

**SAFETY OF
KUDANKULAM NUCLEAR POWER PLANT
AND IMPACT OF ITS OPERATION
ON THE SURROUNDINGS**

**REPORT BY
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1. Introduction

The Kudankulam Nuclear Power Project (KKNPP) is an Indo-Russian joint venture for establishing a nuclear power station with 2 units (KKNPP-1&2) of 1000 MWe Pressurized Water Reactors of VVER design at Kudankulam in Tamilnadu. The proposed Power station is covered by the International Atomic Energy Agency (IAEA) safeguards, on lines with existing stations like Tarapur-1&2 and Rajasthan-1&2 built in collaboration with USA and Canada respectively. The project site has the required clearances from Atomic Energy Regulatory Board and also by various other statutory authorities in the State and centre.

The VVER reactors being established at Kudankulam belong to the family of advanced Pressurized Water Reactors (PWRs). Presently 434 nuclear reactors are under operation in the world and about 269 of them belong to the PWR family including 55 VVERs. Among the 64 reactors under construction worldwide, 53 are PWRs including 10 VVERs.

The activities towards establishing the two reactors were progressing satisfactorily till the last week of July 2011 when a section of the population in the neighborhood, in association with an organization called, People's movement against nuclear energy (PMANE), started an agitation against the project and demanded the closure of KKNPP. Due to this agitation, project work at the site has been adversely affected.

The Government of India constituted a 15 member Expert Group (EG) to provide clarifications on the issues raised by the agitators and allay their fears. The EG has been asked to do this by interacting with the forum provided by the State Government comprising of 2 State Government nominees and 4 representatives of the people.

The first joint meeting of the Expert Group with the forum was held on 8th November 2011 and the second one on 18th November 2011, both at the office of the District Collector, Tirunelveli. In both the meetings no discussion could be held for EG to clarify on the issues and apprehensions raised by the agitators towards allaying the fears in the minds of a section of people. Though the EG had painstakingly prepared power point presentations on selected topics of relevance with details to convey factual information to allay the fears in the mind of public through the representatives of people, making of the presentations by the EG was not accepted by the representatives of people, stating that they were not experts in the field and hence would not be able to properly comprehend the presentations. However, they accepted copies of the report prepared by EG, titled "Presentation to TN Government nominees and people representatives regarding safety of KKNPP on 18-11-2011 in the office of DC, Tirunelveli".

Their single demand was the closure of the nuclear power project at Kudankulam. The representatives also submitted a letter in the second meeting requesting for documents relating to the project on a wide range of subjects which come under the jurisdiction of different State and Central Authorities, Statutory bodies etc.

The EG observed that several statements by protesting leaders in public meetings, news items in the media and the demand for closure of the nuclear power plant are mainly due to misinterpretation of the global trend on the use of nuclear energy for power generation, lack of appreciation of the 4 decades of Indian experience in establishing and operating nuclear plants, misunderstanding and lack of knowledge on the levels of radiation in the neighborhood of NPPs and its impact on health, unfounded fears on the health of present and future generations, inadequate public awareness of the advanced design and safety features of proposed nuclear reactors at Kudankulam, imaginary adverse impact on the livelihood of people in the neighborhood etc. To allay such fears in the minds of public, the EG has prepared this document with brief reports on major topics addressing the perceived concerns of people. While the name(s) of the contributing expert(s) have been indicated in the different sections below, it is to be noted that considerable inputs and information have been given by NPCIL. Further this is a consensus document where there is agreement amongst the experts on the contents of the report.

This report has been prepared by the members of EG based on their expertise, published literature, detailed information obtained from the records provided by NPCIL and inspection of the site. The lead author(s) of the different topics are included below each title. The report is finalized with full agreement of all EG members.

Some text appearing in this report has already been presented in the earlier report titled **“Presentation to Tamilnadu Government nominees and people representatives regarding safety of KKNPP on 18.11.2011 in the office of District Collector, Tirunelveli”**. However, the same has been included here for the sake of completeness and to make the present report a stand-alone document.

2. Global Trends in Nuclear Power and need for Nuclear Power in India (Dr.S.M.Lee, Raja Ramanna Fellow, Safety Research Institute, Kalpakkam)

2.1 Global trends

Internationally, as of early December 2011, 434 nuclear reactors are operating in 30 countries and producing 367580 MW(e) and 64 reactors are under construction to produce 61642 MW(e) (refer **Table 2.1.1** and **Table 2.1.2**).

Further the following Nuclear Power Plants (NPPs) have been connected to respective grids after the Fukushima accident of March 2011:-

- Chashapp Unit-2 (300 MWe, PWR, Pakistan) – on 14th March 2011.
- Lingao 4 (1000 MW, PWR, China) – on 3rd May 2011.
- CEFR- China Experimental Fast Reactor (20 MWe, FBR, China)- on 21st July 2011.
- Bushehr 1- (915 MWe, PWR, VVER, Iran)- on 3rd September 2011.

The status in some other countries, post Fukushima, is summarized below:

Russia: 10 reactors are under construction. 14 reactors are further planned.

USA: There are proposals for over 20 new reactors.

France: Building a 1600 MWe unit at Flamanville for operation in 2012 and second to follow at Penly.

UK: Four 1600 MWe units are planned for operation in 2019.

Germany: It had 17 reactors and it has not granted sanction for further life extension to 8 reactors among them that had completed design life. The design life of the remaining 9 will be completed by 2022. Germany announced that they will not consider further extension of life of these plants. There had been a debate in Germany about the need for nuclear power plants, even before Fukushima accident, based on sufficient availability of electrical energy from other sources and energy availability from neighboring nations.

Switzerland: It has 5 reactors in operation. It has decided to phase out Nuclear power by 2034 on completion of their design life.

Japan: It had 54 nuclear reactors, 11 reactors continued to be in operation even during earth quake and tsunami in Japan and are still in operation. The remaining reactors were put on shutdown/maintenance. Decisions were taken to start them after safety review and the first of these has been restarted in August 2011.

Table 2.1.1: Nuclear Power Reactors in operation (5th Dec 2011)

Country	Reactors	GWe
Argentina	2	935
Armenia	1	375
Belgium	7	5927
Brazil	2	1884
Bulgaria	2	1906
Canada	18	12624
China	15	11078
Czech Republic	6	3678
Finland	4	2736
France	58	63130
Germany	9	12068
Hungary	4	1889
India	20	4391
Iran	1	915
Japan	50	44215
Korea S.	21	18698
Mexico	2	1300
Netherlands	1	482
Pakistan	3	725

Romania	2	1300
Russian Fed.	33	23643
Slovak Rep.	4	1816
Slovenia	1	688
South Africa	2	1800
Spain	8	7567
Sweden	10	9298
Switzerland	5	3263
Taiwan	6	4982
Ukraine	15	13107
UK	18	9920
USA	104	101240
Total	434	367580

(From IAEA website)

China has 15 nuclear power reactors in operation and 27 under construction. Additional reactors are planned, including some of the world's most advanced (like the Russian VVER), to give a five- or six-fold increase in nuclear capacity to at least 60 GWe by 2020, then 200 GWe by 2030, and 400 GWe by 2050. China is rapidly becoming self-sufficient in reactor design and construction, as well as other aspects of the fuel cycle.

Table 2.1.2: Nuclear Power Reactors under Construction (5th Dec 2011)

Country	Reactors	GWe
Argentina	1	692
Brazil	1	1245
Bulgaria	2	1906
China	27	27230

Finland	1	1600
France	1	1600
India	6	4194
Japan	2	2650
Korea S.	5	5560
Pakistan	1	315
Russian Fed.	10	8203
Slovak Rep.	2	782
Taiwan	2	2600
Ukraine	2	1900
USA	1	1165
Total	64	61642

(from IAEA website)

Bangladesh has recently signed intergovernmental agreement with Russia to start construction of a new VVER plant in Bangladesh in November 2011.

Vietnam has signed an agreement recently with Russia for the establishment of their first nuclear power plant (VVER) and with a consortium from Japan to construct a second nuclear plant.

UAE continues work related to setting up of its first nuclear plant through a consortium in South Korea.

Turkey has initiated action for setting up its first nuclear power plant (VVER)

From the above, it is clear that the trend appears to be on continued use of nuclear power globally.

2.2 Need for nuclear power in India

2.2.1 Indian electricity scenario

The growth of the installed electric capacity in India is shown in **Table 2.2.1**. The resource wise breakup of the present installed capacity is given in **Table 2.2.2**.

Table 2.2.1: India Installed Electric Capacity

Year	GWe
1950	2
1970	14
1980	33
1990	72
2000	108
2006	144
2011	182

Table 2.2.2: Classification of India Installed Electric Capacity in 2011

Resource	GWe
Coal/Oil/Gas	118.7 (65.1%)
Hydro	38.7 (21.2%)
Other Renewable*	20.2 (11.1%)
Nuclear	4.8 (2.6%)
Total	182.3

(* Wind, Small Hydro, Biomass, Solar, Geothermal)

(Captive connected to grid is 19.5 GWe)

Poverty, malnutrition, ill health, and under-employment can only be corrected by concerted effort towards economic and industrial development. One of the infrastructure requirements for such development is an adequate electricity supply base. The factors that need to be considered for estimating the future electrical energy demand are expected population growth, national economic growth and industrial development. In addition more intangible factors have to be also taken into account like trade-off of standard of living against environmental protection, cultural and political changes like population shift from rural to urban and so on. To simplify the projection one can consider the projected growth of the product of average per capita energy utilization and the population.

The per capita utilization of electrical energy in India in 2005 worked out to be less than 500 kWh per annum, which is about one fifth of the world average and about one twentieth of that of the industrially developed countries (see **Table 2.2.3**). The per capita utilization of electrical energy could increase by over an order of magnitude as India becomes industrially and technologically advanced. With a population of over one billion, even to attain the present world average electricity utilization will require a production of some 3000 TWh i.e. an installed capacity of about 600 GWe.

2.2.2 Energy resources for electricity production

The energy resources are classified as "conventional", "non-conventional" and "future". By "conventional" is meant coal, oil, gas, hydro and nuclear fission. The conventional energy resources are able to meet the requirements of central power plant electricity generation in a commercially competitive manner. Their availability in sufficient amounts in India also offers scope for long-term sustainability for several centuries.

Table 2.2.3: Per Capita Annual Electricity Consumption of some countries in 2005

(Taken from www.earthtrends.wri.org)

Country	kWh
Canada	17321
USA	13636
United Arab Emirates	12412
Japan	8201
S. Korea	7804
Germany	7114
UK	6234
Russia	5786
Malaysia	3301
Iran	2143
Brazil	2013
Thailand	1950
China	1781
Iraq	1154
Zimbabwe	961
N. Korea	858
Zambia	710
Vietnam	572
India	481
Pakistan	456
World Average	2596

By "non-conventional" in India is meant wind, biomass, small hydro, and solar. These are useful for electricity production on small scale and in localized places or remote areas.

