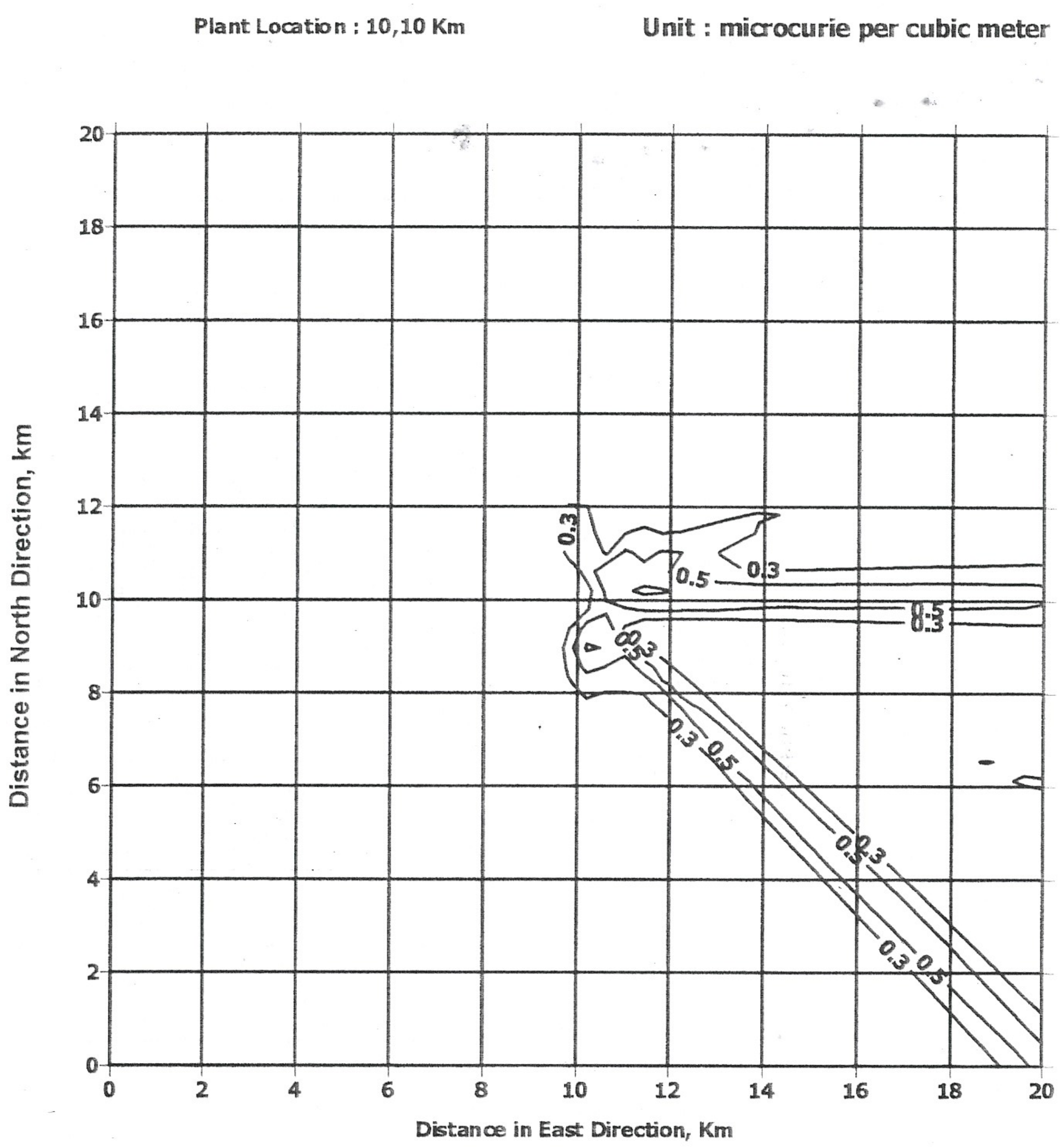


Fig 3.1.1: Predicted GLCs of Inert Radioactive Gas in Summer Season

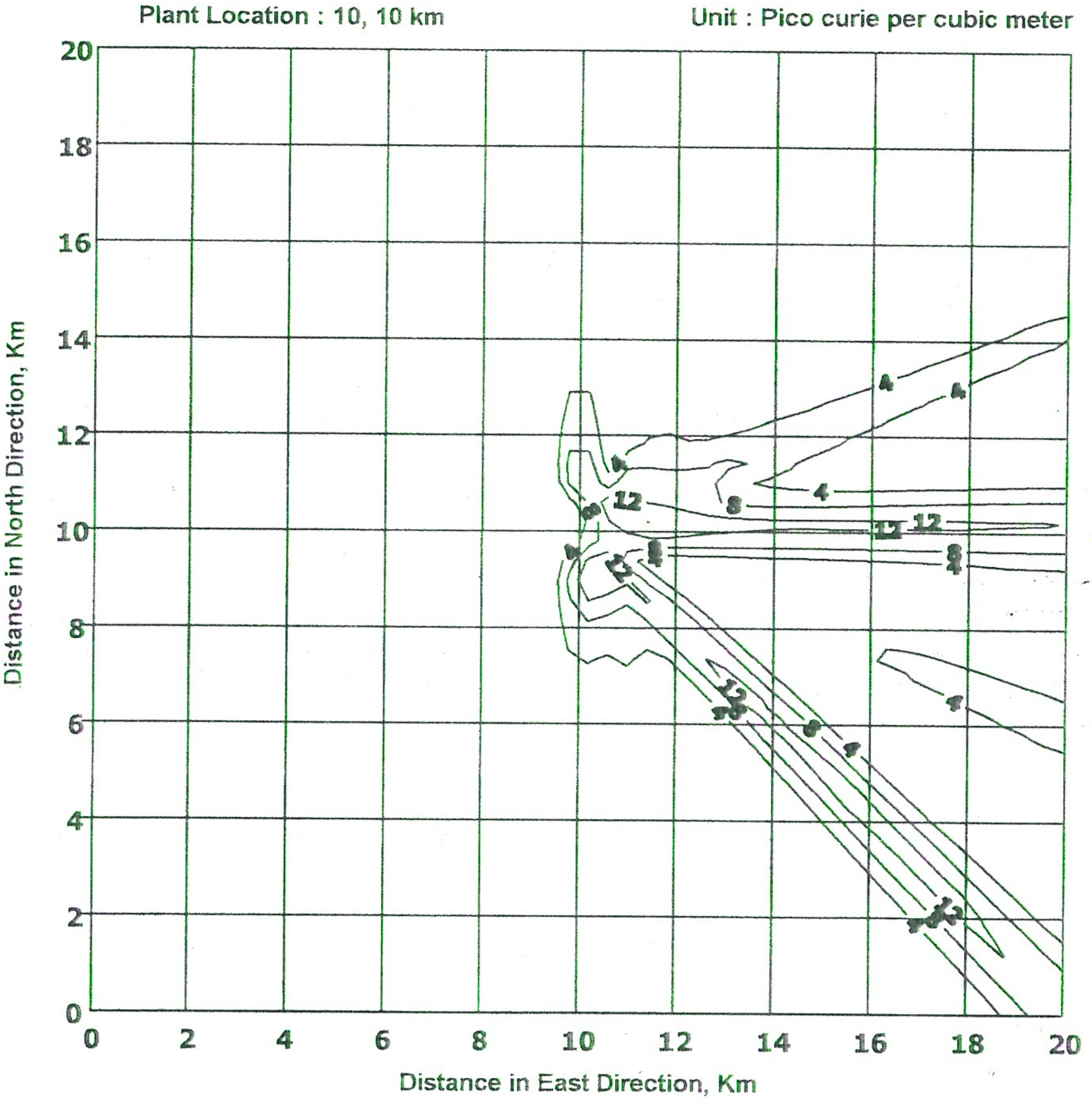


Fig. 3.1.2: Predicted GLCs of Iodine 131 in Summer Season

Plant Location : 10, 10 km

Unit : Pico curie per cubic meter

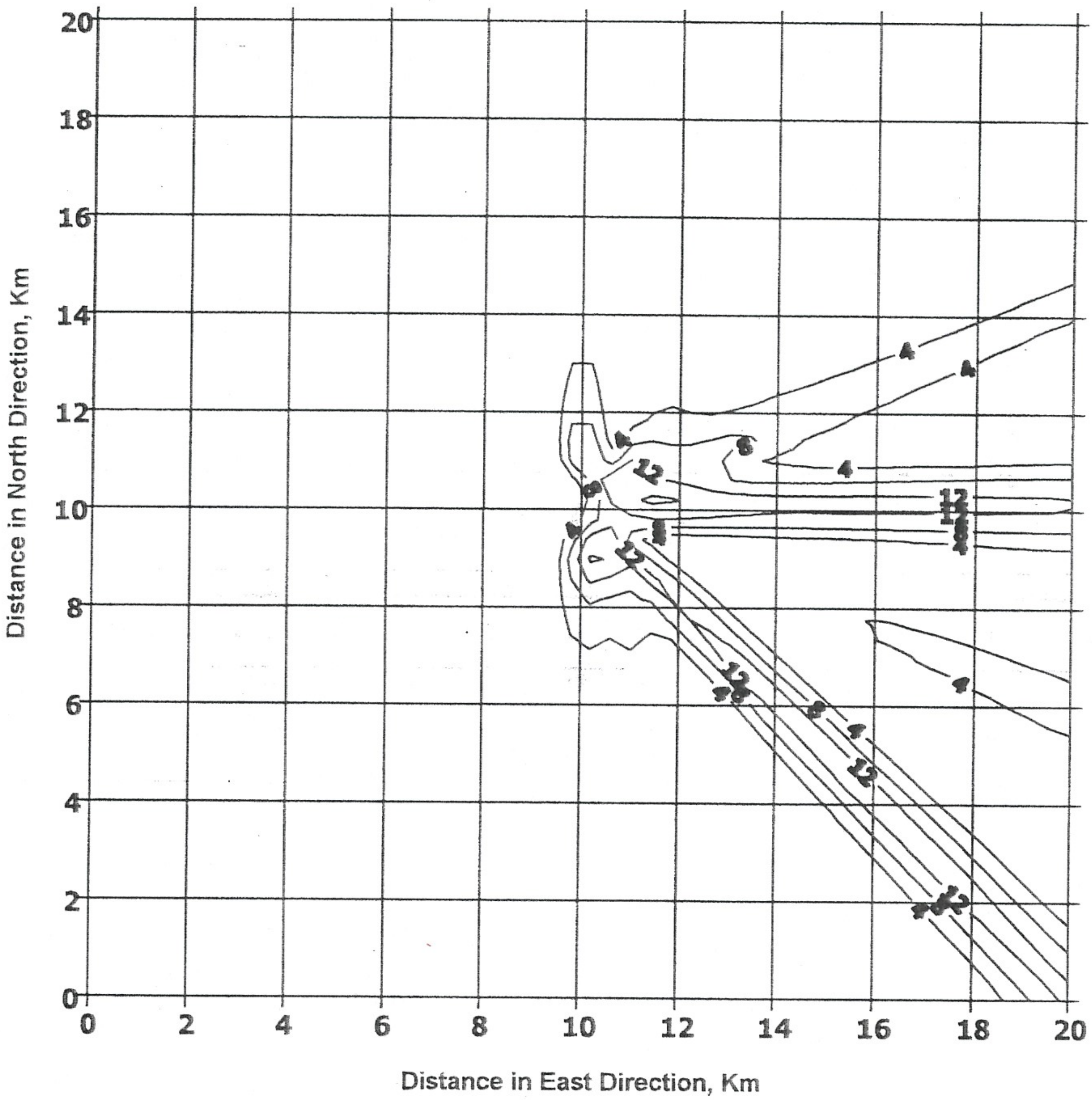


Fig. 3.1.3: Predicted GLCs of Mix of Longlived Nuclides in Summer Season

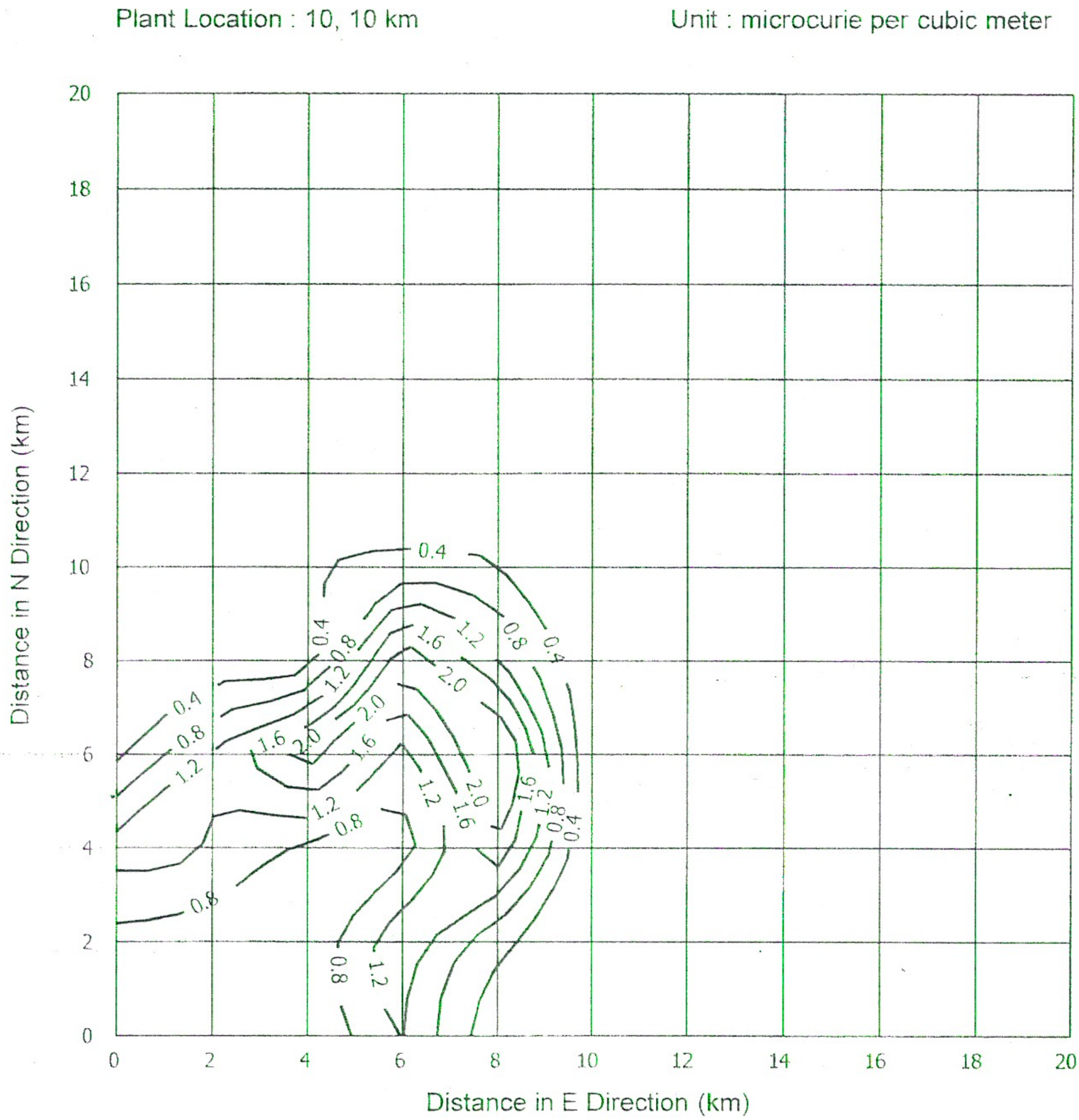


Fig. 3.1.4: Predicted GLCs of Inert Radioactive Gas in Post-Monsoon Season

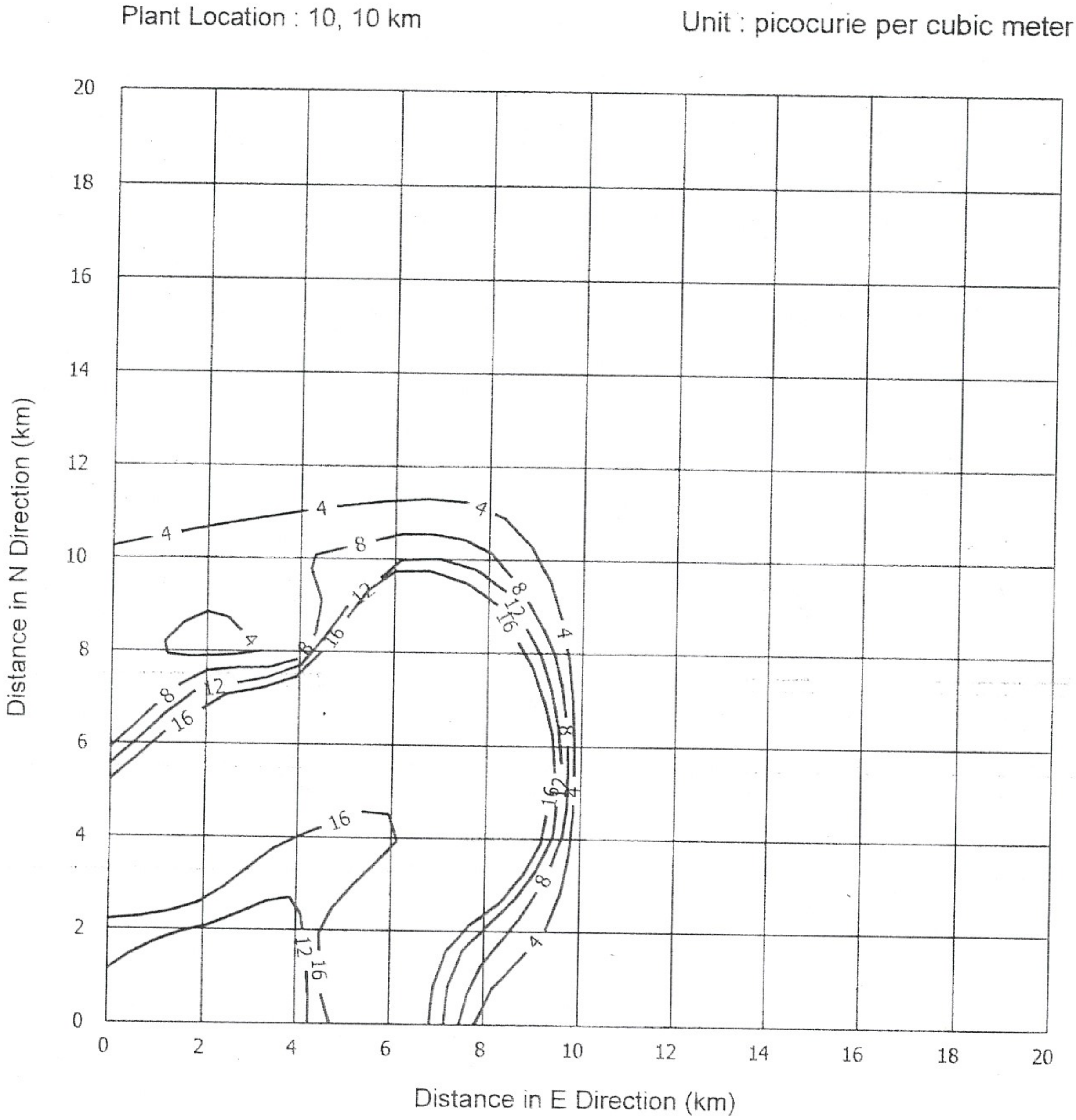


Fig. 3.1.5: Predicted GLCs of Iodine 131 in Post-Monsoon Season

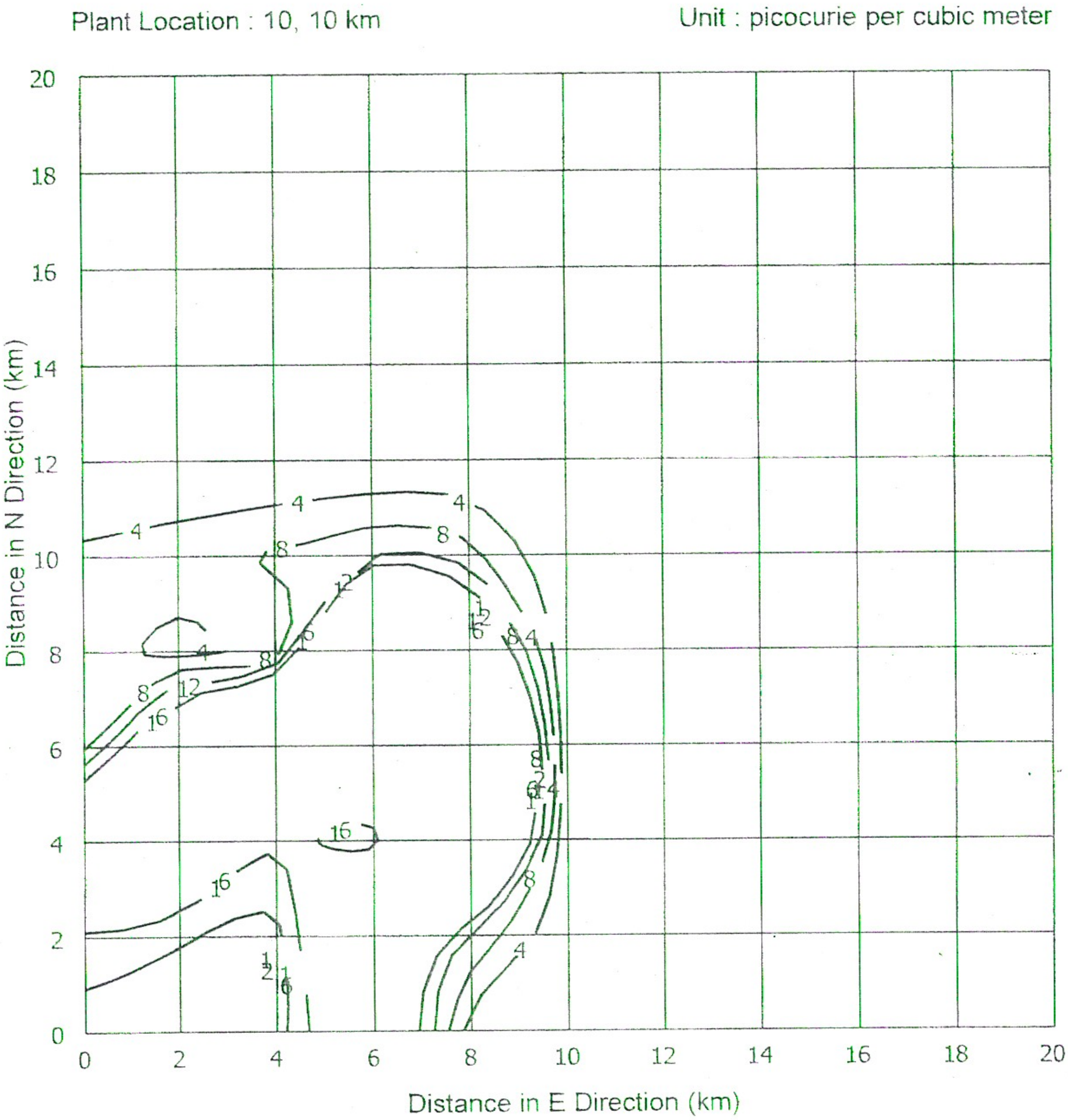


Fig. 3.1.6: Predicted GLCs of Mix of Longlived Nuclides in Post-Monsoon Season

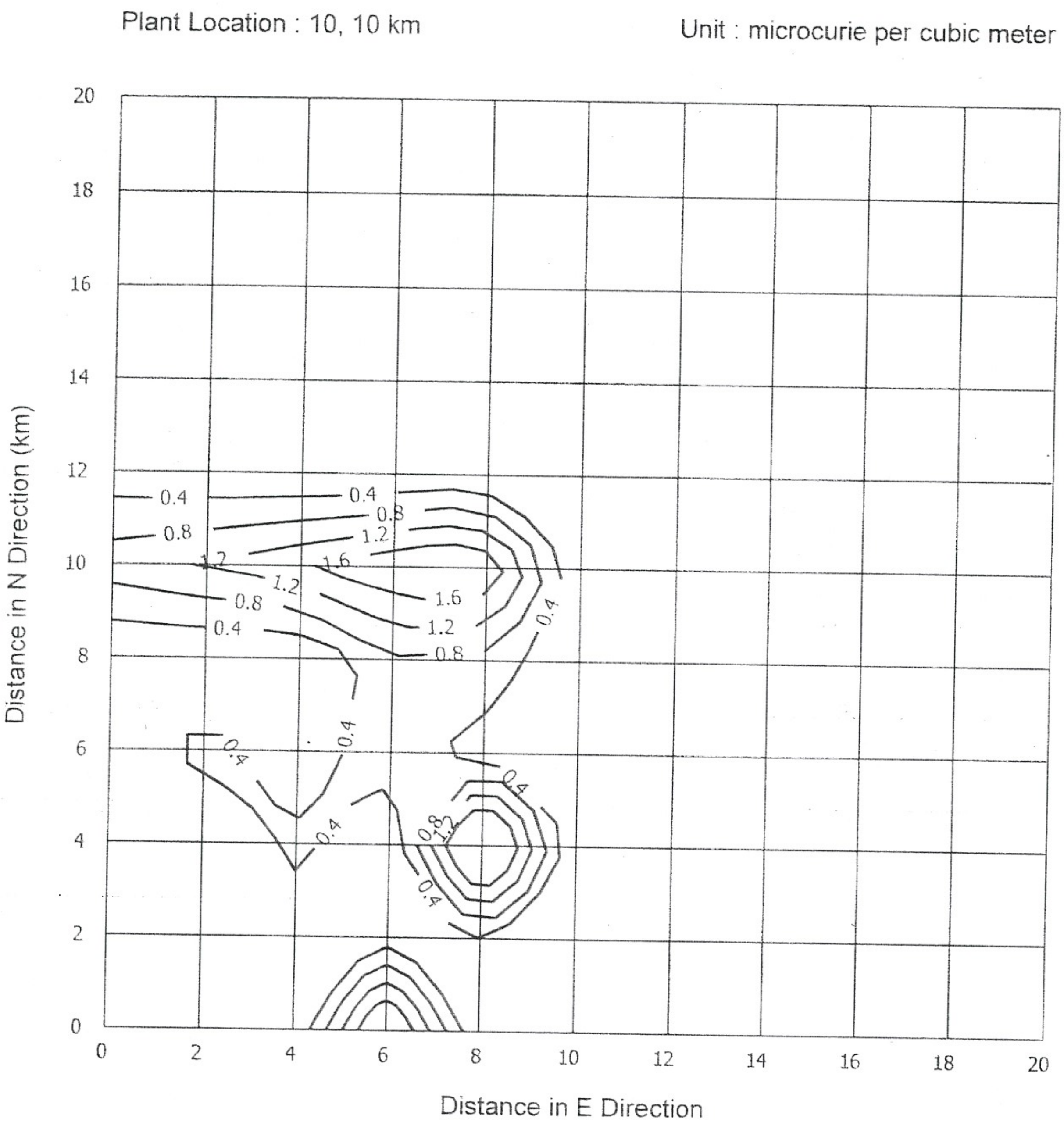