Other resources, which need technological developments before they can be used in a commercially competitive manner for electricity production, are classified "future".

2.2.2.1 Conventional resources

India has substantial coal deposits with the reserves estimated at 286 billion tonnes, of which 114 billion tonnes are in the 'proven' category and 137 billion tonnes are "indicated", the balance being

“inferred”. Much of the resource is of high ash content and consequently of lower calorific value. Coal has major and important uses in metallurgical and chemical industries, transport sector and for heating. Hence only part of the coal can be used for electricity generation.

India’s hydrocarbon reserves are very limited and would necessarily be used in other than the electric power sector.

India has moderate but mostly untapped hydro potential, which is estimated at a possible installed capacity of 148 GWe or 84 GWe generation at about 60% load factor. Of this potential only 38 GWe has been installed as in 2011. The difficulties in full utilization of the potential lie in the fact that much of it is concentrated in Himalayan ranges and Ghat sections where not only access is difficult but also storage sites are limited. The high capital costs, long gestation periods and environmental objections have proved to be other inhibiting factors.

India has relatively small deposits of uranium. The indicated and inferred resources are equivalent to a total of about 60000 tonnes of uranium. India has vast resources of thorium of about 225,000 tonnes of equivalent metal.

Table 2.2.4 approximately compares the approximate energy potential of various resources in India.

Table 2.2.4: Potential of Conventional Energy Resources in India for Electricity Generation

Resource Type	Estimated Recoverable Quantity	Energy Potential GWe.y	Utilization	
			Capacity GWe	Number of years (Load factor)
Coal	100 billion tonnes*	29000	500	81 (70%)
Hydro	Renewable	Renewable	148	Renewable (60%)
Natural Uranium in PHWR (once-through)	61 thousand tonnes	325	12-15	30-35 (70%)
Depleted Uranium in FBR	~ 60 thousand tonnes	16000+	300-350	65 (70%)
Thorium	225 thousand tonnes	155000	500	440 (70%)

* With appropriate reservation for use in other than the power sector.

+ Limited by uranium inventory for the FBR blankets.

It is seen from Table 2.2.4 that coal would deplete in about 80 years. Further development would need coal imports with deleterious effect on the economy. Even saturation development of the hydro resources cannot meet the projected demand. Exploitation of the Indian nuclear resources and utilization of thorium is the key to energy independence for India in coming centuries. The energy

potential of the nuclear resources needs a three stage nuclear power programme as shown in the figure below.

The first stage would produce power from natural uranium while plutonium would be extracted from the spent fuel (which is a mixture of depleted uranium, byproduct plutonium and fission products). The second stage would use fast breeder reactors to produce power from plutonium and create more plutonium from the depleted uranium to grow the plutonium inventory to required levels. The end of the second stage would see the plutonium being used to produce power and also convert the thorium to U-233. The third stage would see the large scale utilization of thorium and U-233. As the uranium in our country is limited and the growth in the second stage is limited by the physics parameters of the fast breeder reactors and not by the rate of investment, it has been decided to augment the indigenous nuclear power programme by importing advanced light waters from abroad as an additional element.

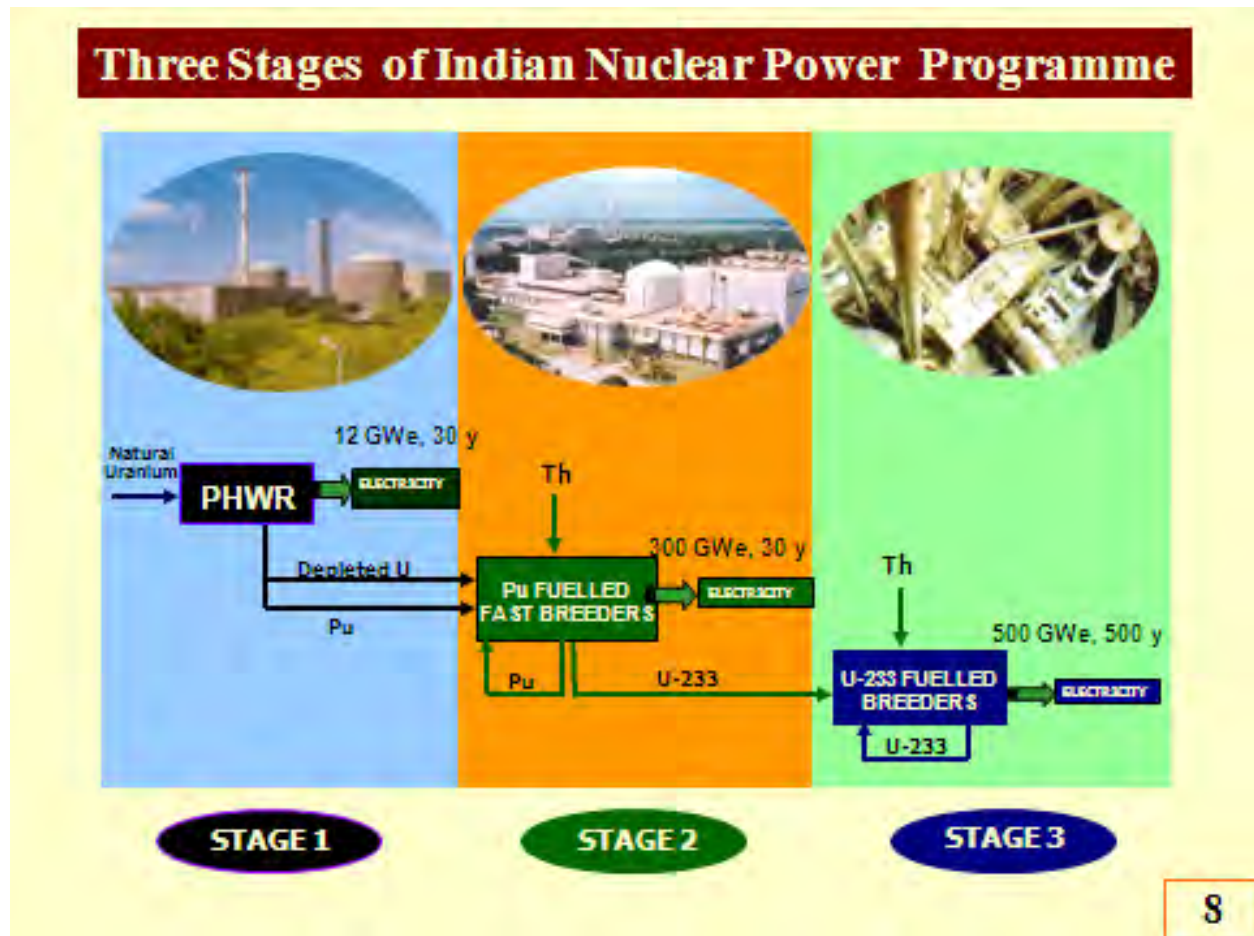


Fig. 2.1 Three Stage Nuclear Power Programme (the numbers quoted are indicative)

2.2.2.2 Non-conventional resources

India needs to exploit all sources of energy like wind, solar, bio-mass and small hydropower. The Ministry of New and Renewable Energy resources is responsible for the development of these forms of energy. The potential and present utilization in 2010 are indicated in **Table 2.2.5**.

Table 2.2.5: India Non-Conventional Energy Potential and Utilization in 2010

Resource	Potential (GWe)	Installed (GWe)
Wind	48.5	12.8
Small Hydro (up to 25 MWe)	15	2.8
Bio Power	24	2.5
Solar	20-30 (per 1000 sq.km.)	0.018
Total		18.2

As can be observed from the Table 2.2.5, the potential of these non-conventional resources (other than solar) is small. Further, they are not suitable for central plant electricity generation with present technologies. While wind has a low availability factor, solar electricity is at present about five times as costly as the conventional means of electricity production.

2.2.2.3 Future resources

Substantially all our energy is presently obtained from fossil fuels and hydroelectric power. There are many other energy resources that have potential for supplying energy needs in the future. Even though some of these energy sources have been used in the past, they do not presently make a significant contribution to the energy supply. These are classified as future energy resources as listed below:

- Accelerator – Breeder;
- Fusion;
- Geothermal;
- Tidal;
- Wave;
- Ocean Thermal Energy Conversion;
- Coal bed methane;
- Deep sea hydrates.

In general, it is not economically attractive, and in some cases it is not technologically feasible, to utilize these energy resources at present. The technological feasibility of many of these new energy resources has been demonstrated analytically, or in the laboratory or in very small installations. The economics of full-scale installations have been projected from these small-scale operations. However, all such extrapolations could be questioned as actual costs may prove to be two or three times the

estimated cost thereby completely negating the anticipated advantage of utilizing a particular energy source. It is even more difficult to predict that major technological breakthroughs can be achieved which will make possible the economic feasibility of utilizing particular energy sources (like fusion or hot dry rock geothermal).

On account of the tremendous potential of these new energy resources it is obvious that substantial amount of R&D for their development is important for the future. At the same time it is clear from the data given in Table 2.2.4 that the long term energy independence of India requires development of the thorium resources on priority.

2.2.3 Comparison of environmental effects of conventional energy resource utilization

The important point to realize in a discussion of environmental effects and hazards of any power producing system is that it should be evaluated by comparing the following:

- a. The benefits accruing from the power production, per se;
- b. The environmental effects associated with any alternate power producing systems.

The benefits of electric power production are enormous. Over the last one hundred years, increased use of energy in the industrialized countries has brought about eight times the real income, double the life expectancy and halving of the working hours. There is a clear correlation between population health and commercial energy use. India still needs an order of magnitude increase in energy utilization to attain these levels. The effects of not having adequate electricity on society and quality of life have to be balanced against the environmental effects of increased electricity production. Human Development Indices (HDI) of the United Nations Development Programme are available country wise and found to be correlated with the per capita annual electricity consumption in the country. Typical HDI are life expectancy, GDP, fertility control and others.

The improvement in HDI starts saturating at higher annual kWh/capita indicating that at above 10000 kWh/capita per annum there may be little gain in increased energy consumption and the risks of energy utilization could become important. However, for developing countries like India with electrical energy utilization in the 600 to 1000 kWh/capita per annum range there is genuine risk in curtailing energy utilization. It can be shown that if the energy utilization were to be increased the reduction of death rate due to increased life expectancy is several thousand times greater than the increase in death rate due to the risk from the increased energy utilization.

The risks of industrial activities such as electric power production are fairly well quantified and relative comparisons are available. Rigorous study of the risks of nuclear power generation shows that it is lower or comparable to other forms of power generation. A low probability of severe accidents exists for all energy producing systems, including nuclear. As an example **Table 2.2.6** gives the normalised fatality rates in different energy options during 1969-1996.

Table 2.2.6: Experience based immediate fatality rates in full energy chain for different energy options during 1969-1996

Energy Option	No. of Severe Accidents with fatalities	No. of Immediate Fatalities (per GWe.y)
Hydro	9	8.8×10^{-1}
Oil	334	4.2×10^{-1}
Coal	187	3.4×10^{-1}
Natural Gas	86	8.5×10^{-2}
Nuclear	1	8.4×10^{-3}

(Source: Stefan Hirschberg et al., "Severe accidents in the energy sector- comparative perspective" in Journal of Hazardous Materials, Vol.111 (2004) pp.57-65)

Comprehensive industrial risk studies taking into account the full energy production cycle including the need for production of the materials of construction, the fabrication and erection, as well as waste disposal and the additional energy needed for these, shows that from the point of view of emissions risk the hydro power is best followed by nuclear, wind, solar photovoltaic and fossil. From the point of view of acute risk the best is nuclear followed by gas, coal, oil and hydro.

The comparison of the effects of utilization of the conventional resources for electricity production namely thermal, hydro and nuclear indicates that while they may be equally commercially competitive they are also of comparable risk to the environment. Under the Kyoto Protocol it is necessary for all countries to restrict the emission of greenhouse gases to certain specified rates. Just to reach the present world average per capita electricity utilization will need an installed electric capacity of 600 GWe in India as compared to the present 182 GWe. Such levels of electricity generation would saturate the hydro resources and deplete the coal reserves in the country in a few decades. To meet the requirements of electricity in our country, taking into account the restrictions of the Kyoto convention, development of the nuclear option to its full potential is essential.

3. Safety features of KKNPP against TMI, Chernobyl, Fukushima type severe nuclear accidents (Shri.S.K.Sharma, Former Chairman, Atomic Energy Regulatory Board)

Three Mile Island (TMI) in 1979, Chernobyl in 1986 and Fukushima in 2011 are the nuclear power plant (NPP) accidents involving damage to the reactor core that have occurred in the nearly 60 year history of NPP operation in the world. TMI was rated at level-5 whereas Chernobyl and Fukushima were rated at level-7 of the International Nuclear Event Scale (INES). The INES has 7 levels in which levels 1 to 3 are assigned to safety significant incidents and levels 4 to 7 are for accidents, with level-7 signifying accidents with highest severity.

The nuclear industry has a well structured system of using operating experience feedback. All incidents and accidents are carefully analyzed to identify the causative factors and this information is used, as applicable, in NPPs towards making necessary design and operational improvements. In India also, all safety significant events that occur in our NPPs as also in NPPs abroad, including accidents, are examined in detail and appropriate safety improvements in hardware, procedures and operator training are implemented. Further, the key operating personnel in our NPPs, unlike in many other countries, are graduate engineers who undergo rigorous theoretical and in-plant training before they are authorized to perform the NPP operating functions. They are also required to be periodically reauthorized after receiving refresher training. Consequently the Indian operators are better placed to correctly interpret off-normal plant situations and adopt the most appropriate course of corrective action. This ability of Indian NPP operators has been amply demonstrated on several occasions.

3.1 The TMI accident and KKNPP

TMI-2, a 900 MW pressurized water reactor in USA, was operating at near full power in the morning of 26 April 1979 when the pumps feeding water to the steam generators tripped due to some electrical or mechanical fault. The turbine and reactor tripped as designed. Two trains of auxiliary feed water pumps had been provided to charge water to the steam generators in the event of failure of the main feed water pumps. Unfortunately the valves at the discharge of these pumps had been left in closed position after carrying out maintenance work earlier rendering the pumps ineffective. With no heat removal in the steam generators, the reactor coolant temperature and pressure started rising due to decay heat from the nuclear fuel. This resulted in the relief valve located on top of the coolant system pressurizer to open to relieve the pressure. The relief valve failed to close back after the pressure had come down, leading to continued loss of coolant system water inventory. However, the indication in the control room showed that the relief valve had closed as the indication had been derived from the instrument signal to the valve rather than from the physical position of the valve itself. As the coolant pressure came down, emergency water injection to the coolant system started as per design but the

operators terminated the injection after some time since the water level instrument was showing the pressurizer as full and they were worried about the system getting over pressurized. In reality, while the pressurizer was full of water, the coolant system had been heavily voided on account of boiling of the coolant.

In the absence of heat removal from the reactor coolant and no make up for the depleting coolant inventory, fuel in the reactor core overheated and partially melted. The accident was terminated after the operators closed a block valve on the pressurizer relief line and restored emergency water injection. Small amounts of radioactivity were released to the environment from the reactor ventilation system exhaust stack when the reactor vessel was vented to the atmosphere to release hydrogen that had got generated from the reaction between steam and the overheated zirconium cladding of the fuel. The reactor vessel did not breach and the molten fuel was retained within the vessel. The reactor containment building also remained intact and hence there was no release of radioactivity at the ground level. There was no death, injury or any over exposure to radiation of plant workers or the public. TMI accident happened due to a combination of equipment failure, lack of sufficient instrumentation and operator error.

The KKNPP has been provided with four 100% capacity trains for each of the safety functions which include the auxiliary feed water pumps. There is an elaborate pre-start up check list through which it is ensured that all safety systems are poised and are in their design intended configuration before reactor start up can be taken up. The pressurizer instrumentation has been sufficiently augmented and improved to provide clear and unambiguous indication of water level and status of all valves connected to the pressurizer. An elaborate set of emergency operating procedures has been developed to cater to all conceivable off-normal situations and the operators are thoroughly trained in their execution which includes training on a full scope training simulator. Further, the KKNPP design has several advanced design safety features like the provision for decay heat removal by natural convection cooling by the Passive Heat Removal System (PHRS). The PHRS functions even in the absence of all power supplies as also with no water injection to the steam generators and the reactor coolant system available. An accident of the type that occurred at TMI-2 is therefore not conceivable at KKNPP.

3.2 The Chernobyl accident and KKNPP

The Chernobyl-4 NPP is an RBMK-1000 MW, graphite moderated, vertical channel type, water cooled, and boiling water reactor. The fuel is located in ~ 10M long vertical pressure tubes and coolant water flows through the pressure tubes from bottom to top. The pressure tubes (1660 nos.) are located

inside vertical channels in a graphite stack and mixture of nitrogen and helium flows through the gap between pressure tubes and graphite to cool the graphite and prevent it from coming in contact with air. Heavy radiation shields are placed at top and bottom of the reactor core. A partial containment is provided for reactor block only unlike a full containment building in modern NPPs. There are 211 water cooled control rods (C/R), each rod with a high neutron absorber section at top and a graphite section below it. With C/R in withdrawn condition, the graphite section resides in the active region of the core. In the lowest part of the C/R, water is present over a small height below the graphite section. When C/R is inserted, the neutron absorber section replaces the graphite section in core, thus increasing the rod's capability to absorb neutrons to reduce reactor power.

A test was planned to check if, on loss of grid power, the energy stored in the rotating turbine can be used to generate sufficient electricity to operate emergency core cooling pumps (before the station DGs come on line).

Unit-4 was scheduled for shut down on 25 April 1986 for normal maintenance activities. Shut down of the reactor was started but had to be stopped with reactor at 50% full power (FP) as per grid requirement and it continued to operate at 50% FP for about 20 hrs. Lowering of power was resumed at midnight to stabilize the reactor at 20-30% FP (as per test procedure) but power fell to 1% FP (due to xenon build up during extended operation at 50% power). Control rods were raised to compensate for xenon and with this action power could be stabilized at 7% FP.

The test was started by closing steam inlet to turbine to start the process of slowing down the turbine generator. An additional cooling water pump was started as per test procedure which caused steam pressure to fall. Reactor trip on low steam pressure had been bypassed and emergency core cooling system had been disabled as per test requirement. More control rods were withdrawn to raise reactor power and steam pressure (consequently only 7 control rods were 'in' against the safety requirement of at least 15 rods to be 'in' at any time). The rise in steam pressure, in combination with low operating power, created a core configuration where overall power coefficient was positive. This meant that any increase in power will drive the reactor power to rise further and can cause power surge. As steam pressure rose, the operator tried to manually trip the reactor by dropping control rods.

As control rods started moving down, their graphite sections first replaced the water below., This caused the neutron population in the core and therefore the reactor power to surge as graphite absorbs much less neutrons compared to water. The power surge resulted in sudden and very high increase in fuel temperature leading to the rupturing of fuel rods. Interaction of overheated fuel with water caused

steam explosion and further heating of fuel caused it to vaporize and gave rise to explosion of fuel vapors. The top shield got lifted due to the pressure wave from the explosions and damaged the pressure tubes severely. The graphite stack now got exposed to oxygen forming flammable carbon mono-oxide which ignited and caused graphite fire. The explosions and the large graphite fire destroyed the reactor completely

The Chernobyl accident was caused by design deficiencies and an inadequate test procedure, coupled with several violations of the prescribed procedure by operators who were not adequately trained for this specific task. This placed the reactor in a configuration that was highly vulnerable to becoming unstable and not amenable to control.

KKNPP is a pressurized water reactor, cooled and moderated by light water, and its core containing the nuclear fuel is located inside a pressure vessel. There are no pressure tubes, no graphite moderator and no boiling of water in the core. The control rods in KKNPP do not have any graphite follower and therefore, unlike in the case of Chernobyl, cannot cause any power surge. The design ensures that in any configuration, the power coefficient of the reactor remains negative. The KKNPP reactor is located inside an airtight primary containment building which is surrounded by the secondary containment. There are also other design features in KKNPP which assure adequate core cooling under all conceivable off-normal conditions including total loss of electric power. Even for the hypothetical case of a core melt down, a core catcher is provided where the molten core is retained and cooled and the double containment ensures that there will be no significant radiological impact in the public domain.

The KKNPP is of a most modern design and its design and safety features have almost nothing in common with Chernobyl as explained above. Therefore, it is just not conceivable that even an accident scenario similar to Chernobyl, let alone the accident per se, can develop in KKNPP.