Fig. 3.1.7: Predicted GLCs of Inert Radioactive Gas in Winter Season

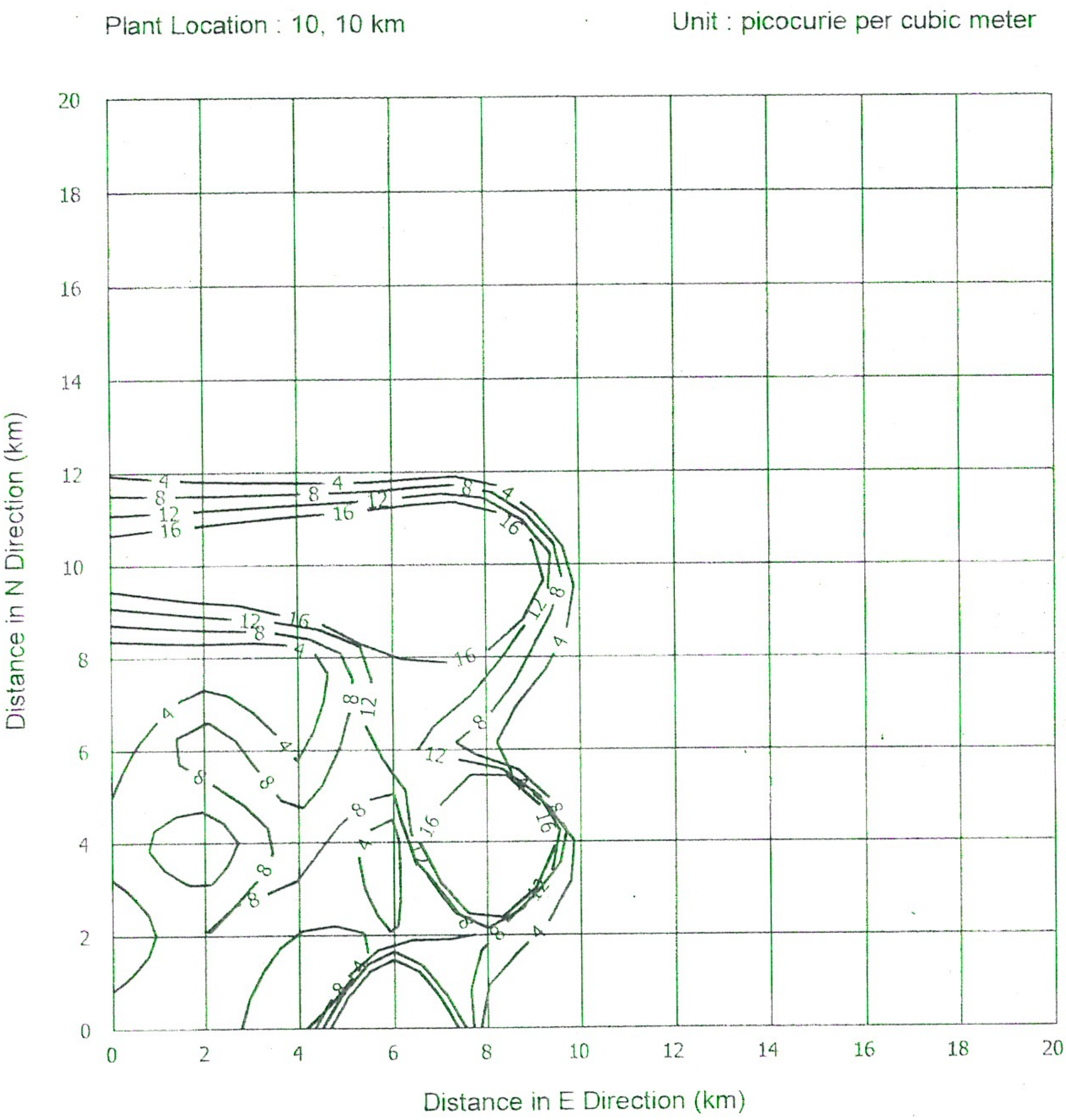


Fig. 3.1.8: Predicted GLCs of Iodine 131 in Winter Season

Plant Location : 10, 10

Unit : picocurie per cubic meter

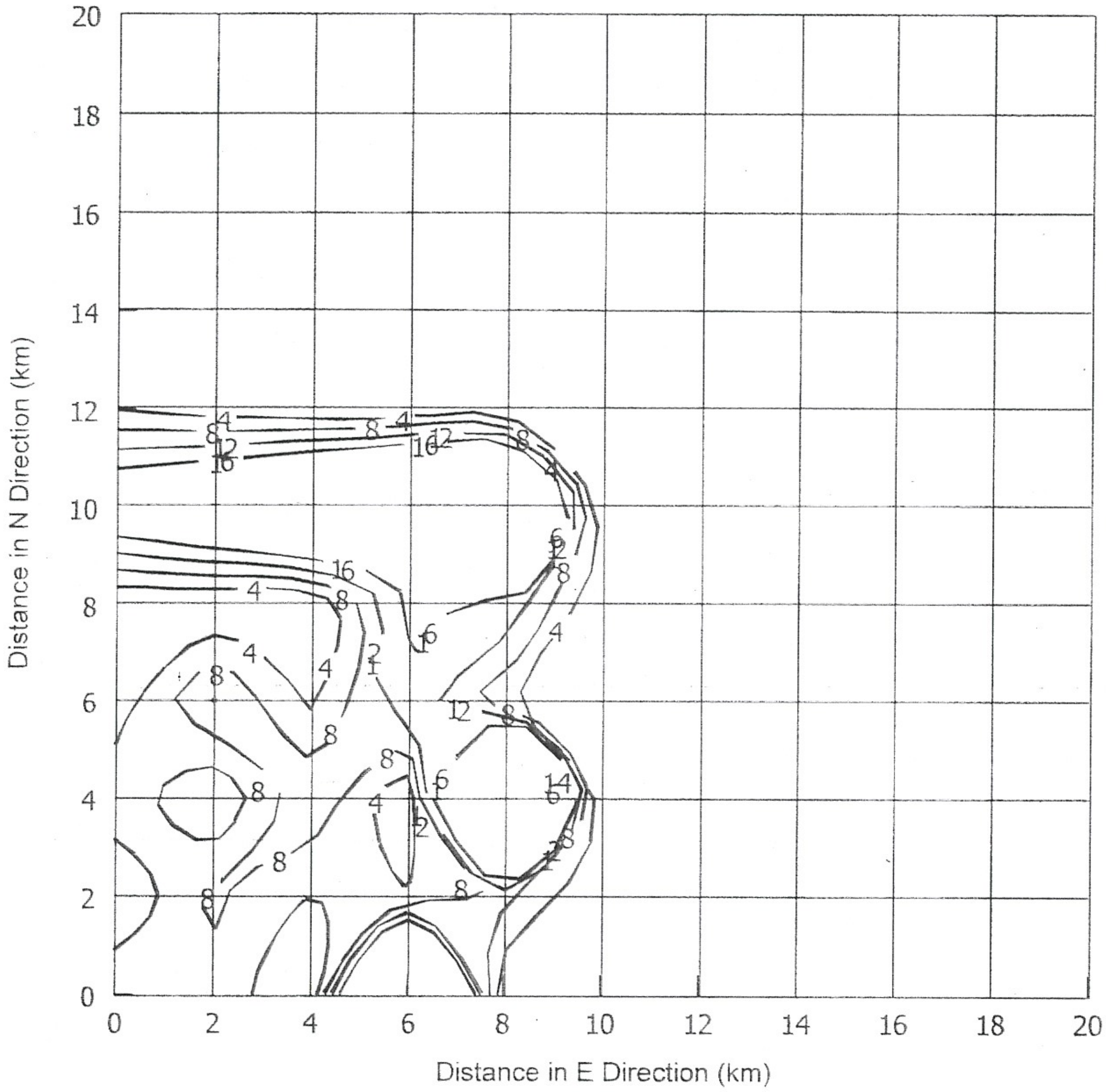


Fig. 3.1.9: Predicted GLCs of Mix of Longlived Nuclides in Winter Season

Table 3.1.1

Gas-aerosol Ejection from one Unit of KK Nuclear Power Plant

Radionuclides	Rated values of gas-aerosol releases into ventilation stack
Fission Product Noble Gases	1.14×10^{10} Bq/day
I^{131}	2.48×10^{5} Bq/day
Long lived Particulate Matter	2.62×10^{5} Bq/day
Sr^{90}	2.03×10^{1} Bq/month
Sr^{89}	4.68×10^{3} Bq/month
Cs^{137}	2.41×10^{5} Bq/month
Co^{60}	1.44×10^{4} Bq/month
Mn^{54}	2.72×10^{3} Bq/month
Cr^{51}	3.96×10^{3} Bq/month