3.3 The Fukushima accident and KKNPP

Fukushima-I NPP, located on northeast coast of Japan, has 6 units of boiling water reactors. An offshore earthquake of magnitude-9 with its epicenter ~ 130 KM from the NPP, struck on 11 March 2011. The quake also generated large tsunami waves. Units-1, 2&3 got shut down automatically (units-4, 5&6 were already in shut down state). Grid power supply was lost due to the earthquake. As per design, emergency diesel generators (EDGs) of the NPP started automatically to supply essential AC power. Batteries of the NPP supplied essential DC power. About 14m high tsunami waves hit the plant after ~ 45 minutes. Due to extensive flooding caused by tsunami, the EDGs failed. DC batteries drained out in ~1 hour leading to total loss of power supply at units-1, 2, 3&4. An air cooled back-up DG for units-5 and 6

located at a high elevation, that was provided as a retrofit to ensure availability of emergency power in the event of a strong tsunami, continued to function. With this power, the reactors of units-5&6 could be cooled. Units-1&2 and units-3&4 were also provided with similar back-up air cooled DGs but unfortunately these were located at a lower elevation and hence failed due to flooding at the site from tsunami.

With no power available, reactor cooling in units-1, 2&3 was lost resulting in overheating and damage of uranium fuel (fuel of unit-4 had been unloaded at that time into spent fuel storage pool located adjacent to reactor vessel). It took a long time and large effort to restore cooling to the Overheated fuel cladding made of zirconium reacted with water producing hydrogen which escaped into reactor buildings. Equipment had been provided to recombine the hydrogen with oxygen in the air but did not work in the absence of power supply, leading to hydrogen explosions. Some radioactivity escaped from the plant and evacuation of population up to 20 KM radius around the NPP and restrictions on consumption of food, milk etc. was imposed as a matter of abundant caution. However, no member of public received radiation dose more than the prescribed limit. With significant efforts over a considerable length of time, the reactors could be secured with adequate cooling. Cleaning of the areas around the plant is in progress to enable people to return to their homes. Fukushima accident happened due to a combination of extreme external events leading to complete loss of power supply.

In the case of KKNPP the nearest off shore fault line (Andaman-Nicobar-Sumatra fault) capable of generating a tsunami, is located about 1500 KM from KK. Thus, unlike in the case of Fukushima, there is no possibility of a tsunami and an earthquake occurring together at KK.

The maximum flood level at KKNPP site on account of the strongest tsunami or storm surge has been determined as 5.44M above the mean sea level. Keeping a further safety margin of 2M, the safe grade level for the site has been decided as 7.44M above the mean sea level. All important structures and components including emergency power supply equipment at KK are located well above this elevation. Thus, unlike in Fukushima, where the emergency power supply equipment failed due to flooding from tsunami, even the strongest tsunami cannot disrupt the emergency power supply at KK and cooling of the reactors can be maintained without interruption.

Even assuming that all power supplies are lost due to some unforeseen reason, cooling of the reactors at KK can still be maintained by the Passive Heat Removal System (PHRS) that is provided as a further measure of defense in depth. The PHRS works on the principle of natural convection cooling and, unlike in Fukushima, does not need any power supply at all. Heat from the reactor is transferred to the

large quantity of water present on the secondary side of the steam generators and this water in turn is cooled by atmospheric air in the coolers provided at a height on the outside of the outer containment.

Even under a hypothetical accident condition of core melt, the molten core is retained and cooled in a core catcher that is provided below the reactor vessel. Radioactivity from the damaged or molten fuel cannot come out of the inner containment building inside which the reactor is housed. This is an air tight pre-stressed concrete building designed for maximum pressure generated from the worst possible accident and is periodically tested for its leak tightness. Any small leaks from cable and pipe penetrations are retained by the outer containment building. The Fukushima NPP did not have any secondary or outer containment.

The catalytic hydrogen re-combiners provided at KK are of the passive type and they do not require any power supply for their functioning. At Fukushima the hydrogen re-combiners needed power supply for their working and since power supply was not available, they failed to function resulting in hydrogen explosions.

Fukushima NPP is of a much older design and did not have several of the safety features that are provided in KKNPP which is of a most modern design. As brought out above, it is not conceivable that any accidents of the type that occurred at TMI, Chernobyl and Fukushima can take place at the KKNPP. Further, the KKNPP has advanced design safety features which provide assurance of reactor cooling and containment of radioactivity under even hypothetical accident conditions.

4. Radiation Safety and Public Health (Dr.M.R.Iyer, Former Director, Division of Radiation Safety, IAEA, Vienna)

4.1 Radiation safety and impact on the public

4.1.1 Introduction

The International Commission on Radiological Protection (ICRP), an International body of multi disciplinary experts is an advisory body providing recommendations and guidance on setting up radiation protection standards; it was founded in 1928. It uses for its data base large volume of scientific information on the effects of radiation and analyzed by other International bodies such as UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) and is based on a highly technical complex feedback mechanism. The ICRP recommendations on limits of safe exposure from radiation are adopted and used by all countries.

In the Indian context the Atomic Energy Regulatory Board (AERB), an independent board regulates the nuclear operations in the country and sets the standards. The Board is being further

strengthened under a new bill to make it more transparent and having appellate, statutory structure. The general notion that the AERB and NPCIL are same is thus wrong. The AERB has an intricate structure of evaluation through scientific committees of experts drawn from all over India for any nuclear project and these are time consuming and thorough technical safety evaluations and makes appropriate safety stipulations. The Board periodically audits the safety, performance and impact of the operation of all the nuclear plants in India. During the operation of NPPs for the last 40 years (20 of them are operating now) only incidences of Nuclear event scale 1 or rarely 2 have happened implying that these had been no effect on the public environment. Thus the safety culture is an integral part of the regulatory structure in India. It might be added that in the past there were internationally acclaimed safety experts in India who were considered as *gurus* of the profession internationally. People might talk of tsunami today, but as early as mid seventies this was foreseen by our safety experts who insisted on installing several key components high enough not to be affected in case of tsunami which did stand the test well during the Tsunami of 2004 at Kalpakkam.

4.1.2 Natural background radiation

Some information on natural background radiation would not be out of place. Like gravity human beings are immersed in a sea of natural radiation from several sources. Radiation is inescapable in nature and Man has evolved with radiation. Radiation is measured in terms of the energy absorbed, through a unit known as Sievert. Its sub units are milli Sievert and micro Sievert are the more common units. Human body receives radiation from external sources or from radioactive materials inside the body. The natural radiation dose varies widely from location to location. The sources of radiation are the cosmic rays which come from the space, radiation from terrestrial materials, as all materials contain some amount radiation emitting minerals such as uranium, thorium, potassium etc. Our body contains lots of potassium and a fraction of this is radioactive. The radioactive gases like radon and thoron emitted from natural uranium and thorium are inhaled by us everywhere. In addition to this we undergo medical diagnostic treatments such as x ray, CT scan, angiography, angioplasty etc. during which we receive radiation dose. The world average of this radiation is also substantial.

The sources of natural radiation exposure and medical exposure to public are given in the **Table 4.1.1** and **Table 4.1.2** below. A person on the average receives a radiation dose of 2.4 mSv per year and an additional dose of 0.6 mSv from diagnostic medical procedures. As compared to this the world average of dose received from manmade sources such as nuclear power production is very insignificant. There is a very wide variation in the natural radiation exposure by man from place to place.

Table 4.1.1: Dose from natural radiation (mSv/year)

Type	Source	World Average	Typical range
Natural	Natural air	1.26	0.2 to 10
	Internal	0.29	0.2 to 10
	Terrestrial	0.48	0.3 to 10
	Cosmic	0.39	0.3 to 10
	Sub total	2.40	1 to 13
Man made	Medical	0.60	0.03 to 20
	Man made	0.0052	0 to 20
	Sub total	0.60	0 to 20
	TOTAL	3.00	1 to tens

Source: UNSCEAR

Table 4.1.2: Radiation exposure to public in common medical investigations

Procedure	Typical dose
Chest x ray	0.02 mSv
Abdomen x ray	6 mSv
CT scan	8 mSv
Angiography	5 – 16 mSv
Angioplasty	8-57 mSv
World average of medical dose to man	0.6 mSv/year
Dose from natural potassium in body	0.3 mSv/year
Average annual dose from natural radiation	2.4 mSv/year
Air travel for 5 hours	0.03 mSv/year
Expected dose to public from KKNPP	0.042 mSv/year

Source: UNSCEAR

The **Fig.4.1.1** below compares pictorially the permitted dose to the public from KKNPP with the natural background dose and that due to other common activities involving radiation.

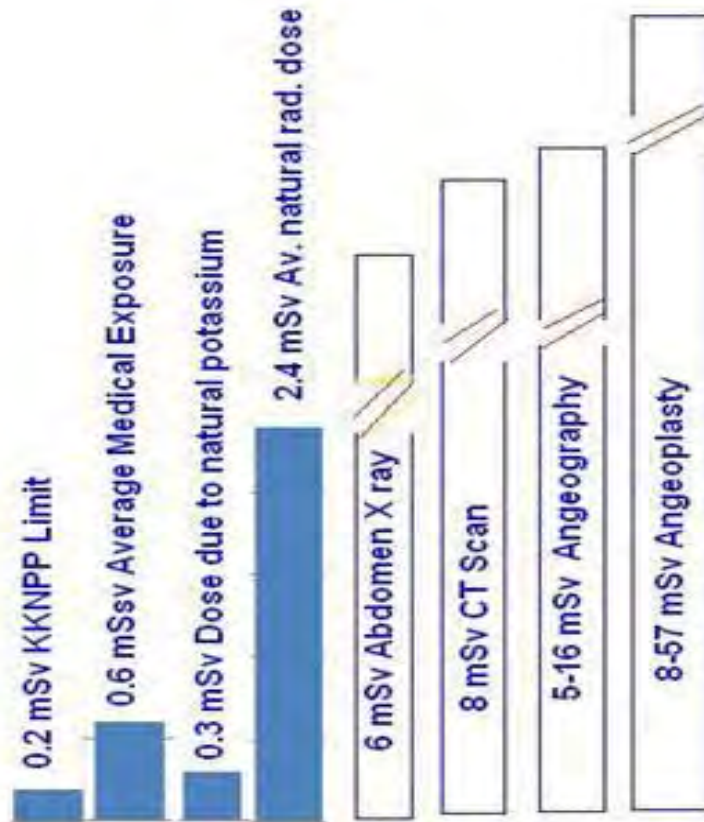


Fig. 4.1.1 KKNPP public dose limit compared to common radiation exposures

4.1.3 Effect of low level radiation as observed in high radiation background areas of Kerala.

There are areas in many parts of the world where the natural background radiation is much higher than other places due to the occurrence of radiation emitting thorium uranium bearing minerals. Such areas exist in our country also. The western coast of Kerala, some coastal areas in Tami Nadu are amongst these where people receive 5 times more radiation dose than elsewhere. Other areas of such elevated radiation background are in Brazil, China and Iran. These locations provide a natural laboratory for the study of the effects of low levels of radiation on the health of the people staying there for generations.