Table : 3.1.2

Meteorological Data used for Air Quality Modelling
(Summer Season)

Hour	Wind Direction	Wind Speed (m/sec)	Temperature (°K)	Stability Class	Mixing Height (m)
1	315.0	1.9	302.1	6	-
2	292.5	1.6	301.6	6	-
3	315.0	1.8	301.4	6	-
4	270.0	2.1	301.6	5	-
5	247.5	2.3	301.2	5	-
6	292.5	1.6	300.9	5	
7	270.0	2.5	301.0	4	450.0
8	315.0	2.7	302.4	3	500.0
9	270.0	2.8	305.1	2	600.0
10	292.5	2.4	305.9	2	850.0
11	270.0	2.6	307.0	2	1000.0
12	315.0	2.8	306.9	1	1200.0
13	247.5	3.0	306.4	1	1300.0
14	225.0	2.8	305.1	2	1050.0
15	225.0	2.5	305.0	2	1000.0
16	247.5	2.4	304.4	3	850.0
17	270.0	2.6	304.1	3	700.0
18	315.0	2.3	304.7	4	600.0
19	315.0	2.4	303.7	5	-
20	315.0	2.2	302.7	5	-
21	292.5	2.1	302.4	6	-
22	270.0	1.6	301.5	5	-
23	247.5	1.9	301.9	6	-
24	292.5	2.0	301.4	5	-

Table : 3.1.3

Meteorological Data used for Air Quality Modelling (Post-monsoon Season)

Hour	Wind Direction	Wind Speed (m/sec)	Temperature (°K)	Stability Class	Mixing Height (m)
1	040.0	5.0	300.1	5	295
2	018.0	4.8	299.2	5	225
3	026.0	5.4	298.9	4	175
4	026.0	6.0	298.8	4	150
5	026.0	6.4	298.7	4	163
6	020.0	6.6	298.6	4	212
7	017.0	6.1	298.6	4	369
8	021.0	6.9	299.4	4	563
9	032.0	7.9	300.9	3	700
10	035.0	7.6	302.3	4	819
11	045.0	7.8	303.5	4	888
12	052.0	8.0	304.8	4	912
13	087.0	9.2	305.0	4	900
14	084.0	9.9	304.1	4	875
15	061.0	10.5	304.1	3	830
16	068.0	10.9	304.1	4	775
17	081.0	9.2	303.4	4	712
18	047.0	8.1	303.2	4	638
19	055.0	6.1	302.5	4	563
20	058.0	5.7	301.8	4	469
21	055.0	5.4	301.6	4	388
22	061.0	5.8	301.3	4	338
23	061.0	6.8	301.0	4	306
24	062.0	6.8	300.6	4	288

Table : 3.1.4

Meteorological Data used for Air Quality Modelling
(Winter Season)

Hour	Wind Direction	Wind Speed (m/sec)	Temperature (°K)	Stability Class	Mixing Height (m)
1	22.0	3.5	298.3	5	193
2	19.0	4.2	298.3	5	113
3	21.0	4.4	298.3	5	100
4	22.0	5.1	298.2	5	107
5	21.0	5.4	298.0	5	100
6	18.0	5.1	298.0	5	100
7	17.0	5.1	297.9	5	107
8	24.0	5.1	298.4	4	240
9	20.0	6.0	299.9	3	440
10	28.0	6.8	301.0	4	753
11	33.0	6.8	301.9	4	102
12	42.0	6.7	302.8	4	125
13	62.0	7.4	303.1	4	140
14	90.0	8.8	302.9	4	140
15	95.0	9.1	302.4	3	130
16	93.0	9.2	302.0	4	110
17	80.0	8.4	301.3	4	806
18	74.0	6.3	300.7	4	694
19	57.0	5.0	300.4	4	595
20	40.0	3.9	299.9	3	480
21	21.0	3.4	299.3	3	367
22	20.0	3.6	299.0	5	253
23	19.0	3.9	298.9	5	140

3.2 Noise Environment

3.2.1 Impacts due to Stationary Noise Sources

The cumulative noise level at a particular location within the study area due to noise source, can be computed by using Wave Divergence Model as given below :

$$L_{p2} = L_{p1} - 20 \log (r_2/r_1) - Ae_{1,2}$$

where,

L_{p2} and L_{p1} are the noise levels at the distances r_2 and r_1 respectively from the source and $Ae_{1,2}$ is the excess attenuation along the path r_2-r_1 due to environmental absorption, scattering and other shielding effects. In the present case, excess attenuation was not considered.

Total noise level Lp (Total) due to all sources can be determined as follows:

$$Lp(Total) = 10 \log (10^{Lpa/10} + 10^{Lpb/10} + 10^{Lpc/10} + \text{--------})$$

where,

Lpa, Lpb, Lpc, are the noise levels at a sampling point due to sources A, B, C, etc.

The above mentioned model was used for predicting increase in noise levels due to proposed nuclear power plant.

The major noise generating units in a nuclear power plant are turbine, diesel generators, air compressors, cooling water pump, deaerator, intake ventilator and exhaust ventilator as given in **Table 2.2.2**. These noise-generating sources will be housed in independent buildings with concrete walls. Noise will be continuously generated from such sources. The noise emitting from each individual source will be of the order of 89-98 dBA.

It is predicted that the contribution from above mentioned sources to the nearest part of boundary wall located at a distance of 500 m will be 46 dBA. It is also predicted that the contribution from these sources at 1000 m distance will be 42 dBA over the background noise levels. The contribution to background noise levels in the nearest village located at a distance of 2 km will be in the range of 22-26 dBA. Therefore, there will be no significant change in background noise levels. The noise level contours due to the noise sources in the proposed nuclear power plant are shown in **Figures 3.2.1 to 3.2.3**.

Considering the excess attenuation due to walls as noise sources will be housed in independent buildings, the noise levels will be 30 dBA at 500 m and 1000 m respectively.

3.2.2 Impact on Community

Equivalent noise levels for day-night are often used to describe community noise exposures. The Leq (day) and Leq (night) calculated for these areas is generally found to be well within the prescribed limits promulgated by CPCB for different types of landuse.

There will not be any significant direct impact of noise due to proposed nuclear power plant on the human settlements around it as the contribution from the proposed sources will be only in the range of 25-30 dBA.

Equivalent Noise Levels

Ldn was also computed for the villages surrounding the project site (**Table 3.2.1**). The levels were found to be in the range of 47 - 64 dBA, which exceed at a few places. This is characterized by local activities. Hence, the proposed two units of the nuclear power plant will not have any significant impact on the surrounding population.

The ambient noise levels in the nearby villages will not increase during the operation of the plant as the noise is expected to be attenuated due to several in-plant measures and greenbelt development as planned by NPCIL. There would be no adverse impact due to the operation of the plant (Units 1 & 2) on the residents in the nearby villages.

3.2.3 Impact on Occupational Health

Equivalent sound pressure level averaged over 8 hours, Leq. (8 hrs) is used to describe exposure to noise in work places. The damage risk criteria for hearing, as enforced by OSHA (Occupational Safety and Health Administration) stipulates that the noise levels upto 90 dBA are acceptable for eight hour exposure per day. Ministry of Labour, Government of India also has recommended similar criterion vide factories Act, Schedule No. XXIV (Government Notification FAC/1086/CR-9/Lab-4 dated 8-2-1988).

In the nuclear power plant premises, most of the machinery/equipment would generate noise levels within the range of 90-98 dBA continuously. Adequate protective measures such as ear muffs/ear plugs to the workers working in high noise areas should be provided by NPCIL to minimize occupational exposure of noise.

The exposure of high noise levels to plant workers and operators is expected to be within the stipulated standards of OSHA and CPCB i.e. 90 dBA for 8 hours exposure. It is necessary to provide operator's cabin with acoustic insulation and provided with special doors and observation windows which will further reduce noise exposure.

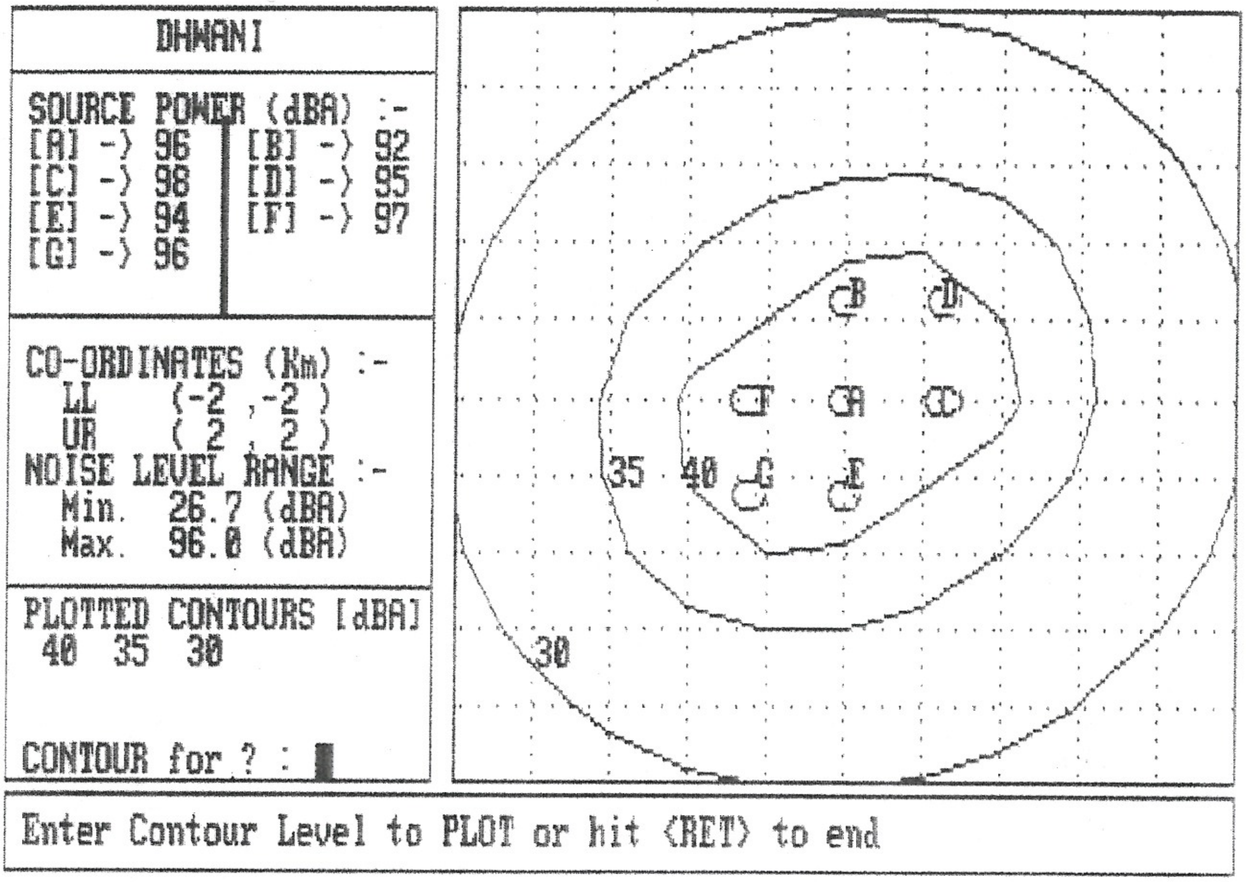


Fig 3.2.1: Predicted Noise Levels due to Noise Sources in the Proposed Nuclear Power Plant (First Set of Monitoring)

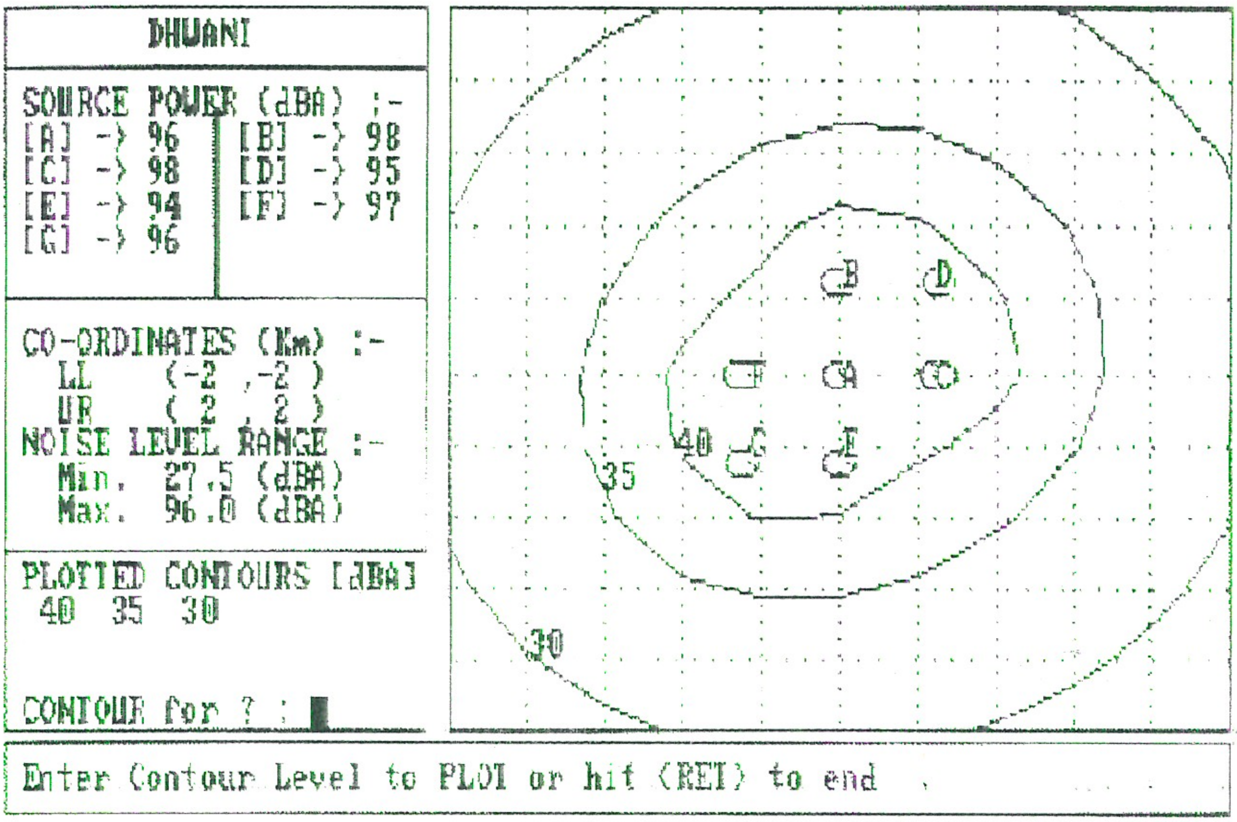


Fig. 3.2.2: Predicted Noise Levels due to Noise Sources in the Proposed Nuclear Power Plant (Second Set of Monitoring)

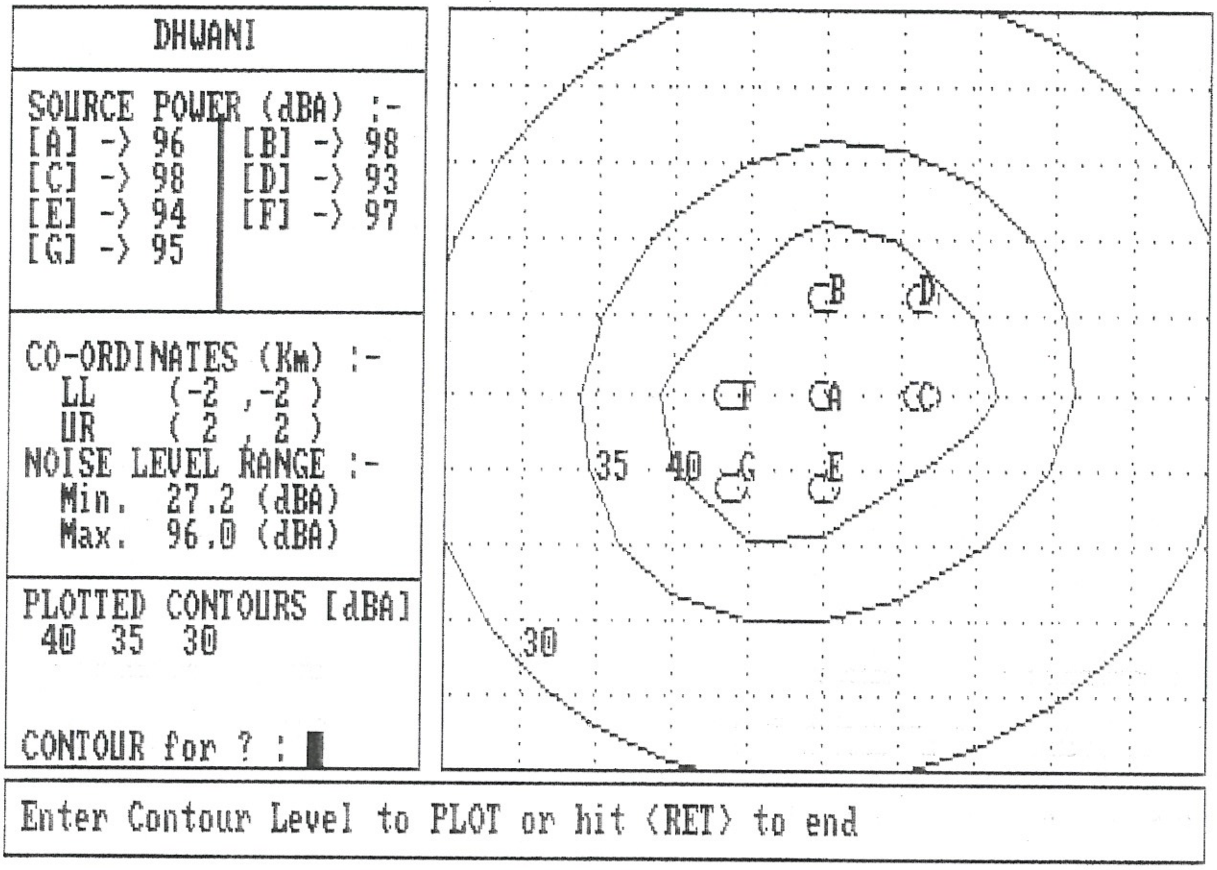


Fig. 3.2.3: Predicted Noise Levels due to Noise Sources in the Proposed Nuclear Power Plant (Third Set of Monitoring)

Table 3.2.1

Day and Night Noise Levels (Ldn) in Surrounding Villages of the NPP

Sr. No.	Location	Post-monsoon season	Winter season	Distance w. r. t. Project site (km)
		Ldn (dBA)		
1	Kudankulam	64	62	-
2	Vijayapathy	57	55	6.1
3	Erukkanthorai	60	58	6.6
4	Chettikulam	-	53	8.8
5	Udayathur	57	57	9.0
6	Radhapuram	62	62	11.2
7	Thiruvambalapuram	55	52	12.4
8	Dhankkarkulam	52	52	9.9
9	Uramangulam	60	56	18.0
10	Ovari	57	78	23.6
11	Nagarcoil	78	75	29.6
12	Kanyakumari	67	66	18.7
13	Perungudi	47	49	15.9
14	Aramboli	75	80	23.6
15	Madapuram	52	52	22.6
16	Kumbikulam	52	52	18.8
17	Thazhakudi	57	-	27.2
18	Chadayameri	47	52	28.6
19	Mahadevankulam	49	52	26.4
20	Kottakarumangalam	52	47	20.2
21	Appuvilai	52	52	25.2
22	Veppilankulam	47	47	15.0
23	Soundarmadiyapuram	52	49	17.7
24	Dhalapathisamudram	47	61	29.9
25	Pamagodi	47	54	21.2
26	Kadukkarai	47	55	29.0
27	Tadakamalai	57	52	25.9
28	Palavur	52	49	13.3
29	Levengipuram	52	52	13.8
30	Kottaram	47	57	20.0
31	Thersor	52	-	25.1
32	Bhutapandi	52	47	30.0
33	Marangoor	47	52	21.4
34	Vadasary	57	61	27.1
35	Vadakku Valliyur	54	49	25.5
36	Azhagappapuram	-	51	17.6
37	Anaikarai	-	52	20.0
38	Agasteeswaram	-	55	20.5
39	Therku Valliyur	-	52	20.9
40	Suchindram	-	78	25.0
41	Theroor	-	52	25.5
42	Thamaraikulam	-	55	27.1
43	Thalakudi	-	57	27.4
44	Parakkai	-	47	27.4

3.3 Water Environment

Impacts due to construction activities would be of short term nature for which the control measures as delineated in EMP would be adequate for minimizing them. However, the operational phase of the nuclear power plant would pose long term adverse impacts due to radioactive pollutants generated through the water route. Although the NPCIL would be meeting the stringent requirements of ICRP and AERB, the impact of radioactive water pollutants, in case of accidental releases, on aquatic biota and members of the public can not be ruled out. However, the environmental radioactive surveillance programme as indicated in EMP chapter, if followed scrupulously, these impacts can be easily mitigated by adopting timely control measures.

The other impact area of concern to the marine environment is due to discharge of condenser cooling waters into the sea and its consequent adverse impact on marine aquatic life. NPCIL has planned the control measures for implementing the same during operational phase of the project so as to control the temperature of receiving sea water which will not rise by more than 7°C in any case. However, this needs to be monitored on continuous basis by NPCIL.

As regards the domestic sewage to be generated from the township, offices and canteen, NPCIL has planned to treat the sewage so as to meet the requirements of TNPCB. The treated sewage is proposed to be reused for development of greenbelt and raising plantations in and around the proposed units 1 & 2 of the NPP. Therefore, the impact of domestic effluents on water resources of the region would be insignificant.

3.4 Land Environment

The area under consideration is a coastal track at an elevation of +3 to +45 m above MSL forming southern fringe of soil. The topography of site is such that it has slopes towards the sea. The proposed site is on east coast of southern part of Indian Peninsula and is rich in monazite deposits, which are known to be thorium bearing minerals. The distribution of monazite and its impacts on background radiation levels in soils formed the basis for radiation survey in this region. The natural radioactivity levels measured by scintilla meter showed spectra of thorium and its daughter products. The existing environmental radiation activity levels are not expected to change due to reactor operation of the proposed Nuclear Power Plant because of proper management of hazardous wastes likely to be generated. The existing non-uniform radiation dose profile as indicated in baseline data is expected to remain unchanged due to the operation of the proposed power plant.

Rainwater precipitation of the atmospheric radioactivity increases the levels in soil. Kudankulam being a low rainfall area will not contribute to fallout radioactivity in the soils and terrestrial biota.

The effect of radiations exposures for various pathways have been studied worldwide. The data collected on radiation levels for soil environment indicates that it will not have any impact on vegetation grown in such soil due to negligible emissions from proposed nuclear plant. Greenbelt development around project site of proposed NPP using conventional method may add to mitigate dust and gaseous concentrations in inhabited area.

3.5 Biological Environment

The Gulf of manner is rich in biological diversity and is required to be protected from the adverse impacts due to the discharges of nuclear power plant operations. Hence, the control measures as outlined in EMP as also continuous monitoring of liquid effluents, if not adopted and implemented appropriately, may impose adverse impacts on the marine biota. However, NPCIL would be taking due care to meet the stringent standards of AERB and ICRP, which may not impose significant adverse impacts on the marine environment.

As regards the terrestrial ecosystem, NPCIL has been suggested to raise the plantations and develop greenbelt in and around the project site. If these are implemented, it should help in increasing the green cover of the area.

3.6 Socio-economic Environment

Setting up of 2 units of the nuclear power plant (unit 1 & 2) within area would create certain impacts with beneficial as well as adverse effects on the socio-economic environment. Some of these impacts would be more effective for the immediate vicinity with short term effects whereas the others would be of higher order or of long term in nature.

It is necessary to identify the extent of these impacts for further planning of control measures leading to mitigation of the adverse impacts.

The impacts of NPP (units 1 & 2) on parameters of human interest have been assessed in terms of :

- The impact due to acquisition of land needed to set up the plant buildings and other support facilities

- The potential impacts due to unavoidable releases radioactive of pollutants from the power plant reaching to the public domain.

Beneficial Impacts

The impacts identified as beneficial support the existing project activities. They are:

- Job opportunities for the local people as well as for those from the nearby surrounding area would increase due to operation and construction of 2 units of the Nuclear Power Plant

- Due to influx of population, the trade, business opportunity for the local people would increase, raising the economic status of the people around

- Establishment of township as well as the influx of working people within the study area would lead to favourable changes in the existing infrastructure facilities, which may further improve the quality of life of the study concerned area

- There would be local participation in supply of materials and services for construction of township and other infrastructure such as access roads, pier, and fresh water pipeline and warehouses

- The proposed 2 units of the NPP, at Kundankulam, would help partially in bridging the gap between the demand and inadequate supply of electricity within the country in general, and the region in particular

- The electricity generated by the two units of the NPP will result in electrification of villages, development of irrigation facilities, drinking water supply, development of industries etc.

- Due to proposed 2 units of the nuclear power plant there would be an overall development of the area and job opportunities, which may improve the quality of life of the area.

Adverse Impacts

The impact identified as adverse would go against the project activities. These impacts can be minimized by proper follow up of an Environmental Management Plan. These impacts are :

- Influx of workers during the project construction and operation phases would impose some strain on the existing basic amenities within the study area.
- The project activities may disturb the fishing activity, if appropriate measures for liquid waste management are not taken as per EMP.
- For meeting various demands in the power plant, fresh water would be drawn from 'Pechiparai dam', which may affect the drinking water & agricultural needs of the local population. However the impacts may be insignificant

It is anticipated that the adverse impacts on parameters of human interest could be mitigated by proper fallow-up of the measures indicated in the Environmental Management Plan.

Chapter 4

Environmental Impact Statement

Chapter 4

Environmental Impact Statement

Based on the field environmental quality data collected for summer, post-monsoon and winter seasons within the study area as also the prediction of impacts, an Impact statement has been prepared indicating the impact areas under pre-operational and operational phases of the proposed units 1 & 2 of the nuclear power project at Kudankulam. Componentwise statement is furnished hereunder.

4.1 Air Environment

As far as conventional air pollutants are concerned viz. SPM, RSPM, SO_2 and NOx, their concentrations in the ambient air during three seasons were observed to be well within the prescribed limits. However, with the rapid progress in construction activities of the project, concentrations of these air pollutants are expected to increase. Since the existing levels of conventional air pollutants are less, the incremental increase in the levels of these pollutants may not be crossing their respective prescribed limits. However, proper follow-up of measures outlined in EMP will help in mitigating the adverse impacts, if any.

As regards the radioactive air pollutants, appropriate measures are expected to be taken by NPCIL in controlling these pollutants and these should form an integral part of project planning and implementation so as to avoid adverse environmental impacts, particularly on human, plant and animal life.

4.2 Noise Environment

Over a period of time, there have been changes in local activities within the study area and as a result the noise levels have increased as was observed during field measurements during three sets of monitoring. However existing noise levels in surrounding villages are not on much higher side. With the rapid progress in construction activities, the baseline noise levels will increase due to heavy earthmoving machineries and construction equipments as also due to the movement of trucks deployed for material handling. However, increase in ambient noise levels will be for the duration of construction activities only.

With the commissioning of nuclear power reactors (units 1 and 2), noise would be generated by compressors, turbines, fans, pumps, air dryers and ventilators.. If proper preventive and control measures are not taken, the baseline noise levels are expected to increase. However, the greenbelt development within and around the plant premises would help in attenuating noise to certain extent.

4.3 Water Environment

The baseline data on water quality of groundwater sources during three seasons indicate pollution of these resources due to anthropogenic activities of the surrounding population. Some of the well waters have been detected positive for faecal contamination due to absence of sanitation facilities and land disposal of domestic sewage. Due to this, adverse impacts are imposed on groundwater sources and marine waters.

During construction, waste materials and spillages of oils etc. would contribute to certain amount of water pollution. But these would be for a short duration. This requires follow-up of control measures during construction to protect the water resources from occurrence of adverse impacts.

The operational phase of the NPP is expected to generate radioactive as well as non-radio active water pollutants. NPCIL has already prepared comprehensive plans for liquid waste and gaseous waste management which are required to be scrupelously followed. The other impact area of concern would be thermal pollution due to discharge of heated waters from once through cooling water system. Due attention is required to be given to this aspect so that the resultant rise in the temperature of marine water does not go beyond $7^{O}C$ or so which is also one of the requirements of State PCB and MoEF. In view of the adverse impacts due to thermal discharges on aquatic flora & fauna, this needs to be viewed critically while implementing control measures.

4.4 Land Environment

Adverse impacts would be felt on land use pattern and topographical features of the area due to construction of NPP at Kudankulam. During operational phase, soils may get exposed to radionuclides which will travel through food chain and may cause problems to living beings including animals within the impact zone. With the implementation of control measures for liquid and gaseous radioactive pollutants as also solid radio-active wastes, the levels of these radionuclides are expected to be well within the limits as prescribed by the concerned regulatory authorities and under normal operating conditions, there may not be any significant impact on the land environment. In case of unforeseen accidents, radionuclides in excessive concentrations are likely to be generated. This warrants proper planning to handle emergency situations. The greenbelt development suggested in EMP, if implemented by NPCIL, would help to adsorb most to the particulate radionuclides. These measures are expected to generate insignificant adverse impacts on land environment.

4.5 Biological Environment

The project site at Kundankulam and the surrounding area in Tirunelveli District has plain land with dry climate. The whole area has cultivated fields and barren fields were observed to be occupied by scrub vegetation. The forests and fairly dense vegetation is mostly present in Kanyakumari District. Therefore, the proposed 2 units of the NPP at Kundakulum may not adversely affect the existing green cover in the area, on the contrary, the plantations, which would be grown in the plant area, and residential area will be helpful in increasing green cover in the area.

The discharge of the radioactive liquid wastes from the proposed 2 units of the nuclear power plant in the marine water, if not adequately treated, may deteriorate the quality of marine water and affect the biodiversity of flora and fauna in the Gulf of Mannar. The Gulf of Mannar is rich in marine biodiversity and the discharges from the proposed 2 units of the NPP should not adversely affect the biodiversity, commercial fishery and clean sand beaches.

4.6 Aesthetics

Aesthetic environment of the whole area is very good and it will not be affected adversely due to the proposed activity. Topographical features, however, will be affected due to the construction of structures. Water, air and land aesthetics will show improvement.

4.7 Socio-economic Environment

An increase in the energy input is expected due to the proposed activity leading to cheap availability of electricity and with little pollution load compared to any other power generating source. This proposed activity (units 1 & 2), will contribute to creation of job opportunity. Education and transportation facilities will also improve.

Human health is likely to be affected due to the total radiation doses received through different routes viz. air water, land. The total dose will be kept below the permissible limit.

Chapter 5

Environmental Management Plan

Chapter 5

Environmental Management Plan

Based on the three seasons monitoring for different environmental components within the impact zone, identification and prediction of potential impacts due to installation and commissioning of the units 1 & 2 of the NPP at Kudankulam, appropriate strategies have been formulated for minimizing the adverse impacts and enhancement of beneficial impacts. These have been presented in the form of an Environmental Management Plan under two separate phases i.e. construction phase & operational phase. It is necessary for NPCIL to encompass these control measures in the planning and implementation of proposed units 1 & 2 of the NPP. The componentwise EMP is presented herewith.

Recommendation on Earthquake Design Basis for the Proposed NPP, Kudankulam

In view of the importance of seismic aspects in the design and construction of a nuclear power plant it is necessary that the recommendations contained in the report "Earthquake Design Basis for Kudankulam Site" prepared by Mr. A.K. Ghosh and Mr. D.C. Banarjee must be followed by NPCIL for Safety of the structures.

Due consideration should be given to the water retaining structures which will be built around the project site. This is necessary to account for induced seismicity and the consequences of dam failure on the safety of proposed nuclear power plant. The effect due to the nearest existing dam at Pechiparai is implicitely taken care of since the events postulated in the abovementioned report for SSE cater to earthquakes at shorter distances from the site of proposed nuclear power plant at Kudankulam.

5.1 Construction Phase

The construction of units 1&2, at Kudankulam is yet to commence and construction of ancillary buildings etc. is in progress. Hence, environmental management plan for this phase has been recommended.