There have been several evaluations on the effect of elevated natural radiation background in the country; the noted one is by the Regional Cancer Research Centre, Trivandrum. As you will see such elevated radiation background has not given rise to any deleterious effects on human beings. . And the levels of radiation from nuclear plants don't exceed a small fraction of even the variation in natural radiation background. In fact the philosophy of ICRP in setting the limits of exposure to public is *inter alia* to consider the variation in dose from natural radiation to which public is always subjected to. This

clearly demonstrates that there is no cancer incidence or genetic effects from exposure to radiation at low levels of radiation.

The public around Kudankulam will not receive more than 1 percent of this dose due to the operation of KKNPP. We can safely conclude that there will not be any deleterious effects due to radiation from the operation of the power station on the public.

4.1.4 Limits of radiation exposure adopted by AERB

The limits of radiation dose from the man made nuclear operations for the public and for occupational workers recommended by ICRP and adopted by AERB are summarized below. These are recommended by ICRP after extensive review of the research the world over on the effects of radiation. Exposure at these levels will not lead to any ill effects.

The radiation exposure to workers in nuclear operations (Occupational Dose Limits) should not exceed any of the following:

- Dose of 20 mSv/yr averaged over five consecutive years
- A dose of 30 mSv in any year;
- Lifetime effective dose limit 1 Sv

Dose Limits for Members of the Public: an effective dose of 1 mSv in a year (this is over and above the 2.4 mSv on the average everybody receives naturally). This is illustrated schematically in the **Fig.4.1.2** below.

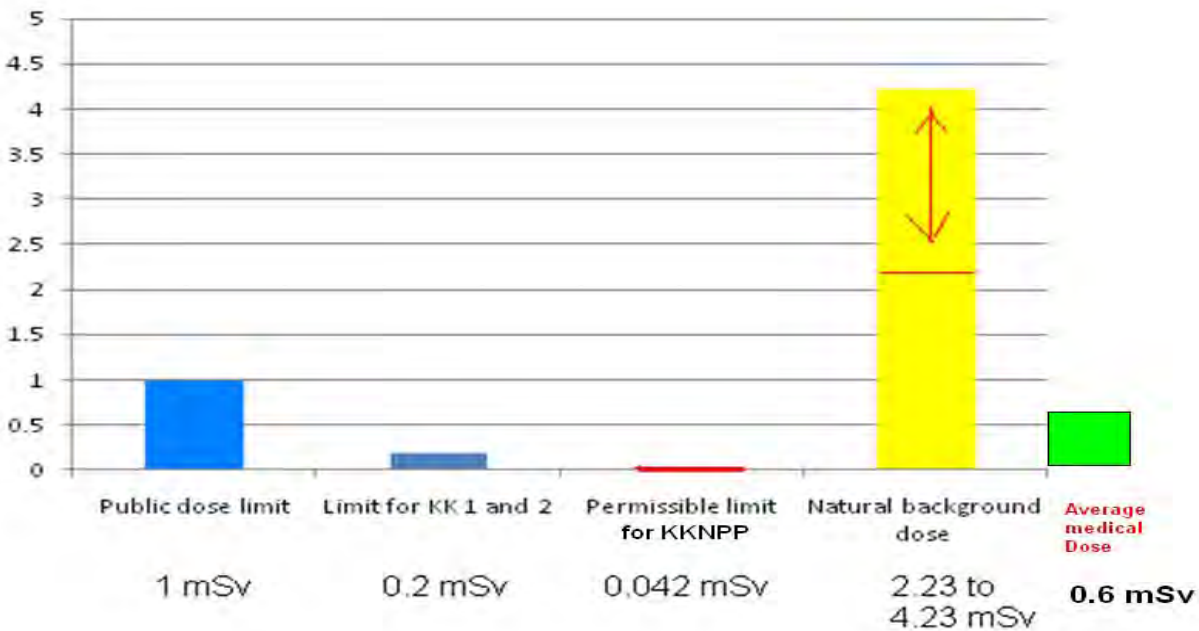


Fig. 4.1.2 Dose limits for public

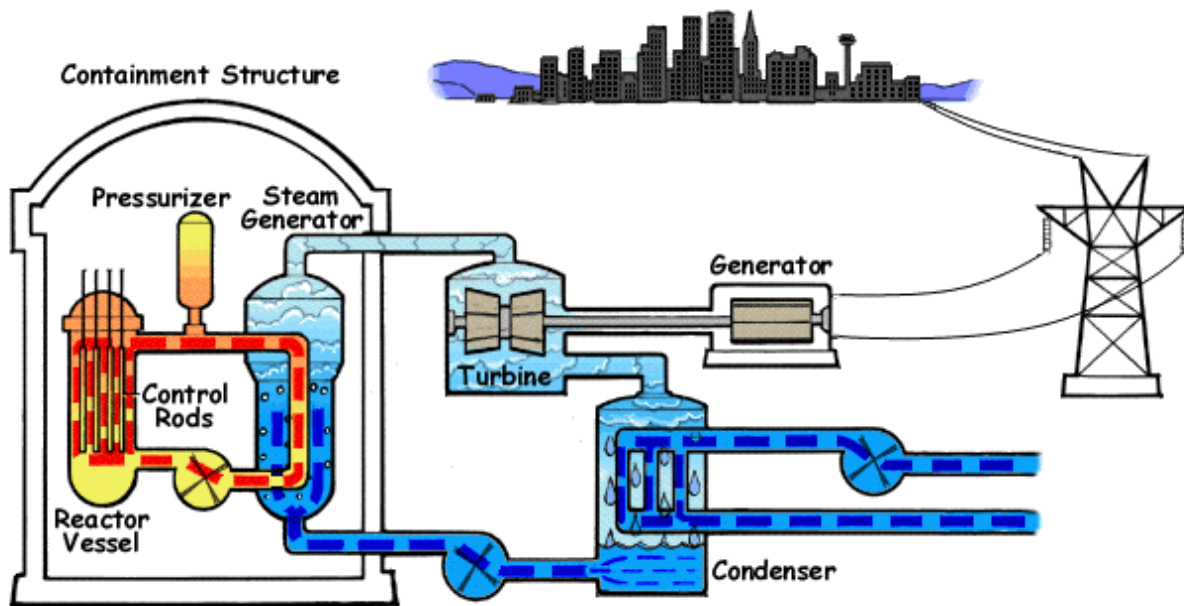
4.1.5 Routine radioactive emissions from KKNPP

In the context of these limits let us examine the situation proposed for KKNPP. After going through the documents of KKNPP it is seen that:

- No radioactivity release through the sea water cooling is possible since this loop is physically separated by three levels from the coolant loop which enters the reactor as indicated in **Fig.4.1.3** below.
- However some low and medium level waste would be generated in the station which is treated inside the plant. Very low level effluents from these would be generated and there are norms and limits for their releases.

Gaseous routine emissions are basically exhaust air from building ventilation systems. It is filtered in High Efficiency Particulate Air (HEPA) filters and Activated Charcoal filters before discharge to the Stack

Fig. 4.1.3: Sea water coolant loop physically separated from the primary coolant loop at KKNPP



4.1.6 Limits of radioactivity releases for KKNPP

As stated above the regulatory limit of exposure to public: is 1 mSv/year from all sources excluding the natural radiation. Generally regulatory authorities stipulates only a small portion of this limit should be allowed from a single unit and for twin KKNPP reactor units the limit is 0.2 mSv.

The limits of concentration of radio nuclides released are set such that the resulting dose from the release of radioactivity in air and water are:

From Atmospheric Release: 4.26% of limit.

For Liquid Discharges: 0.02 % of limit,

Total Dose: 4.26 % of limit,

This is only a small fraction of even the variation in dose due to natural background. (In the villages around KKNPP dose due to natural radiation varies from 2.23 to 4.23 mSv/year).

The authorized limit of low level effluents through air and water from KKNPP is restricted such that it will not lead to more than around 4.26 percent of the dose limit for the public recommended by ICRP (1 mSv). The expected rated releases would however be much lower (0.02 %). The concentrations of discharges are measurable and their limits are fixed to ensure this. The limits of concentrations in aquatic and atmospheric releases fixed are such that the dose will never exceed the authorized limits. The concentrations of discharges through stack are monitored continuously. The activity levels of liquid discharge are monitored daily to ensure this.

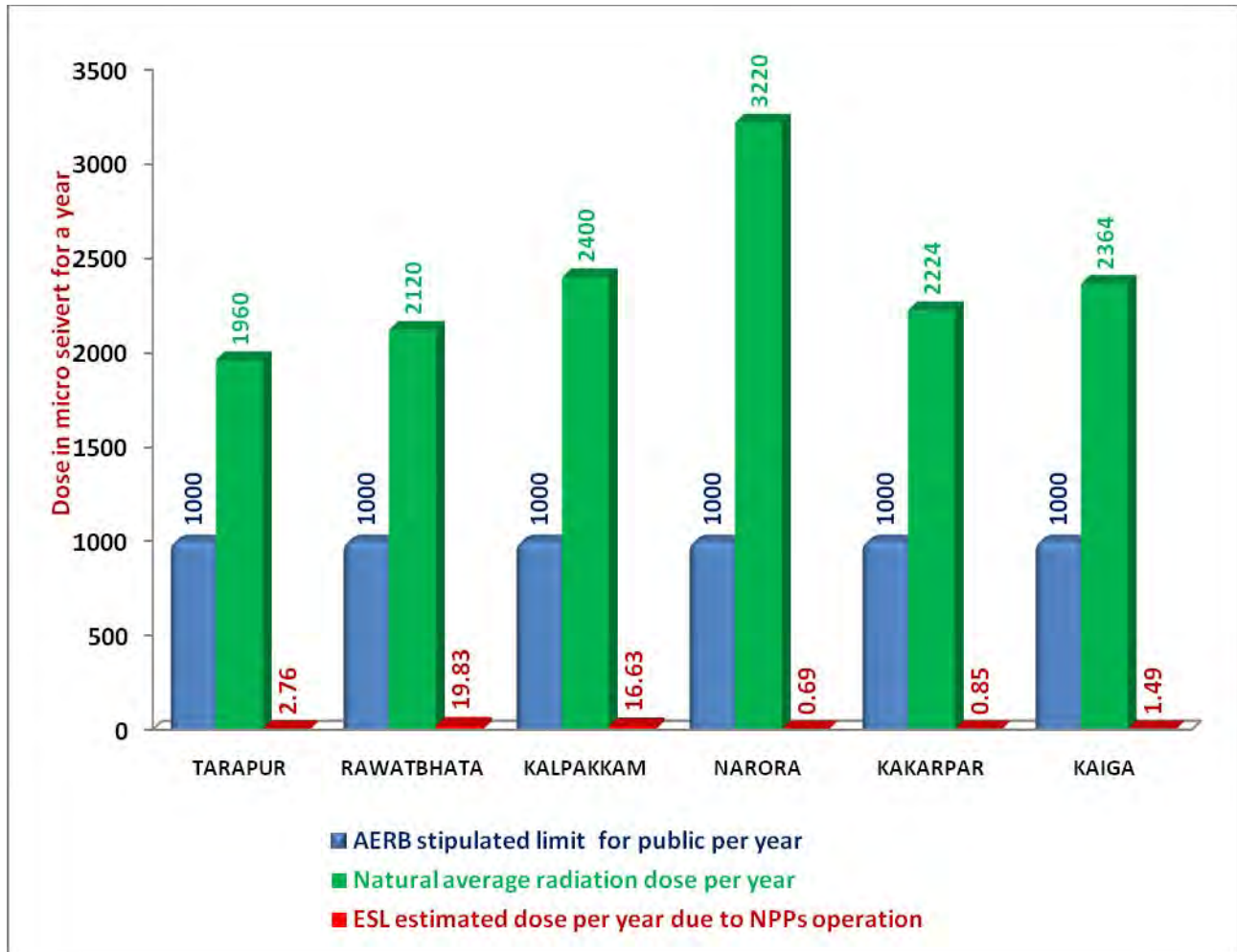
Environmental radiation and radioactivity monitoring is performed for the purpose of assessing the dose to the general public from the operation of nuclear facilities to demonstrate compliance with regulations that the limits of allowable doses are never exceeded. In India the environmental survey program of the Environmental Survey Laboratory, an organization independent of NPC is sufficiently intense to assess the impact, if any, on the flora and fauna and in estimating the dose to a member of the public. An ESL laboratory is in operation at KKNPP since 2004 and routine pre operational radioactivity analyses of the samples are being carried out to establish background levels and to establish the strategies of monitoring. As in all the other nuclear sites the environmental radioactivity assessment program would be continued after the station goes into operation to ensure that there is no impact of the station on the environment and to the public. The periodic reports are audited by the Regulatory Board. These records also would prove to the public that the releases are within the limits

ESL monitors the external dose around the power station and also the radioactivity content in samples like water, air, soil, flora and fauna to assess the internal dose. Thus the dose to the public from external radiation as well as possible intake of radioactive materials is assessed periodically. The baseline data has been established and records are available for reference. This activity will be continued throughout the entire lifetime of the Plant and records maintained. This is done to insure that

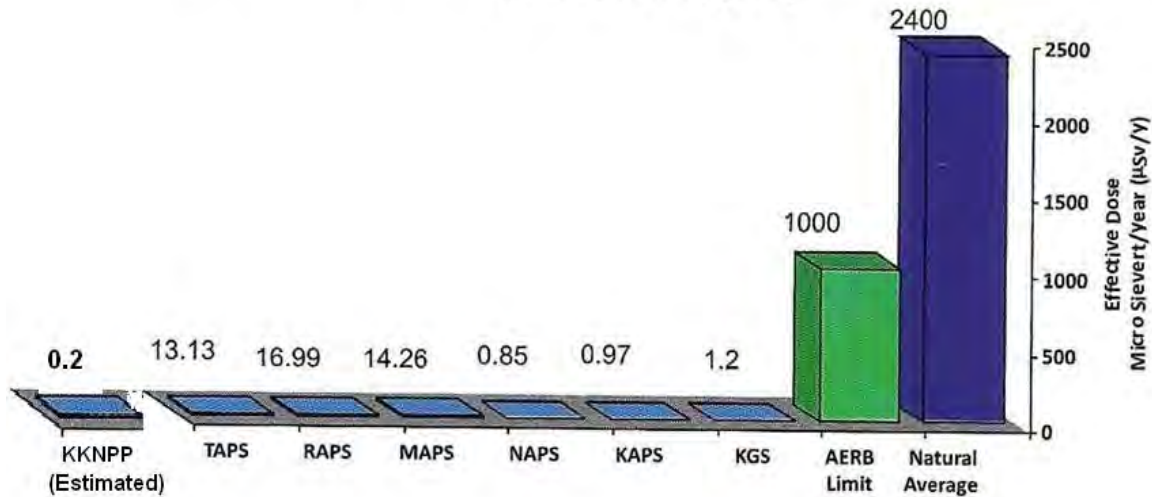
the impact of the operation of the plant is within the limits prescribed by AERB and is a statutory requirement.

Environmental radiation dose at various NPP sites in India recorded during 2006-2010 is shown in the Fig.4.1.4 and Fig.4.1.5 below.

Comparison of Environmental Radiation Dose at NPP Sites (2006-2010)



Average Annual Effective Dose from NPPs at 1.6 Km(2006-2010) (MicroSievert/year)



4.1.7 Impact of the low level of radiation around NPPs

- People who have been living for generations in the high background areas in our country, receiving 25 times more dose from natural radiation do not have any ill effects as medically proved by the studies of Regional Cancer Centre Trivandrum.
- DAE workers live in close vicinity of atomic centers all over India (their limit for exposure is 100 times more than the KKNPP limit) have been proved to have no noticeable health effects as observed from the detailed epidemiological survey conducted by the scientists Nambi and Mayya in 1998.
- Further, UNSCEAR, an International committee on the effects of atomic radiation working for more than 60 years found no genetic effects even amongst the progenies of the Hiroshima Nagasaki atomic bomb victims.

When these are the facts, how could a small percent (1%) of the natural radiation dose that might be received around nuclear power stations lead to any genetic effect or cancer incidence?

The fear about genetic effects of radiation around nuclear sites is more psychological and is contrary to scientific facts. As such we feel that the radiation safety of the people around KKNPP is guaranteed and there would be no impact of the operation of the power station on the public.

4.1.8 Workers safety and well being

The recommendations of limits of exposure for radiation workers adopted by AERB were listed earlier. KKNPP further stipulates in-house limits to ensure that in no case workers will exceed these limits. They have monthly, quarterly limits to ensure this.

KKNPP has an intense program of monitoring the monthly radiation exposures using TL dosimeters. These are augmented by use of direct reading dosimeters. The records of the exposures are kept by the station and by the centralized DAE dose registry.

The operations carried out in KKNPP do not envisage leading to any significant internal exposures through inhalation or ingestion of radioactivity. However there are internal monitoring programs at KKNPP such as whole body counting to assess the dose to workers through this route.

For regulatory auditing and control a system of periodic reporting and auditing is in place to ensure the station operates with no impact on the personnel. The experience in all NPCIL nuclear reactors shows that during the last 5 years no worker has exceeded the cumulative limits.

The exhaustive epidemiological survey of the radiation workers in India by Nambi and Mayya in 1998 has shown that the incidence of cancer amongst the radiation workers and their families who live in the vicinity of nuclear power plants in India is no different from control populations.

4.1.9 Conclusion

From the exhaustive analysis given above it is concluded that there need to be absolutely no concern amongst the public living around KKNPP and the operation of the nuclear power station would not certainly give rise to any deleterious effects amongst people.

4.2 Nuclear radiation and health

4.2.1 Introduction

There are widespread beliefs amongst the lay public about the potential safety hazards from nuclear radiation to the general population primarily related to cancer and birth defects. Much of this fear and concern has resulted from lack of understanding/awareness in public minds about radiation in general and its effects on health in particular. This lack of awareness has resulted in unfounded fear and panic about radiation and health hazards. While it is easy to get carried away by passionate rhetoric, it is important to remain dispassionately scientific and objective about evaluating the potential and real effects of nuclear radiation on human health.

4.2.2 Causation of Cancer

Cancer is a complex biologic phenomenon. There are several causative factors – tobacco, obesity/diet and alcohol are responsible directly or indirectly to more than two-thirds of all cancers. The other factors are related to ultra violet rays, ionising radiation, excessive thermal sources (as in Kangri cancers) and chronic irritation (as in sharp tooth causing ulcer in the tongue), in addition to heredity, racial factors and viruses. It is important to understand that radiation **is only one of the many causes of cancer** and its contribution to cancer causation is small (attributed to 2% of all cancers). Moreover, cancers do not occur due to exposure to low dose radiation. **Low dose exposure of radiation does not contribute to increased incidence of cancer.**

4.2.3 Background radiation

Before we go on to look at the evidence on nuclear radiation and health, it is important to understand a few basic points about radiation. Radiation is universal, and occurs naturally in our environment from the soil, outer space, televisions and diagnostic medical tests. An ‘average’ person is struck by about 15,000 particles of radiation every second from natural sources, and a routine x-ray involves being struck by about 100 billion particles! Although this might appear dangerous, it is not, because the likelihood of a radioactive particle to cause cancer or genetic disease in the human body is one in 30 million billion. The average year will result in approximately 2.3 mSv background radiation to a human being while radiation due to a nuclear plant being nearby is far less. The radiation exposure in and around nuclear power plants is not different from preoperational levels (**Table 4.2.1**).

**Table 4.2.1: Levels of Radiation in and around Nuclear facilities (Kalpakkam) and Control areas
(Exposure Rate mSv/yr)**

	Zone/Location	Preoperational	Operational
a.	1.6 to 8 km zone	2.79 – 3.20	2.49-2.99
		1.21-1.48	1.08-1.26
	<u>Mahabalipuram</u>	1.19-1.36	0.95-1.32
		1.49-1.56	1.26-1.40
b.	8-16 km zone	2.38-2.82	2.23-2.88
		0.93-1.06	0.87-1.12
	Thirukazhukundram	1.60-2.04	1.42-2.22
c.	> 16 km zone		
	Kovalam	0.89-0.98	0.86-1.00
	Madras	1.11-1.34	0.88-1.20
	Chingleput	0.83-1.24	0.68-0.92
	Madhuranthakam	1.11-1.12	0.99-1.32

No significant difference is seen around nuclear power plants before and after it started operation.

There are many areas in India which have a much higher natural radiation exposure than the national average. For example, in Kerala, some people living along the high radiation areas receive 10 times the national average exposure. It is a less-known fact that radiation from a nuclear power plant in normal operation is less than radiation emitted from a coal power plant! Most of the adverse publicity of nuclear radiation stems from their supposed effects on human diseases, mainly cancer and congenital anomalies (birth defects). There have been several studies in different parts of the world on populations living close to nuclear power plants. Most of the studies in India have been done in areas close to established nuclear power stations and high radiation areas like Karunagapally in Kerala (close to the thorium-rich sands).

4.2.4 National studies

The Regional Cancer Centre at Thiruvananthapuram performed a study involving more than 4 lakh people living in the area covering an area of 192 square km. Here, the entire population was studied for their lifestyle, habits etc., and radiation levels inside and outside the house as well as in the soil were measured. Cancer incidence was recorded from the population based cancer registry using internationally accepted methods. The overall cancer incidence was found to be similar between Karunagapally and Thiruvananthapuram although Karunagapally received a much higher radiation dose. Moreover, cancer was found to be less than half the incidence found in other parts of India like the north east states of Mizoram where there were no nuclear power plants.