The potential for environmental pollution during construction phase is considerably less than when the reactors are in operation. However, control of environmental pollution during construction is of considerable importance. Wherever applicable, detailed procedures should be developed for control of pollution during the project execution phase. Following aspects require control during the construction phase.

5.1.1 Site Preparation

During construction substantial quantity of soil and rock will be produced requiring stock piling and back filling. All the disturbed land should be stabilized. During dry weather condition, it is necessary to control the dust nuisance created by the excavation, leveling and transportation activities. The top soil containing rich humus soil may be utilized for development of greenbelt development in and around the plant area.

5.1.2 Sanitation

During construction, the sites should be provided with sufficient sanitation facilities like supply of potable water and sanitary latrines for the workers to achieve proper standards of hygiene.

5.1.3 Air Environment

The engine exhausts from construction vehicles, dust and other sources of emission can affect air quality during construction phase.

It should be ensured that both gasoline and diesel powered construction vehicles are properly maintained to minimize smoke in the exhaust emissions.

5.1.4 Noise Environment

During construction phase, noise resulting from blasting operations and operation of construction machinery such as concrete mixers and heavy earth moving machineries may constitute an additional environmental stress.

On-site workers need to be provided with noise protective devices like earmuffs. The total noise effect on nearest villages during the construction stage should be as less as possible.

5.1.5 Water Environment

The stock piling of waste material generated during excavation can pose serious problems of erosion and leaching which may have impacts on aquatic system and/or ground water. Enough care need be taken by soil stabilization and providing trenches all around the stock pilings.

The vehicle maintenance area should be located in such a manner so as to prevent contamination of ground water by accidental spillage of oil. Unauthorized dumping of waste oil should be prohibited.

Care should be exercised in batch concrete plant so that the water is conserved. The water arising from washing platforms shall be collected separately and settled before its discharge.

5.1.6 Land Environment

No solid wastes during construction phase should be disposed off on land. Combustible waste should be burnt in a controlled manner. Construction must be examined with regard to the aesthetic considerations.

5.1.7 Site Security

A construction site is a potentially hazardous environment. To ensure that the local inhabitants are not exposed to these hazards, the site should be secured by fencing and manned entry points.

5.2 Operational Phase

5.2.1 Air Environment

For all practical purpose, the emissions of conventional air pollutants will be negligible during operational phase of the nuclear power plant as there will not be any direct sources related to processes at project site. However, ambient air concentration with respect to Suspended Particulate Matter (SPM) need be monitored on 24 hourly basis at minimum of four sampling stations between 1 to 5 km radial distance from the NPP (two in upwind direction and two in downwind direction) at a frequency of four samples in a month with seasonal changes in sampling locations.

The radiological pollution arising out of the nuclear power plant operations would be only from the discharge of ventilation air mainly through stack. The ventilation air of reactor building (RB) and service building (SB) of units 1&2 will be passed through High Efficiency

Particulate Absorber (HEPA) filters with 99.98% efficiency at 0.3 micron particle size, before its release in to the atmosphere. High efficiency activated charcoal filter may be used to control radio-iodine releases.

Ventilation air need be monitored on regular basis for Tritium, FPNG, radioactive iodine and active particulate matter in all ducts connected to each stack. The monitoring sensors shall be connected with the alarming system to indicate the atmospheric release levels.

The environmental surveillance programme should be adopted alongwith diagnostic studies (diagnostic studies in this context are to find out the probable reason for high concentrations in ambient air through detailed meteorological analysis and to find out sources contributing to high concentrations) and arrangements to communicate results to operating personnel for taking necessary control measures in plant operations, if needed, should be made.

NPCIL should carry out necessary studies to identify the causes for significant changes in annual external radiation dose levels as compared to those collected during pre-operational phase.

The exclusion zone (1.6 km radius) around 2 units of the NPP will be strictly fenced. In view of the existing inhabitation in sterilized zone (5 km radius), NPCIL should take precautionary measures such as adoption of proper land use plans and transport facilities for effective evacuation under emergency conditions.

During emergency conditions, although the prescribed standards for short term doses are to be maintained within exclusion zone, there may be possibility of higher radiation doses to public immediately beyond the exclusion zone. Under such circumstances, the atmospheric releases shall be controlled keeping in view the expected radiation doses to public within and around the sterilized zone.

5.2.2 Noise Environment

* All the machines should be provided with enclosures and should be maintained properly. Particular attention should be given to mufflers and silencers
* The operator's cabins should be acoustically insulated with special door and observation windows

* The operators working in high-noise area should be provided with ear-muffs/ear-plugs and they should be properly trained to use the same

* The duties of employees working in high noise area be rotated systematically to avoid occupational exposure

5.2.3 Water Environment

- **Thermal Regulation**

The thermo-regulatory behaviour is governed by various factors (other than temperature) such as availability of food, dissolved oxygen (D.O.), absence of predators and parasites, limited gas pressures and avoidance of high temperatures.

About 70% of heat produced in the nuclear power plant is discharged as unutilized heat to the aquatic environment in condenser effluents and coolant air. The heated waters will mix with the waters of the sea and rapidly discharge its heat into the sea waters. A small rise in temperatures of the sea water at outfall has been a matter of concern to the ecologists. The temperature of receiving sea water should not rise by more than $7^{0}C$ so as to protect Marine Ecology.

- **Water Quality Monitoring**

The marine water quality and ground water quality of surrounding villages should be regularly monitored for the physico-chemical parameters as stipulated by the State Pollution Control Board. In addition, the following should be carried out :

* Identification and estimates of total mass in stressed and unstressed areas for phytoplankton and zooplankton content in the Gulf of Mannar

* Determination of macrobenthos characteristics

* Controlling radioactivity releases into the sea with respect to Quantity & Quality

Wastewater

* The purpose of the liquid waste management plan is to hold, control and dispose off all active liquid effluents from the operation of the plant. A centralized effluent treatment system need be constructed to process the liquid effluents generated from both the reactors

* Holding tanks should be designed in such a manner that they can hold all liquid effluents generated both under normal and off-normal conditions. Provisions for

holding the contents of these tanks may be made in case of rupture on structural failure

* Monitoring of radioactivity in effluents should be carried out as per AERB guidelines in force from time to time. Further, the final effluent should also conform with the standards for non-radioactive parameters stipulated by the State Regulatory Board i.e. TNPCB

* The treated sewage from the colony should conform with the standards stipulated by the TNPCB and it should, preferably be reused for gardening or plantations.

5.2.4 Land Environment

5.2.4.1 Radioactive Solid Wastes

* The construction of trenches and RCC storage vaults should be supervised critically with extreme care so that the structure may not collapse in the long run.

* The embankment around the RCC trenches should be properly constructed so that during unfavourable heavy rains, it may not get washed away resulting in the spread of the wastes around the area.

* Constant vigilance of storage vaults/RCC trenches is necessary, even if the plant may not be in operation because of the possibilities of nearby groundwater sources getting polluted due to radionuclides.

5.2.4.2 Township Solid Wastes

The domestic solid waste normally constitutes about 50% organic matter. This material can be composted to yield the compost which can be used along with the chemical fertilizer in the surrounding farms. Studies carried out by various authorities have clearly shown that the yield that is obtained by using chemical fertilizers along with compost is normally more than the yield obtained by the use of chemical fertilizer alone. The progressive farmers will hence readily accept to utilize the produced compost. The quantity of the compost produced is quite small as compared to the anticipated demand and hence no problem is visualized in its sale.

Composting

As the quantities to be composted are small, the semi-mechanized method of composting will have to be used. Adequate land (4 ha) for composting will have to be identified at a low-lying site. The method of operation of the composting plant will be as given below :

The refuse vehicles coming to the compost plant would directly go to the windrow site. This will cover 0.6 ha of land with flagstone paving. The material would be directly put on the ground from where it will be turned at 5 days intervals manually or by using a front end loader. The windrow would be 2 m wide, 1 m high and 6 m long. Thus every windrow would contain about 6 tonnes of material and would be turned 4 times and at the time of final turn, it will be loaded in a trailor which would take it to a hopper. The material from below the hopper would fall on a horizontal conveyor belt where workers standing on either side of it can manually remove glass, plastics, metals etc. The material would then fall into input hopper of a size reduction unit. As the material has already undergone decomposition, it would be amenable for disintegration and the size reduction can be done now with the expenditure of lesser energy. The material after size reduction can be taken to the maturation pile where it can be stored in 2 m high windrows for a minimum period of 1 month. At the end of this period, much of the resistant organic matter would also have been degraded and the material can be conveniently applied on the farms.

The total area that will be required for this composting plant will be 1.5 ha. In addition to the plant, a building will have to be provided to house the front end loaders and other equipments.

Sanitary Landfilling

The non-compostable that will be removed from the township solid waste will have to be disposed of. Similarly, if for some reasons the composting cannot be carried out, the whole quantity will have to be landfilled. For the entire operation adequate land must be available. These materials can be disposed of by using sanitary landfilling.

In general, the process involve filling of low-lying land with refuse in such a manner as to ensure the process to remain sanitary. Normally, after the material is deposited at the site, it is spread, compacted and covered at the end of every days operation with a layer of earth. The earth layer precludes the possibility of rats burrowing through it, fly breeding etc. Sanitary landfilling is normally carried out in 3 ways :

i) Trench Method

ii) Area Method

iii) Ramp Method

Trench method is normally used in the case of flat terrain or where the soil can be easily excavated.

Area method is suitable for irregular or marshy waste land having a high level of groundwater as in such cases excavation for the more orderly method of trench and ramp types cannot be carried out.

Ramp method is commonly used in the case of flat or gently rolling areas.

Suggested Landfilling Method

In the studies carried out all over India, NEERI has observed that bulky wastes such as furnitures etc., are absent in Indian solid wastes. Also the initial density of city refuse in India is observed to be between 500-800 kg/cm^3 as compared to 125-200 kg/m^3 in developed countries. The use of manual labour is quite cheap in India.

1. Selection of site should be made by using the same criteria as in the case of mechanized method

2. Provide an all weather access road from existing main road to the point at which filling is to commence. This road can be prepared from construction and demolition waste, ash, clinker, etc. A small stock of this material should be maintained at the site for day to day repairs

3. To help guide vehicle to the spot provide flags or pegs on the location which will help demarcate it. To indicate height to which filling has to be done, 'sight rails' should be provided

4. The filling should start from point nearest to road. The vehicles should approach the point after reversing. Tipping vehicles can unload faster and hence assure a quicker out-turn. The dumped material can be spread and leveled manually by using rakes having a number of teeth. By using Ramp method, the filling will move progressively inside the site

5. To indicate the point where vehicles should stop for unloading, a strong heavy wooden bumper bar can be provided

6. To avoid the rear wheels of vehicles from sinking in the newly deposited mass, cover the area near working face with steel or wooden sleepers.

7. Cover the waste at the end of a days operation

This method needs at the site about 60 to 90 persons/million population and hence for the NPP township a minimum of about 5 labourers will have to be provided for carrying out the work at the site.

5.2.4.3 Plantation

For plantation of small species, proper attention and management is required to maintain the survival rate of the planted species. In most cases, it has been observed that proper scientific technique are not employed for plantation of trees and if planted adequate attentions are not given to maintain the planted species. Post plantation management is equally important to maintain high survival rate.

For plantation of small plants, digging of pits is very important for preparing soil environment near the roots of the plants. Size of the pit should be sufficient enough to supply required nutrients to the roots of the plants. The usual method is to dig pit of required size 3 to 4 months before planting of species, which is generally done at the break of the monsoon. The pits are of 50 cm x 50 cm x 50 cm size, in case of harder species like Eucalyptus, Shisham, Acacia etc., but larger pit size is preferred for fruit yielding trees like mango, jamun etc. for which 1m x 1m x 1m pits may be used. In soils where nutrient content is poor, a suitable manure may be mixed in the proportion of one-third, volume by volume basis.

Species Selection

Based on the regional background and soil quality, greenbelt has to be developed. In greenbelt development, monoculture is not advisable due to it's climatic factor and other environmental constraints. Greenbelt with varieties of species is preferred to maintain species diversity, rational utilization of nutrients and for maintaining health of the trees. Prepared in this way, the greenbelt will develop a favourable micro-climate to support different micro-organisms in the soil and as a result of which soil quality will improve further.

During the course of survey, it has been observed that the soil quality of the plant site is fairly good and can support varieties of dry deciduous plant species for greenbelt development. Manure as discussed earlier, may be mixed with the soil used for filling the pit for getting better result for survival of plant species. Adequate watering is to be done to maintain the growth of young seedlings.

The study area gets low rainfall so the vegetation is often affected by draught. During drought, tree is the only source to provide food, fruits and leaf fodder to birds.

Based on the regional background, extent of pollutional load, soil quality, rainfall, temperature and human interactions, a number of species have been suggested to develop greenbelt in and around the Nuclear Power Plant as reported in **Table 5.1**. These species can be planted in staggering arrangements within the plant premises. Some draught resistant plant species have been identified which can be planted for greenbelt development if sufficient water is not available (**Table 5.2**).

The layout plan for greenbelt development near Nuclear Power Plant is shown in **Figure 5.1**. The details of greenbelt, 50 m away from Nuclear Power Plant is shown in **Figure 5.2**.

Details about Selected Species

The following trees are recommended towards the plant boundary 50 m away from the Nuclear Power Plant as per the details shown in **Figure 5.2** for greenbelt width of 100 meters.

***Acacia auriculiformis* (Seven Row)**

On the Nuclear Power Plant side (50 m away from the plant) at a distance of 4 m. horizontally and diagonally.

***Cassia Siamea* (Seven Row)**

The trees should be planted at about five meters horizontally and diagonally.

***Casisa fistula* (Eight Row)**

The trees should be planted at about 5 meters horizontally and diagonally.

***Dalbergia sissoo* (Eight Row)**

The trees should be planted at about 5 meters horizontally and diagonally.

Azadirachta indica may be planted in between the trees.

In addition, a lawn and floral garden with the varieties of small flowering plants may be developed near the office site to keep aesthetic value of the entire complex. For other buildings and sites which are away from the reactor at a distance of 50 meters, suitable sector belts on area available towards NPP may be developed with the same conceptual species placements as presented in **Figure 5.2**. The following trees are recommended towards the boundary of NPP site for greenbelt of of 200 m width.

- Mangifera indica (one row) on the road side at an interval of 8 m planted towards road side
- *Thespesia populnea* (4 rows) : The trees may be planted at about 4 m intervals
- *Acacia leucophloea* (Six rows) : The trees may be planted at about 5 m Interval horizontally and diagonally
- *Dalbergia sissoo* (4 rows) : The trees may be planted at about 6 m interval horizontally and diagonally
- *Acacia auriculiformis* (Five rows) : The trees may be planted at about 5 m. interval horizontally and diagonally
- *Cassia biflora* (Five rows) : The trees may be planted at about 3 m interval horizontally and diagonally
- *Terminalia arjuna* (Five rows) : The trees may be planted at about 7 m interval horizontally and diagonally
- *Syzgium cumini* (Three rows) : The trees shall be planted at about 7 m interval horizontally and diagonally
- *Prosopis juliflora* (Five rows) : The trees may be planted at 5 m interval horizontally and diagonally
- *Azadirachta indica* may be planted in between the tree for getting better growth of trees

Road Side Plantation

Road side plantation plays a very important role for greening the area, increasing the shady area, increasing aesthetic value and for eco-development of the area. The approach roads to NPP, colony, hospitals, etc. can be planted with flowering trees.

NPCIL should encourage plantation outside the plant boundary. Adequate care should be taken to encourage greenbelt development on the road side, however to uplift the regional ecosystem of the area by greenbelt development, all the voluntary organizations should take initiative to encourage massive plantation along the road side. Trees can be planted to increase aesthetic value as well as shady area along the roads as detailed in **Table 5.3**.

Other Considerations

For Kudankulam Nuclear Power Plant, proper greenbelt has to be designed to reduce pollutants arising from the activities of nuclear power plant. Greenbelt has to be designed to reduce pollutants arising from the vehicular movements. In addition, greenbelt is necessary for emergency preparedness plans during accidents to reduce adverse effects of accidents. Proper greenbelt development around Nuclear Power Plant will reduce the adverse effects of reactor accidents by absorbing significant amounts of the radio-active materials before they reach the public (Gupta & Kapoor, 1985). The pollution attenuation factors of three different widths of greenbelt for different considerations are presented in **Table 5.3**.

The pollution attenuation factor (AF) is given by the equation :

$$A_f = \frac{F(X_1 + X_2)}{F(X)\left[erF \dfrac{he}{\sqrt{2\sigma_2 (X_1)}} e - \lambda X^2 + erF_C \dfrac{he}{\sqrt{2\sigma_2 (X_1)}} F_D^1 (X_2) \right]}$$

Where,

X_2	=	Width of greenbelt (m)
he	=	Effective height of greenbelt (m)
Af	=	Pollution Attenuation Coefficient
X_1	=	Separation distance between the greenbelt and pollution source (m)
ρ.	=	Standard deviation of concentration distribution in vertical (m) at downwind distance
F_D	=	Plume depletion factor for downwind distances

F_D (X_1 + X_2), F_D (X_1) and F_d (X_2) are the plume depletion factors due to dry deposition of pollutant on natural surface for down wind distances (X_1 + X_2), X_1 and X_2 respectively.