The Tata Memorial Hospital performed studies in Tarapur (Maharashtra) and Kakrapar (Gujarat). The Tarapur study was done with over 10,000 individuals working at the nuclear plant, their families and children. No increase in cancer incidence was seen amongst all the categories compared to those who were not exposed to radiation. There was no increase in the incidence of birth defects among children born to radiation workers. The Kakrapar study showed no cancers amongst those living in the area.

Using the same methods as the Tata Memorial Hospital, the Arignar Anna Memorial Cancer Research Institute in Kanchipuram performed a similar study in Kalpakkam. More than 5000 radiation workers, nearly 4000 spouses, and over 5000 children born of these workers were studied for the occurrence of cancer and birth defects. No differences were seen in cancer incidence between radiation workers in Kalpakkam and non-radiation workers; there was also no difference in cancer incidence between radiation workers at Kalpakkam and non-radiation workers at BARC, Mumbai. The prevalence of cancer

seen was in fact, lower than the national average prevalence of cancer. Occurrence of birth defects were also similar to the national average.

The SMS Medical College, Jaipur conducted a similar study in Rawatbhata with similar results. The Jawaharlal Nehru Medical College, Aligarh conducted the same study in Narora Atomic Power Station and came to similar conclusions as the previous studies. Overall studies done in Tarapur, Kakrapar, Kalpakkam, Rawatbhata, and Narora have all reached similar conclusions that cancer incidence and birth defects amongst people living in nuclear installations are similar or lower than the national average.

4.2.5 International studies

These studies are not confined to India alone. There have been several studies conducted in different parts of the world including Canada, UK, France and Finland. In a large study in Eldorado, Canada, over 17,000 individuals were followed up for several decades. The incidence of cancer and all diseases were found to be actually lower than the national average. Another study investigated 29 nuclear power stations in France and a 20 km radius around the nuclear plants. This study also showed a lower incidence of cancers compared to the national average. Similar studies were carried out in Finland and Taiwan with no increase in the incidence of cancers or birth defects.

All National and International studies have clearly documented that **nuclear facilities do not contribute to any significant difference in incidence of cancer, including leukemia.**

4.2.6 Other health concerns

4.2.6.1 Birth defects

Birth defects, abortion etc., occur only when radiation is received during pregnancy – directly to the fetus as in x-rays or CT scans being done during pregnancy. X-rays and CT scans during pregnancy is banned except under life threatening conditions to the mother. Hiroshima and Nagasaki studies which had the largest number of persons exposed to radiation did not find any increase in birth defects or hereditary effects.

4.2.6.2 Genetic Effects of Radiation

Studies so far in and around nuclear facilities do not find any evidence of genetic effects of radiation. This is confirmed by:

- a) the Karunagapally study of 4 lakh population for over 10 years;
- b) the UNSCEAR study on genetic effects among progenies of Hiroshima, Nagasaki atomic bomb victims.

4.2.7 Medical uses of radiation

Nuclear radiation has several medical uses both in diagnostics and treatment. Many millions of lives have been saved by both diagnostic and therapeutic applications of radiation.

4.2.7.1 Diagnostic uses

Most diagnostic tests, especially those involving imaging use the principles of radiation. It would be impossible to think of modern medicine without the support of radiological imaging, which use nuclear radiation extensively. These tests, to name a few, x-rays, CT scans, bone scans, PET scans - help clinicians – surgeons and physicians the world over diagnose human diseases accurately, thereby enabling optimal treatment. Radio isotopes are used extensively in diagnostic procedures like thyroid iodine scans, bone scans, lung perfusion scans and brain scans. Radiation exposure due to diagnostic procedures and permissible limits has been outlined elsewhere.

4.2.7.2 Therapeutic uses

Nuclear radiation is also extensively used in the treatment of a number of human cancers. Several cancers like those of the larynx and hypopharynx (throat), esophagus (foodpipe), cervix etc are treated curatively using radiation therapy. In addition, radiation is used along with surgery and chemotherapy in a number of other solid cancers including the oral cavity (mouth), tongue, stomach, rectum and bone tumors amongst others. It is estimated that over half (50-70%) of all patients with cancer are treated using radiation therapy at some point in their disease. Radio isotopes are also used in treatment of cancers like thyroid cancer in addition to diagnostic purposes.

4.2.8 Summary

To summarise, nuclear radiation is one of the most important sources of energy, giving clean, green energy with very minimal risks to the population or to the environment. Modern nuclear power plants are safe and cause no major increase in environmental radiation. The incidence of cancers and birth defects are not increased due to radiation from functional nuclear plants. Nuclear radiation is extremely useful to medicine and is applied widely in diagnosis as well as treatment of human diseases.

5. KKNPP Reactor Design and Safety

(Shri.S.K.Mehta, Former Director, Reactor Group, BARC & Prof. Kannan Iyer, IIT, Bombay)

- a. VVER is a pressurized light water cooled and moderated reactor with four independent cooling loops. The reactor has horizontal steam generators in each loop that gives high water storage

capacity. It uses hexagonal fuel assemblies which have low enriched fuel in oxide matrix, housed in sealed Zirconium- Niobium alloy tubes.

- b. KKNPP is an advanced model of the Russian VVER 1000 that adopts the basic Russian design model marked V320 with Enhanced Safety Features to make it in line with IAEA GEN III reactors. Further, certain additional safety features were incorporated like Passive Heat Removal System taking it to GEN III+ category. Russian Federation has marked KKNPP reactor as V412.
- c. The safety features of KKNPP were comprehensively reviewed by a task force of NPCIL in the context of recent Fukushima accident. The report of the task force is available in the website of NPCIL and DAE.

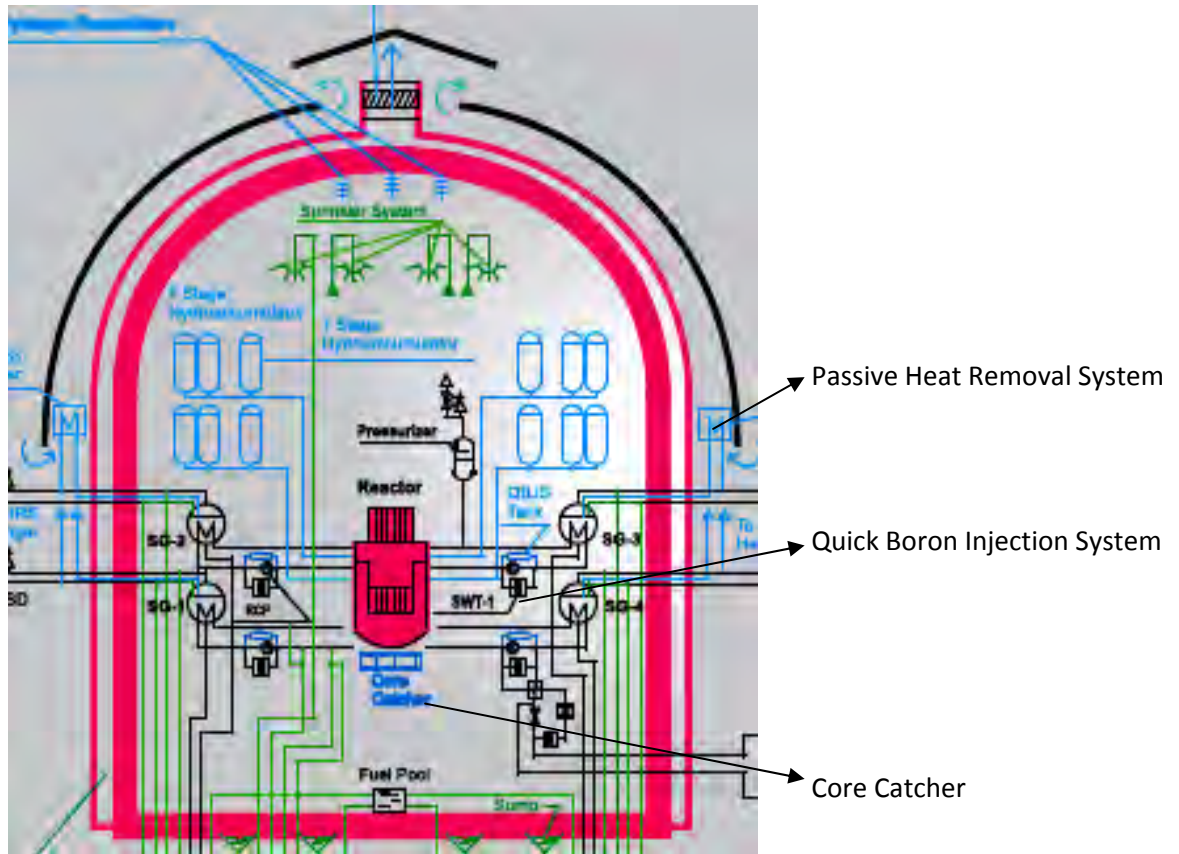
d. Salient Normal Operating Parameters of KKNPP Reactors:

- Electrical Power 1000 MWe
- Thermal Power 3000 MWt
- No. of FAs 163
- Coolant inlet temp 291°C
- Coolant outlet temp 321°C
- Coolant Pressure 15.7 MPa
- No. of Loops 4
- No. of Control Rods 103
- Pressure Maintenance by Pressurizer

e. Enhanced Safety Features:

Key Safety Features incorporated in KKNPP as required by India:

- Quick Boron Injection System
- Passive Heat Removal System
- Second Stage Hydro Accumulators
- Passive Hydrogen Re-combiners
- Annulus passive filtering system (passive system)
- Core Catcher
- Emergency Control Room.