The plume depletion factor FD (X) for any distance x need to be calculated using the following equation :

$$F_D(X) = \left[\exp \int_0^x 1/\sigma_Z \exp - H/2\sigma_Z \, d_Z \right]^{-(2t)^{1/2v} \, d/u}$$

Where,

H	=	Release height (m)
z	=	Standard deviation of concentration distribution in vertical (m) direction for downwind distance x
V_d	=	Dry deposition velocity (m/s)
u	=	Mean wind speed (m/s)

The concept of effective height he (which is less than the physical height of the greenbelt) is introduced to account for reduced wind speed in the greenbelt region; value of it is to be computed from the following relationship.

$U(z)\, dz = h_e\, U_c$

Where,

h	=	height of greenbelt
U(z)	=	is the wind speed profile outside the greenbelt
Uc	=	is the average wind speed inside the greenbelt

The pollution attenuation coefficient (m-1) of the greenbelt is given by :

$= K\ Pt\ Vd/Uc$

Where,

Pt	=	foliage surface area density of single tree ($m^2 x m^{-3}$)
K	=	$\frac{Pc}{Pt}$
Vd	=	dry deposition velocity of the pollutant (ms^{-1}) for the vegetative canopy

Plantation at Proposed Township of NPP

Proper greenbelt has to be developed in the proposed township of Nuclear Power Plant. Different varieties of species have been suggested keeping in view the attenuation of dust pollution, vehicular emissions and other environmental pollution. At township, the goal is to reduce environmental pollution and increase aesthetic value. With this in view, some of the plant species to be planted along the road side, park and garden are reported in **Table 5.4**.

5.2.5 Biological Environment

Aquatic Characteristics

Adequate care need be exercised for discharge of domestic wastes in the water to avoid enrichment of nutrients which may result in profound algal growth leading to eutrophication. Increase in pollutant level may also harm the aquatic organisms. Anthropogenic activities should be prohibited along the sea shore to avoid enrichment of water with nutrients.

Biomagnification Study

It has been observed that NPCIL is monitoring samples for radiological parameters from different sampling sites. Collection of samples should be done in a systematic way. Samples should be monitored on monthly basis from the site. It is also further necessary that regular analysis of samples in the study area should be done in the manner as given below :

At Receptor Sites

Concentration of different radioactive materials in :

- Water
- Land (irrigated, unirrigated)
- Rice, Wheat, Pulses
- Millets
- Milk
- Fruits
- Vegetables
- Phytoplankton, zooplankton, small fish, big fish, goat (different parts of the body)

Once such data is generated, the status of food chains should be established alongwith biomagnification levels due to release of radioactive materials in the environment.

Mitigation Measures

- A protective green belt should be developed around the power plant for air filtration, and from aesthetic point of view it is essential also. This would also create a buffer zone

- Regular monitoring of physico-chemical and radiation parameters need to be carried out in biological samples as a post-project activity

- The wastewater from power plant and residential colonies should be treated to meet the disposal standards and domestic sewage should be completely reused for irrigation of plantations and green belt development

- Regular monitoring of diversity and density of marine and terrestrial flora and fauna needs to be carried out as a part of post-project activity.

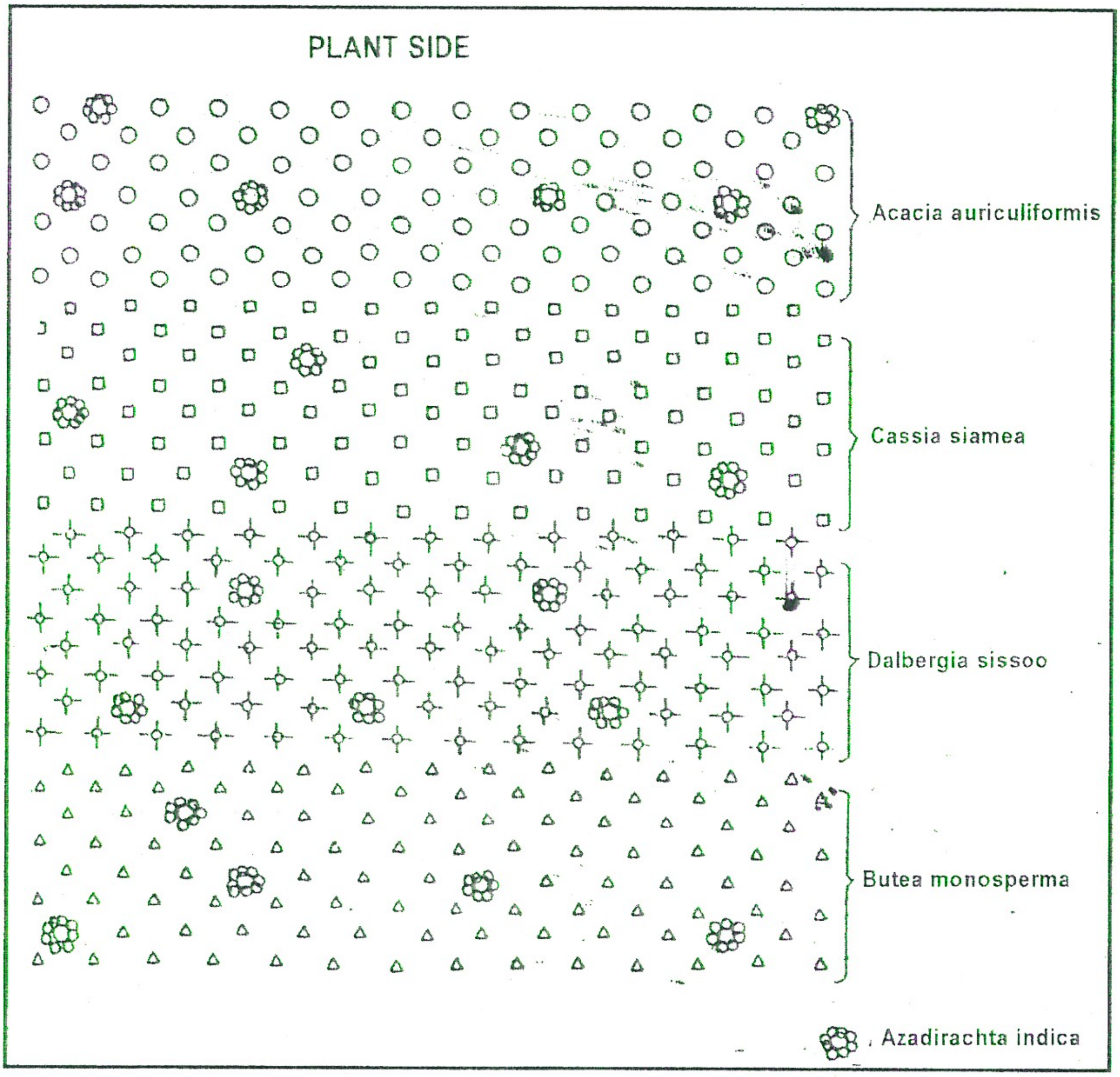


Fig. 5.1 : Green Belt Development Near the NPP Site

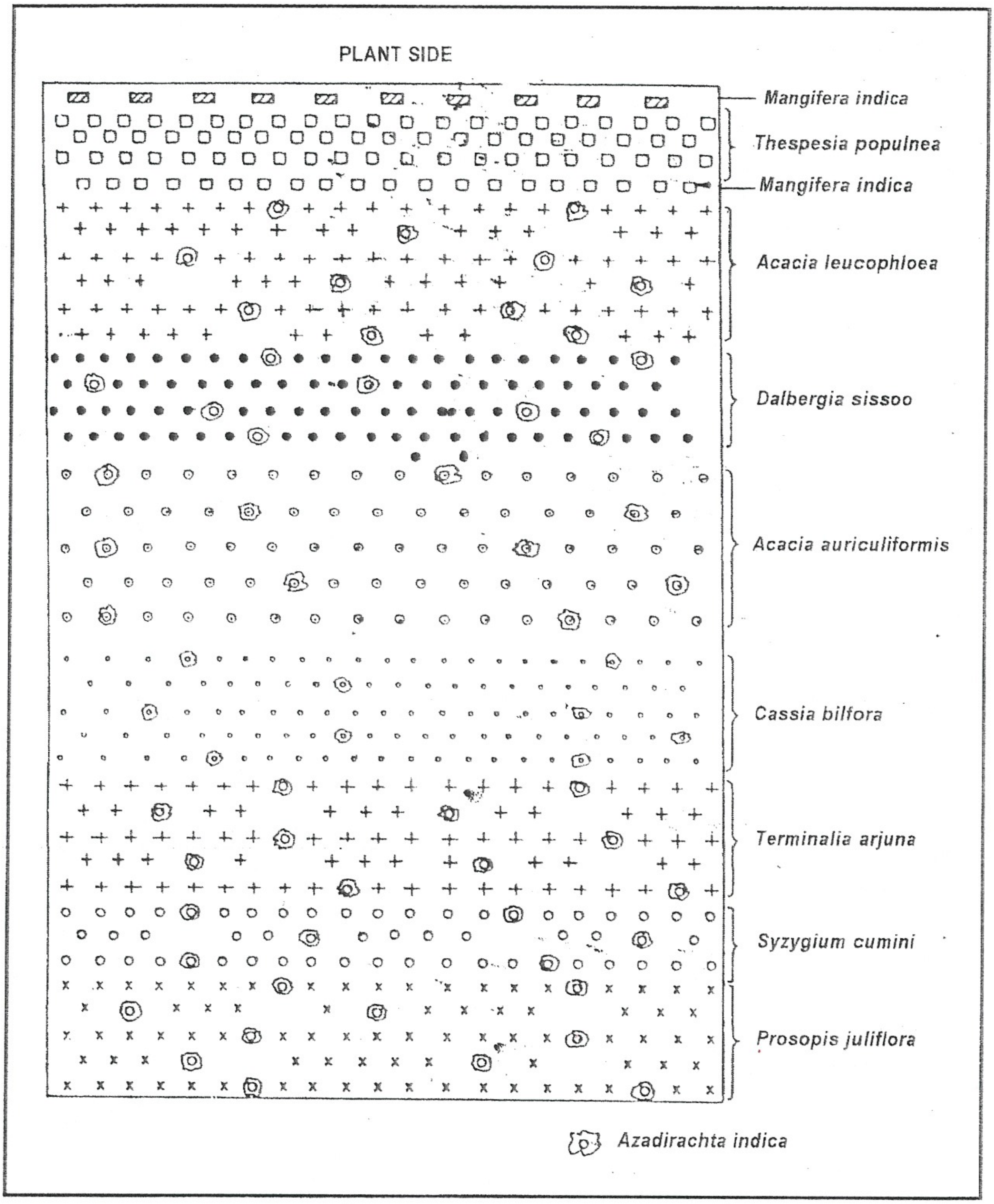


Fig. 5.2 : Section of Green Belt Development

Table 5.1

Species of Plants Suggested for Greenbelt Development

Botanical Name	Vernacular Name
Acacia auriculaeformis	-
Acacia leucophloea	Velvayalam
Acacia nilotica	Karu Velamaram, Karucelei
Acacia farnesiana	Kadivel
Acacia tortilis	-
Ailanthus excelsa	Perru, Perumaruttu
Albizia lebbeck	Vagei
Albizia procera	Konda vegei
Azadirachta indica	Vembu, Veppam
Butea monosperma	Parasa, Pilasu
Cassia biflora	-
Cassia siamea	Manje-Konne
Cassia auriculata	Avaram
Careya arborea	Ayma
Casuarina equisetifolia	Savukku
Dalbergia sissoo	Sisuith, Gette
Dendrocalamus strictus	Kalmungil
Emblica officinalis	Nelli
Eucalyptus spp.	-
Ficus religiosa	Arasu, Asurattham
Leucaena leucocephala	-
Madhuca indica	Illupei, Elupa
Mangifera indica	Manga, Mau
Melia azedarach	Malai vembu
Moringa oleifera	Murungai
Morus alba	Musukette, Kamblichedi
Parkinsonia aculeate	-
Pithecellobium dulce	Kodukkaapuli

Table 5.1 (Contd....)

Botanical Name	Vernacular Name
Pongamia pinnata	Ponga, Pongam
Prosopis Chilensis	-
Punica granatum	Madulai
Prosopis cineraria	Perumbay, Jambu
Phoenix dactylifera	Perichchankay, Karchuram
Salvadora oleoides	Kalawa, Karkol, Kohu, Ughai
Syzygium cuminii	Neredam, Naual, Sambal
Terminalia arjuna	Vellamatta
Tamarindus indica	Puli, Amilam
Tecoma undulata	-
Thespesia populnea	Poovarasam kallal, Cheelanthi
Tamarix troupii	-
Ziziphus mauritiana	Elandai, Yellande, Elladu

Table 5.2

Drought Resistant Species for Greenbelt Design within the NPP Area

	Botanical Name	Vernacular Name
1.	*Acacia auriculaeformis*	-
2.	*Acacia farnesiana*	Kadivel
3.	*Acacia nilotica*	Karuvelei
4.	*Acacia tortilis*	-
5.	*Aegle marmelos*	Bilva, Vilvam
6.	*Albizia lebbeck*	Vagei
7.	*Azadirachta indica*	Vembu, Veppam
8.	*Bougainvillea spectabilis*	Bangainvillea
9.	*Butea monosperma*	Paras, Pilasu
10.	*Caesalpinia pulcherrima*	Mayikonnai
11.	*Callistemon lanceolatus*	-
12.	*Cassia auriculata*	Avaram
13.	*Cassia fistula*	Konnei
14.	*Cassia siamea*	Manje-konne
15.	*Casuarina equisetifolia*	Savukku
16.	*Cochlospermum religiosum*	Kongilam, Tanakku
17.	*Cordia sebestena*	-
18.	*Crataeva nurvala*	Maralingam
19.	*Dalbergia sissoo*	Sisuitti, Gette
20.	*Delonix regia*	Mayarum
21.	*Dodonaea viscosa*	Velari
22.	*Erythrina viriegata*	Kaliyanamurukku
23.	*Eucalyptus citriodora*	-
24.	*Ficus benjamina*	-
25.	*Grevillea robusta*	Savukkumaram
26.	*Kigelia pinnata*	-
27.	*Lagerstroemia indica*	Pavalak-kurinji, Sinappu
28.	*Melia azedarach*	Malaivembu

Table 5.2 (Contd....)

	Botanical Name	Vernacular Name
29.	*Oncoba spinosa*	-
30.	*Parkinsonia aculeate*	-
31.	*Peltophorum pterocarpum*	Ivalvagai, Perungondrai
32.	*Phoenix dactylifera*	Perichchankay, Karchuram
33.	*Phoenix sylvestris*	Icham
34.	*Pongamia pinnata*	Ponga, Pongam
35.	*Prosopis chilensis*	-
36.	*Pterospermum acerifolium*	-
37.	*Putranjiva roxburghii*	Irukolhi, Karupalai
38.	*Salvadora persica*	Kalwa, Karkol, Perungoli
39.	*Schleichera oleosa*	Puvathipuvam
40.	*Tamarix aphylla*	Shivappu-atru-shavakku
41.	*Tamarix troupii*	-
42.	*Thespesia populnea*	-
43.	*Thevetia peruviana*	Pachaiyalari
44.	*Zizyphus mauritiana*	Elandi, Yellande, Elladu

Table 5.3

Pollution Attenuation Factor A_f of Green Belt of Different Widths

Stability Category	A_f for Green Belt Width (m)		
	700	1000	1500
A	2.31	2.37	2.38
B	3.12	3.37	3.39
C	3.40	3.97	4.26
D	4.71	7.75	12.61
E	16.71	44.80	96.68
F	27.69	128.04	1792.59

Table 5.4

Species Selected for Plantation along the Road Side and Township

Based on Color

Yellow Flowered Trees

1.	*Acacia auriculaeformis*	10.	*Erythrina parcelli*
2.	*Acacia baileyana*	11.	*Laburnum anagyroides*
3.	*Acacia dealbata*	12.	*Michelia champaca*
4.	*Acacia decurrens*	13.	*Parkinsonia aculeata*
5.	*Acacia implexa*	14.	*Peltophorum pterocarpum*
6.	*Anthocephalus chinensis*	15.	*Pterocarpus dalbergioides*
7.	*Bauhinia tomentosa*	16.	*Schizolobium excelsum*
8.	*Cassia calliantha*	17.	*Tabebuia spectabillis*
9.	*Cassia fistula*	18.	*Thespesia populnea*

Red Flowered Trees

1.	*Bombax ceiba*	5.	*Erythrina variegata*
2.	*Brownea grandiceps*	6.	*Saraca asoca*
3.	*Erythrina blakei*	7.	*Spathodea campanulata*
4.	*Erythrina laurifolia*	8.	*Wrightia coccinea*

Scarlet Flowered Trees

1.	*Barringtonia acutangula*	5.	*Callistemon lanceolatus*
2.	*Brassia actinophylla*	6.	*Delonix regia*
3.	*Brownea coccinea*	7.	*Stenocarpus sinuatus*
4.	*Butea monosperma*	8.	*Sterculia acerifolia*

Pink Flowered Trees

1.	*Bauhinia purpurea*	5.	*Hibiscus collinus*
2.	*Cassia javanica*	6.	*Kleinhovia hospita*
3.	*Cassia nodosa (Red)*	7.	*Lagerstroemia speciosa*
4.	*Cassia renigera*	8.	*Samanea saman*

Blue Flowered Trees

1.	*Bolusanthus speciosus*	3.	*Solanum grandiflorum*
2.	*Jacaranda acutifolia*	4.	*Solanum macranthum*

White Flowered Trees

1.	*Albizia lebbeck*	8.	*Mesua ferrea*
2.	*Bauhinia acuminata*	9.	*Millingtonia hortensis*
3.	*Calophyllum inophyllum*	10.	*Mimusops elengi*
4.	*Kydia calycina*	11.	*Moringa oleifera*
5.	*Madhuca indica*	12.	*Oncoba spinosa*
6.	*Magnolia grandiflora*	13.	*Plumeria alba*
7.	*Magnolia pterocarpa*		

Table 5.5

List of Trees Having Peak Flowering Season

Spring Season			
1.	*Acacia baileyana*	8.	*Michelia champaca*
2.	*Bauhinia acuminata*	9.	*Moringa oleifera*
3.	*Bombax ceiba*	10.	*Plumeria alba*
4.	*Brownea coccinea*	11.	*Saraca asoca*
5.	*Butea monosperma*	12.	*Spathodea campanulata*
6.	*Callistemon lanceolatus*	13.	*Sterculia acerifolia*
7.	*Erythrina variegata*		
Summer Season			
1.	*Acacia decurrens*	14.	*Jacaranda acutifolia*
2.	*Acacia salinga*	15.	*Laburnum anagyroides*
3.	*Albizia lebbeck*	16.	*Lagerstroemia speciosa*
4.	*Barringtonia acutangula*	17.	*Magnolia grandiflora*
5.	*Bauhinia acuminata*	18.	*Mesua ferrea*
6.	*Brownea gradiceps*	19.	*Mimusops elengi*
7.	*Calophyllum inophyllum*	20.	*Oncoba speciosa*
8.	*Cassia fistula*	21.	*Peltophorum pterocarpum*
9.	*Cassia javanica*	22.	*Pterocarpus dalbergioides*
10.	*Cassia renigera*	23.	*Stenocarpus sinuatus*
12.	*Delonix regia*	24.	*Tabebuia spectabilis*
13.	*Erythrina parcelli*	25.	*Wrightia coccinea*
Rainy Season			
1.	*Acacia auriculaeformis*	2.	*Acacia implexa*

5.2.6 Socio-economic Environment

Environmental Management Plan is delineated to mitigate the adverse impacts and to ensure that the maximum benefits are achieved without deteriorating the quality of environment and also without adversely affecting the quality of life of the people in the area.

The measures being suggested are based on the critical review of the socio-economic profile of the study area as well as available welfare schemes and facilities to be provided by NPCIL in the study area.

It is felt that the project should contribute towards improvement of quality of life of the people in the area. With this in view, following recommendations are made :

- A job should be provided to one person from each family whose land has been acquired for the project
- There is an annoyance and fear amongst the fishermen population due to likely deterioration in fish catch as a result of the project activity. As such there should be some schemes to increase employment opportunities for the fishermen population
- The local youth should be trained for undertaking skilled jobs in the plant
- There should be adequate infrastructural facilities, viz. housing, medical, education, transportation, communication, play ground, library, canteen, market for the NPP township so that there would be no strain on the existing infrastructure resource base
- Infrastructural facilities should be provided by NPCIL in the nearby villages, viz. medical, education, transportation and recreation etc. since the villages have these facilities in inadequate proportion. This will also help in getting moral support to the project in the long run.

It is obvious that the radiations are always dangerous for the human being. Some mitigative measures are suggested for smooth and effective operations of the power plant. These are given below :

It is envisaged :

1. To arrange medical personnel with adequate facilities for training, adequate equipments and necessary medication to deal effectively with the patients occupationally exposed to radiations.

2. That the direct handling of material should be limited and remote control be used wherever possible

3. That the working area must be supplied with filtered air and highly efficient filtration systems be installed to remove air borne particulates from the exhaust air from the ventilation systems

4. There should be individual monitoring of personnel engaged on operations (according to the International Commission on Radiological Protection, ICRP publication 12(61).

5. In case of female workers, they should be made aware, according to the need to inform the medical division promptly, if they think that they are pregnant, in order to ensure that the foetus is not exposed to more than the permissible radiation limit.

A continuous monitoring of the radiations is required besides the following measures :

- Monitoring of the working environment to ensure that the design features of the plant and its mode of operation are such that the personnel are adequately protected from exposure, both internally from contamination and externally from penetrating radiations.

- Monitoring of personnel occupationally exposed to radiations to ensure that the total exposure for each individual is within the prescribed limits and as low as is reasonably practicable for the operations involved.

- Maintaining of records of all such measurements to permit analysis of the radiological impacts on those employed in the process and the general public.

- Providing safety services, such as protective equipment to safeguard the plant operations and advice on operating procedures for both normal and abnormal conditions; and

- Deploying medical staff to carry out surveillance of workers; including pre-employment medical examinations & periodic subsequent examinations to monitor health of those involved
- Maintaining close interaction and close collaboration with the Health Physics Department and Medical Services.

Training

Working in a nuclear power plant always requires adequate personnel training with respect to the associated potential hazards with emphasis being placed on the significance of contamination.

Personnel engaged directly on the process must be trained in the techniques of material transfer and processing methods to ensure contamination of material within sealed enclosers at all times. Such techniques should be perfected using inactive materials prior to starting the work.

5.3 Post-Project Environmental Quality Monitoring

With a view to see the effectiveness of implemented control measures under different environmental components, it is necessary to implement the Post - Project Environmental Quality Monitoring Programme (PPEQM) on a continuous basis. Therefore, a PPEQM has been drawn for it's follow-up by NPCIL.

In view of the stringent requirements for radiation protection, recommendations have already been made in **Chapter 2** at appropriate places under various environmental components which need be followed in a monitoring programme. In addition, a radioactive monitoring and surveillance programme has been incorporated separately under **item 5.3.6**.

The components of post-project environmental quality monitoring programme to be pursued by NPCIL, are depicted in **Figure 5.3.1**.

5.3.1 Air Quality

5.3.1.1 Monitoring Parameters

The ambient air quality monitoring parameters are suspended particulate matter (SPM), sulphur dioxide (SO_2) and Nitrogen-dioxide (NO_2).

5.3.1.2 Sampling Stations

To establish general status of ambient air quality and resulted impact of pollutants, minimum eight monitoring stations on grid basis within 10 km zone from the source should be operated. One station on the upwind of the source at a distant location which shall be treated as a control may be essential. The other stations should be selected on seasonal basis depending upon the prevalence of wind direction.

5.3.1.3 Sampling Frequency

Sampling duration of each sampling schedule for all 24 hours for 2 days continuous and twice in a week. The background station may be operated once in 7 days for 24 hours period. The sampling period for gaseous pollutants shall be decided depending upon the frequency of change of wind direction and persistence.

5.3.1.4 Air Quality Monitoring - Equipments Required

Impingers	100 Nos.
Chemicals/Glasswares and other Lab. equipment	
Weather Monitoring equipment (continuous recorder type for speed direction and turbulence.)	1 No.
Sampling pumps	4 Nos.

High Volume Sampler

Blower	:	1.5 m^3/min capacity with adopter for uniform section through filter
Voltage Stabilizer	:	A properly calibrated manometer assembly for the determination of flow rate through filter paper
Rotameter	:	Calibrated rotameter (0-5 l/min) for maintaining flow rate for gaseous sampling
Main Housing	:	Rectangular main housing (29 cm x 36 cm)

SO_2 Analyzer

Minimum Range	:	0-100 $\mu g/m^3$

Flow Rate	:	1 l/min
Min. Detectable level	:	4 ppb
Response Time	:	1 min

NOx Analyzer

Minimum Range	:	0-100 $\mu g/m^3$
Min. Detectable	:	5 $\mu g/m^3$
Linearity	:	+ 2% of full scale
Accuracy	:	+ 2% of full scale
Response time	:	25 sec
Output	:	0-10 mv DC

Wind Speed

Cupwheel	:	5 to 10 cm diameter
Distance Constant	:	5 m

Wind Direction

Damping Ratio	:	0.5 - 0.6
Gust Wave length	:	1.0 m

Signal output should be electrically connected with microprocessor based data analyzer.

5.3.2 Noise Environment

Monitoring of noise levels is essential to assess the efficacy of maintenance schedules undertaken to reduce noise levels and noise protection measures. A good quality sound pressure level meter is essential for this purpose.

Sound pressure level meter

Bruel & Kjaer, Denmark made

5.3.3 Water Quality Monitoring

Water quality is to be monitored for assessing potability as well as for its suitability for general uses. Conventional parameters and health-related parameters are required to be monitored.

5.3.3.1 Sampling Frequency

Weekly, i.e. One sample from each sampling site every week.

5.3.3.2 Analysis Methodology

The methods prescribed in "Standard Methods for Water and Waste Water Analysis" published by APHA, AWWA & WPCF should be strictly adhered.

5.3.3.3 Monitoring Laboratory

An independent laboratory with facilities for chemical and bacteriological analysis should be constructed. The laboratory should have the provision for Fume-hood and Cold-room. A separate air conditioned dust-proof room should be provided for the instruments: Following instruments will be required.

i)	Single Pan Balance	2 Nos.
ii)	pH Meter	2 Nos.
iii)	Conductivity Meter	1 No.
iv)	Turbidimeter (Preferably HACH)	1 No.
v)	D.O. Analyser	1 No.
vi)	Spectrophotometer (UV & Visible) Wave-length (preferably Spectronic) 190 - 1000 nm.	1 No.
vii)	Flame Photometer (CORNING)	1 No.

5.3.4 Staff Requirement for Environmental Quality Monitoring

i)	Environmental Engineer (M.E. Env. Engg.)	1 No.
ii)	Chief Chemist with Post-graduate Degree in Chemistry, and 10-15 years experience in Water and Air Pollutants Analysis	1 No.

iii)	Chemist with Post-graduate Degree in Chemistry (one each for Air and Water Environment)	2 Nos.
iv)	Laboratory Technician B.Sc. (Chemistry)	3 Nos.
v)	Field Sampling Staff	3 Nos
vi)	Horticulturist B.Sc. (Agriculture) with 3-5 years experience	1 No.

The staff may be deputed to a reputed organization for training in Water and Wastewater Analysis and instrumental method for analysis. An organizational set-up required for environmental quality monitoring on continuous basis, is shown in **Figure 5.3.2**.

5.3.5 Budgetory Provisions for EMP

Adequate budgetory provisions have to be made by NPCIL for execution of environmental management plan. The details of capital and recurring (per annum) budget that needs to be earmarked for pollution control/monitoring equipments and for green-belt development are as follows :

(i) Pollution Control

- a. Non-recurring : 100 Lakhs
- b. Recurring / Annum : 25 Lakhs

(ii) Pollution Monitoring

- a. Non-recurring : 30 Lakhs
- b. Recurring / Annum : 10 Lakhs

(iii) Green-belt development

- a. Non-recurring : 30 Lakhs
- b. Recurring / Annum : 10 Lakhs

(iv) Social Welfare Measures

a) Health facilities

- Non - Recurring : 20 Lakhs
- Recurring / Annum : 4 Lakhs

b) Water Supply & Sanitation

- Non - Recurring : 20 Lakhs
- Recurring / Annum : 5 Lakhs

Note: Item at S. N. (I) & (ii) pertain to Non-Radiological Pollution Control. For radiological pollution control, NPCIL can plan for a budget of its own or in consultation with agencies like BARC.

5.3.6 Radioactive Monitoring and Surveillance Programme

Assessment of doses to members of the public is done not by individual monitoring but by assessment through sampling in the environment and statistical calculations. In order to achieve this, a comprehensive environmental surveillance programme has to be established at all major facilities. The programme shall have the following objectives :

i. Baseline radioactivity measurements

ii. Pre-operational studies regarding identification of critical pathways, radionuclides in air, water and food chain to help in the establishment of authorized limits for different radiological parameters.

iii. Collection of data to determine the assimilative capacity of the environment

iv. Monitoring during normal operation of the nuclear power plant

v. Provision of monitoring services in cases of uncontrolled releases of radio-activity into the environment

vi. Establishing a well equipped Environmental Surveillance and Monitoring Laboratory (ESML) with deployment of well trained staff for monitoring of relevant parameters of nuclear power generation on a continuous basis.

The surveillance programme is carried out on a permanent basis by Health Physics Division, BARC (which is outside the control of the plant O & M organization). The personnel incharge, of the surveillance programme are well qualified and experienced. The results of all operational aspects of the station are subject to review by a three tier Safety Committee System of AERB to implement safety regulations. The final review is by the Atomic Energy Regulatory Board.

NPCIL states that experience during the last 15 years of such programmes has given satisfactory results to contain radioactivity within ICRP limits.

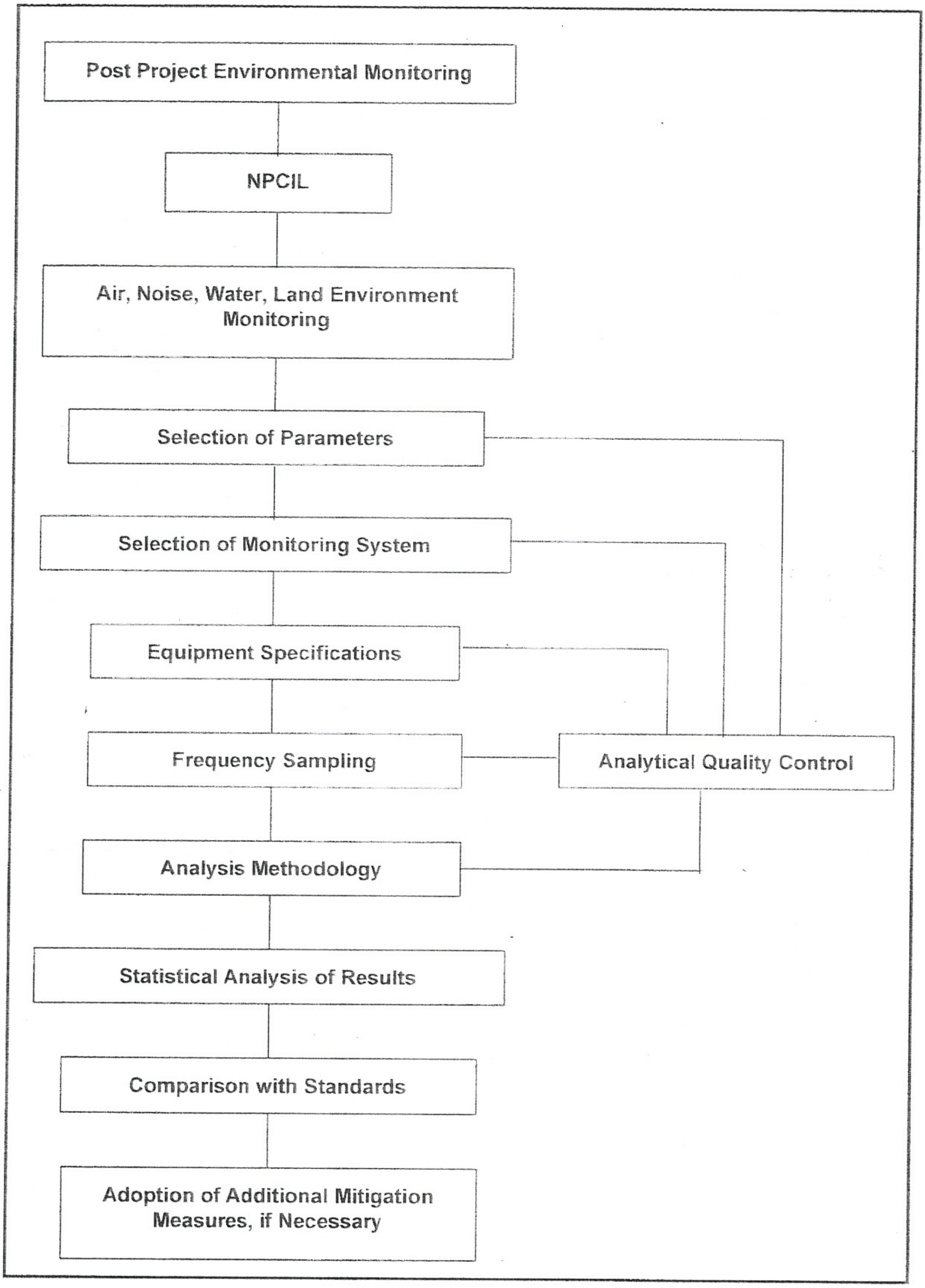


Figure 5.3.1 : Components of Post-Project Environmental Monitoring Programme for NPCIL

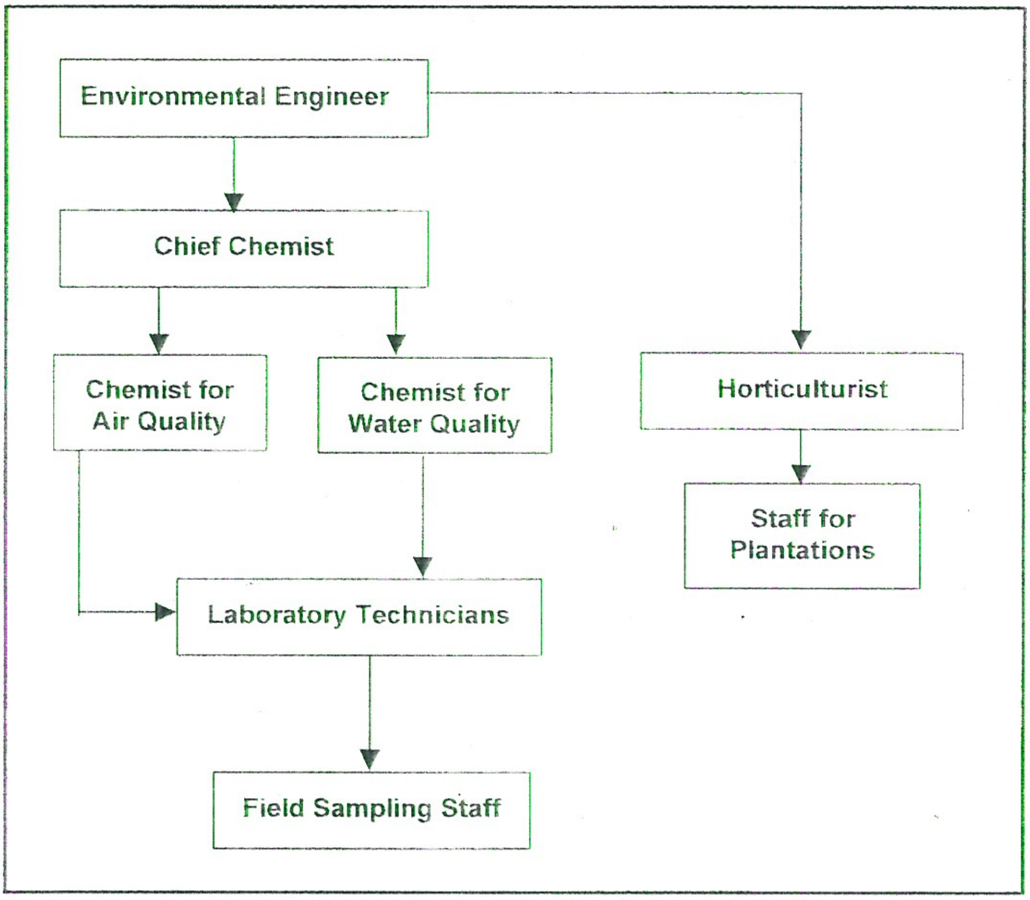


Figure 5.3.2 : **Recommended Organizational Set up for Environmental Quality Monitoring (For Non-Radiological Parameters) for NPCIL**

Annexures

Annexure I

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) (1994)

Pollutant	Time weighted average	Concentration in ambient air			
		Industrial area	Residential, Rural & mixed use area	Sensitive area	Method of measurement
Sulphur dioxide (SO_2)	Annual average* 24 hours**	80 µg/m³ 120 µg/m³	60 µg/m³ 80 µg/m³	15 µg/m³ 30 µg/m³	- Improved West & Caeke method - Ultraviolet fluorescence
Oxides of Nitrogen method (as NO_2)	Annual average*	80 µg/m³	60 µg/m³	15 µg/m³	- Jacab & Hochheiser(Na-Arsenite)
	24 hours**	120 µg/m³	80 µg/m³	30 µg/m³	- Gas phase chemiluscence
Suspended Particulate Matter (SPM)	Annual average* 24 hours**	360 µg/m³ 500 µg/m³	140 µg/m³ 200 µg/m³	70 µg/m³ 100 µg/m³	- High volume sampling (average flow rate not less than 1.1 m³/min)
Respirable Particulate Matter (size less than 10 µm) (RPM)	Annual average* 24 hours**	120 µg/m³ 150 µg/m³	60 µg/m³ 100 µg/m³	50 µg/m³ 75 µg/m³	- Respirable particulate matter sampler
Lead (Pb)	Annual average* 24 hours**	1.0 µg/m³ 1.5 µg/m³	0.75 µg/m³ 1.00 µg/m³	0.50 µg/m³ 0.75 µg/m³	- AAS method after sampling using EPM 2000 or equivalent filter paper
Carbon Monoxide (CO)	8 hours** 1 hour	5.0 mg/m³ 10.0 mg/m³	2.0 mg/m³ 4.0 mg/m³	1.00 mg/m³ 2.00 mg/m³	- Non-dispersive infrared spectroscopy

* Annual arithmatic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval

** 24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days

NOTE

1. National Ambient Air Quality Standards : The levels of air quality necessary with an adequate margin of safety, to protect the public health, vegetation and property
2. Whenever and wherever two consecutive values exceeds the limit specified above for the respective category, it would be considered adequate reason to institute regular/continuous monitoring and further investigations
3. The above standards shall be reviewed after five years from the date of notification

Noise Standards

Area Code	Category of Area	Noise Level in Leq dB(A)	
		Day Time (6 am to 10 pm)	Night Time (10 pm to 6 am)
A	Industries Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence zone	50	40

* Area up to 100m around premises such as hospitals, educational institutions, and courts

Note :

The silence zones are to be declared by the competent authority. Use of vehicular horns, loudspeakers, and bursting of crackers are banned in theses zones

Source

CPCB 1998, Pollution Control Acts, Rules, and Notifications issued thereunder. Volume-1 p313 New Delhi : Central Pollution Control Board, Ministry of Environment and Forests 501 pp

INDIAN STANDARDS/SPECIFICATIONS FOR DRINKING WATER
IS : 10500 - 1991

S. No.	Substances or Characteristic Max.	Requirement (Desirable limit)	Undesirable effects outside the desirable limit	Permissible limit in absence of alternate source	Method of Test Cl Ref of IS : 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Essential Characteristics						
1.	Colour, Hazen unit	5	Above, consumer acceptance decreases	25	4 of 3025, 1983	Extended upto 25 only if toxic substances are not suspected in absence of alternate source
2.	Odour		Unobjectionable	-	5 of 3025, 1983	a. Test cold and when heated b. Test at several dilutions
3.	Taste		Agreeable	-	-	Test to be conducted only after safety has been established
4.	Turbidity, NTU	5	Above, consumer acceptance decreases	10	8	-

S. No.	Substances or Characteristic Max.	Requirement (Desirable limit)	Undesirable effects outside the desirable limit	Permissible limit in absence of alternate source	Method of Test Cl Ref of IS : 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5.	pH value	6.5-8.5	Beyond this range the water will affect the mucous membrane and/or water supply system	No relaxation	8	-
6.	Total hardness, mg/L as $CaCO_3$	300	Encrustation on water supply structure and adverse effects on domestic use	600	-	-
7.	Iron (as Fe), mg/L	0.3	Beyond this limit, taste/appearance are affected, has adverse effect on domestic uses and water supply structures, & promotes iron bacteria	1.0	32 of 3025, 1964	-
8.	Chlorides (as Cl)m mg/l	250	Beyond this limit, taste, corrosion and palatability are affected	1000	32 of 3025, 1988	-

S. No.	Substances or Characteristic Max.	Requirement (Desirable limit)	Undesirable effects outside the desirable limit	Permissible limit in absence of alternate source	Method of Test Cl Ref of IS : 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
9.	Residual free chlorine, mg/L	0.2	-	-	26 of 3025, 1986	To be applicable only when water is chlorinated Tested at consumer end, When protection against viral infection is required, it should be min 0.5 mg/L
Desirable Characteristics						
10.	Dissolved solids, mg/L	500	Beyond this palatability decrease and may cause gastrointestinal irritation	2000	16 of 3025, 1984	
11.	Calcium (as Ca), mg/L	75	-	200	40 of 3025, 1984	
12.	Copper (as Cu), mg/L	0.05	Astringent, taste discoloration of pipes, fitting and utensils will be caused beyond this	1.5	36 of 3025, 1964	

S. No.	Substances or Characteristic Max.	Requirement (Desirable limit)	Undesirable effects outside the desirable limit	Permissible limit in absence of alternate source	Method of Test Cl Ref of IS : 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
13.	Manganese (as Mn), mg/L	0.1	Astringent taste, discoloration of pipes, fitting and utensils will be caused beyond this	0.3	35 of 3025, 1964	
14.	Sulphates, (as SO_4), mg/L	200	Beyond this causes gastro intestinal irritation when magnesium or sodium are present	400	24 of 3025, 1986	May be extended upto 400 provided (as Mg) does not exceed 30 mg/L
15.	Nitrates (as NO_3), mg/L	45	Beyond this methaemoglobinemia takes place	100	-	-
16.	Fluoride (as F), mg/L	1.0	Fluoride may be kept as low as possible. High fluoride may cause fluorosis	1.5	23 of 3025, 1964	-
17.	Phenolic substances, mg/L (as C_6H_5OH)	0.001	Beyond this, it may cause objectionable taste and odour	0.002	54 of 3025, 1964	

S. No.	Substances or Characteristic Max.	Requirement (Desirable limit)	Undesirable effects outside the desirable limit	Permissible limit in absence of alternate source	Method of Test CI Ref of IS : 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
18.	Mercury (as Hg), mg/L	0.001	Beyond this, the water becomes toxic	No relaxation	see note mercury ion analyser	To be tested when pollution is suspected
19.	Cadmium (as Cd), mg/L	0.01	Beyond this, the water becomes toxic	No relaxation	see note mercury ion analyser	To be tested when pollution is suspected
20.	Selenium (as Se) mg/L	0.01	Beyond this, the water becomes toxic	No relaxation	28 of 3025, 1964	To be tested when pollution is suspected
21.	Arsenic (As), mg/L	0.05	Beyond this, the	No	37 of 3025, 1988	To be tested when
22.	Cyanide (CN), mg/L	0.05	Beyond this, the water becomes toxic	No relaxation	27 of 3025, 1986 pollution is suspected	To be tested when
23.	Lead (Pb), mg/L	0.05	Beyond this, the water becomes toxic	No relaxation	See note 86	To be tested when pollution plumbosolvency is suspected
24.	Zinc (as Zn), mg/L	5	Beyond this limit it can cause astringent taste and an opalescence in water	15	39 of 3025, 1964	To be tested when pollution is suspected

S. No.	Substances or Characteristic Max.	Requirement (Desirable limit)	Undesirable effects outside the desirable limit	Permissible limit in absence of alternate source	Method of Test CI Ref of IS : 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
25.	Anionic detergents, mg/L (as MBAS)	0.2	Beyond this limit, it can cause a light froth in water	1.0	Methylene blue extraction method	To be tested when pollution is suspected
26.	Chromium (as Cr^{+6}), mg/L	0.01	May be carconogenic above this limit	0.05	28 of 3025, 1964	To be tested when pollution is suspected
27.	Polynuclear aromatic hydrocarbons (as PAH), mg/L	-	May be carcinogenic	-	-	-
28.	Mineral oil, mg/L	0.01	Beyond this limit undesirable taste and odour after chlorination takes place	0.03	Gas chromatographic method	To be tested when pollution is suspected
29.	Pesticides, mg/L	Absent	Toxic	0.001	58 of 3025, 1964	-
30.	Radioactive materials					
	a. Alpha emitters Bq/L	-	-	0.1	-	-
	b. Beta emitters pci/L	-	-	1.0	-	-

S. No.	Substances or Characteristic Max.	Requirement (Desirable limit)	Undesirable effects outside the desirable limit	Permissible limit in absence of alternate source	Method of Test Cl Ref of IS : 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
31.	Alkalinity (as $CaCO_3$), mg/L	200	Beyond this limit taste becomes unpleasant	600	13 of 3025, 1964	-
32.	Aluminimum (as Al), mg/L	0.03	Cumulative effect is reported to cause dementia	0.2	31 of 3025, 1964	-
33.	Boron (as B), mg/L	1	-	5	29 of 3025, 1964	-

Note : Atomic absorption spectrophotometric method may be use

Annexure IV

Calculated Discharge Rate, Discharge Limit and Dose Apportionment, for one unit of Kudankulam Project

Radionuclide	Calculated Normal Discharge (Bq/d)	Discharge Limit (Bq/d)	$ Dose apportionment μSv/year (mrem/yr)
Atmospheric			
- Inert radioactive gases	1.14×10^{10}	1.85×10^{13}	30 (3.0)
- I-131	2.48×10^{5}	3.70×10^{8}	5 (0.5)
- Mixture of long lived nuclides (as Sr-90)	2.62×10^{5}	5.5×10^{8}	1 (0.1)
Aquatic			
- Tritium	2.3×10^{11}	7.0×10^{15} (8880 Bq/ml)*	1 (0.1)
- Gross Beta (other than H-3)	8.5×10^{5}	6.0×10^{11} (0.074 Bq/ml)*	1 (0.1)

$ Based on the MAPS site specific data

* The values in parenthesis are the concentration limits is Seawater

Annexure V

INDIAN STANDARDS FOR INDUSTRIAL AND SEWAGE EFFLUENTS DISCHARGE IS:2490-1982

Sr. No.	Parameters	Industrial Effluent			
		Into Inland Surface Water	On land for Irrigation	Into Marine Coastal Area	Into Public Sewers
1.	Colour/Odour	-	-	-	-
2.	Suspended Solids, mg/l	100	200	100 (For process waste)	600
3.	Particle Size Suspended Solids	Shall pass 850 micron IS sieve	-	Floatable Solids Max 3mm Settleable Solids Max 850 microns	-
4.	Dissolved Solids (Inorganic) mg/l, Max.	2100	2100	-	2100
5.	pH Value	5.5-9	5.5-9	5.5-9	5.5-9.0
6.	Temperature ^{o}C	Shall not exceed 40 in any section of the stream within 15 mts downstream from the effluent outlet	-	45 at the point of discharge	-
7.	Oil & Grease, mg/l, Max	10	10	20	20
8.	Total Residual Chlorine, mg/l, Max	1	-	1	-
9.	Ammonical Nitrogen (as N) mg/l, Max	50	-	50	50
10.	Total Kjeldahl Nitrogen (as N), mg/l, Max	100	-	100	-
11.	Free Ammonia (as NH_3) mg/l, Max	5	-	5	-

Sr. No.	Parameters	Industrial Effluent			
		Into Inland Surface Water	On land for Irrigation	Into Marine Coastal Area	Into Public Sewers
12.	Biochemical Oxygen Demand (5 Days at 20°C), Max	30	100	100	350
13.	Chemical Oxygen - Demand mg/l, Max	250	-	250	
14.	Arsenic (as As), mg/l Max	0.2	0.2	0.2	0.2
15.	Mercury(as Hg), mg/l Max	0.01	-	0.01	0.01
16.	Lead (as Pb), mg/l, Max	0.1	-	1.0	1.0
17.	Cadmium (as Cd), mg/l Max	2	-	2	1
18.	Hexavalent Chromium (As Cr6+), mg/l, Max	0.1	-	1	2
19.	Total Chromium (as Cr) mg/l, Max	2	-	2	2
20.	Copper (as Cu), mg/l Max	3	-	3	3
21.	Zinc (as Zn), mg/l, Max	5	-	15	15
22.	Selenium (as Se), mg/l, Max	0.05	-	0.05	0.05
23.	Nickel (as Ni), mg/l Max	3	-	5	3
24.	Boron (as B), mg/l Max	2	2	-	2
25.	Percent Sodium, Max	-	60	60	-

Sr. No.	Parameters	Industrial Effluent			
		Into Inland Surface Water	On land for Irrigation	Into Marine Coastal Area	Into Public Sewers
26.	Residual Sodium Carbonate, mg/l, Max	-	50	-	-
27.	Cyanide(as CN), mg/l, Max	0.2	0.2	0.2	0.2
28.	Chloride (as Cl), mg/l, Max	1000	600	-	1000
29.	Fluoride (as F), mg/l, Max	2	-	15	15
30.	Dissolved Phosphate (As P), mg/l, Max	5	-	-	-
31.	Sulphate (as SO_4) mg/l, Max	1000	1000	-	1000
32.	Sulphide (as S) mg/l, Max	2	-	5	-
33.	Phenolic Compounds (as C_6H_5OH), mg/l, Max	1	-	5	6
34.	Radioactive materials				
	a) Alpha emitters µc/ml, Max	10^{-7}	10^{-8}	10^{-7}	10^{-7}
	b) Beta emitters µc/ml, Max	10^{-6}	10^{-7}	10^{-6}	10^{-6}
35.	Manganese (as Mn), mg/l	2	2	-	2
36.	Iron (as Fe) mg/l	3	3	-	3
37.	Vanadium (as V) mg/l	0.2	-	0.2	0.2
38.	Nitrate Nitrogen mg/l	18	20	-	0.2