The above systems have been developed based on extensive R & D and simulated testing by Russian design institutes. Functional performance of these systems are established during commissioning stage. These systems are described in subsequent sections.

f. VVER 1000

Plant model	Site (units)	Status	No. of Units
V-320	Balakovo NPP (1-4), Zaporozhe NPP (1-6), Rovno NPP (3,4), Khmel'nitsky NPP (1,2), South Ukraine NPP (3), Rostov NPP (1,2), Temelin NPP (1,2), Kalinin NPP (3), Kozloduy NPP(5,6)	Operating	22
V-412	Kudankulam NPP (1,2)	Under Construction	2
V-428	Tianwan NPP (1,2)	Operating	2

* In addition to the above:

- VVER -1000 reactors are under construction in Russian Federation.
- Recently VVERS are planned in Vietnam, Turkey and Bangladesh.

g. IAEA Safety Review Of VVER1000 (V-320)

This review was done by international Experts in 1994 and recommendations have been incorporated in the V-320 and are part of KKNPP - V412 also.

h. Safety Functions for a NPP

The following safety functions shall be performed in all operational states, i.e. during normal operation, during and following design basis events conditions and specified beyond design basis events (BDBEs):

- Control of the Reactivity (control of fission chain reaction)
- Heat removal from the core and
- Confinement of radioactivity

i. Safety during Normal Operation:

During Normal Operation (NO) & Operational Transients (such as Turbine trip, pump trips etc), the reactor is controlled by the controllers within certain operational limits and conditions. The control is achieved by following parameters:

- Control of Reactivity:
 - i) CPSAR (Control and Protection System Absorber Rods)
 - ii) CVCS (Chemical Volume Control System)
- Heat Removal from Core:
 - i) Primary Coolant Circuit (four independent loops)
 - ii) Steam Generator (one in each loop)
 - iii) Turbine & Condenser
- Confinement of Radioactivity by following multiple barriers:
 - i) Fuel Matrix and sealed Fuel Clad
 - ii) Reactor Coolant System with Chemistry control
 - iii) Containment and Containment filtration Systems
- Plant operation shall be carried as per Technical Specifications for operation approved by AERB which ensures that the plant is operated within safe parameters.

j. Systems Catering to Design Basis Events (DBE):

Though a detailed design analysis indicates that the reactor will operate within the design parameters, safety systems have been provided to ensure safety during postulated events, known as Design Basis Events (DBEs).

DBE postulations have been made as per AERB guidelines which follow international practices. An example of DBE is break of main coolant pipe resulting in loss of coolant accident, known as LOCA.

During DBEs, reactor is shutdown by the control rods.

The Reactor core cooling will be maintained by the following safety systems, which are four train independent systems:

- High Pressure Emergency Injection System: Starts injecting borated water to the reactor core when primary pressure falls below 7.9 MPa
- First Stage Hydro Accumulators (Passive system): Starts injecting borated water to the reactor core when primary pressure falls below 5.9 MPa
- Long term decay heat removal System: Starts injecting borated water to the reactor core when primary pressure falls below 1.9 MPa
- Emergency Safety Boron Injection System: Injects borated water to the pressuriser to depressurize the reactor during steam generator tube leak, so as to minimize the leakage of primary coolant.

k. Backup Systems for Control Rods (4 Trains):

Control rods are passive systems which are designed to drop under gravity. They are tested extensively in the test set ups and during commissioning. During reactor operation and annual shutdown, the performance of the rods is monitored. However, even under the postulated failure of control rods (event known as Anticipated Transient Without Scram or ATWS) , reactor is designed to shutdown using following additional safety systems:

- Emergency Boron Injection System: Injection of boric acid solution to the reactor at high pressure - 16 MPa
- Quick Boron Injection System (Passive System): Injection of concentrated boric acid solution to the reactor.

I. Systems for catering to Beyond Design Basis Events DBE (Enhanced Safety Features)

In line with the current international practices, certain beyond design basis events have been postulated. To ensure the safety under these conditions, following systems have been provided. These enhanced safety features are additional systems in KKNPP.

- **Passive Heat Removal System (PHRS):**

Decay heat removal from the core following complete loss of power supply, known as station black out (SBO).

- **Additional Core Passive flooding system (passive II stage accumulator):**

Supplies borated water to the reactor core during a multiple failure such as simultaneous occurrence of LOCA and SBO.

- **System for retaining and cooling of molten core (Core Catcher):**

Retention and long term cooling of molten core under a postulated severe accident condition.

m. Reactor Containment

Nuclear steam supply systems are housed in a Reactor Containment, to contain any release of radioactivity. It also provides protection against external hazards.

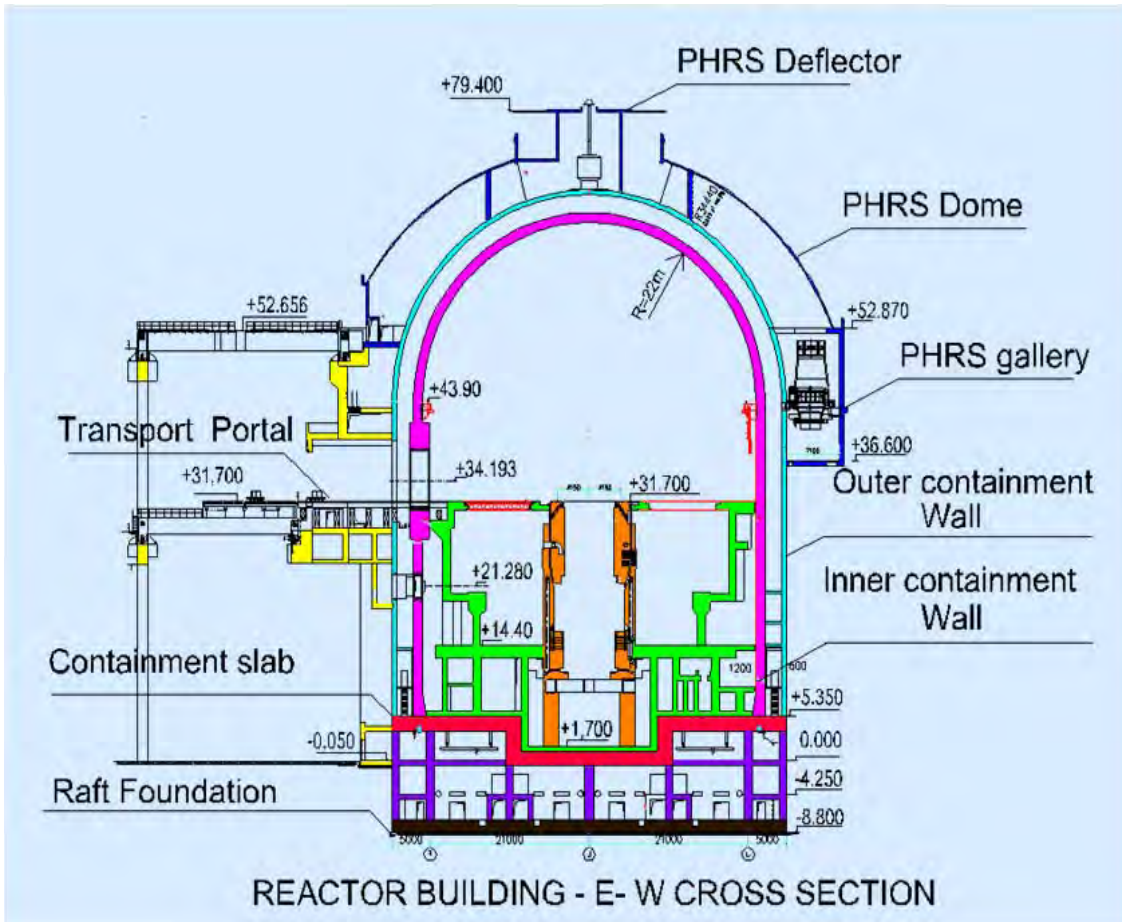
- Salient Features of Containment structure
 - i. Double containment structure: Pre-stressed inner Containment (IC) with leak tight inner steel liner & Reinforced concrete Secondary Containment.
 - ii. Air locks with double doors;
- Design pressure is 0.4 MPa (g) based on estimated pressure due to loss coolant accident
- Design temperature is 120°C
- Containment has been tested up to a test pressure of 0.46MPa
- Permissible containment leakage rate is 0.3% volume/day. Leakage rate observed during containment leak rate test conducted during pre-commissioning was 0.18 % volume/day. As part of in-service inspection, containment leak test is carried out periodically.
- Secondary Containment Designed to withstand
 - i. Aircraft Crash (such as Cessna and lear jet aircraft)
 - ii. Air Shock wave

- Sub-atmospheric pressure maintained during normal operation and under accident conditions so as to minimize ground level releases

n. Containment Systems:

Following systems are provided to maintain the integrity of the containment and its functional capability under abnormal conditions:

- Containment Spray System: Condenses steam due to any leakage from the primary or secondary system, thus limiting pressure rise in the containment.
- Annulus passive filtering system (passive system): The annular space between the primary and secondary containments is always maintained at a negative pressure which prevents any ground level releases. During an SBO condition, this negative pressure is maintained by the natural draught created due to the PHRS operation.
- Passive Hydrogen Re-combiners: Hydrogen, if generated during accident conditions, is recombined in Passive Hydrogen Re-combiners to convert it to water. This prevents any hydrogen ignition within the containment. They are located at various locations within the containment.



o. Supplementary Control Room

Supplementary control room (SCR) is provided in the shielded control building, to enable essential safety functions and monitoring of all the important parameters in case of main control room (MCR) becoming inaccessible.

p. Training and Qualification

- Training - Three Phase Programme
 - i. Operators are graduate engineers with adequate experience
 - ii. Phase – A → Orientation course and Examination
 - iii. Phase – B → Theory & Simulator Training in RF
 - iv. Phase – C → Participation in commissioning activities and Simulator Training – in India
- Qualification of O & M
 - i. Licensing of O&M personnel by AERB and their periodic
 - ii. Requalification including managerial cadre.
 - iii. Details of Qualification Methodology Finalized

q. In Service Inspection

- Monitoring of healthiness of equipments and components is conducted as per ISI program.
- ISI data is compared with baseline data collected during Pre-Service Inspection
- Typical systems monitored are
 - i. Reactor coolant pressure boundary.
 - ii. Systems essential for safe reactor shut down and/or safe cooling of nuclear fuel.
 - iii. Containment Systems
 - iv. Other systems and components whose functioning is essential for systems mentioned above.

r. Material Surveillance

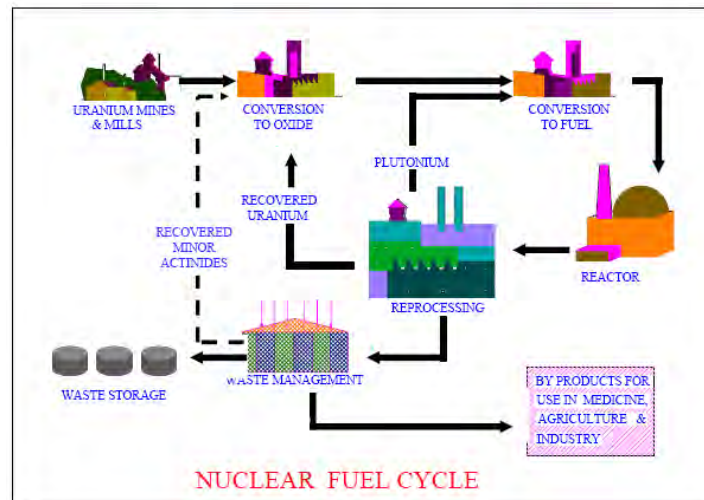
- Material surveillance coupons are installed inside the reactor to assess state of RPV material typically due to neutron irradiation & temperature effects.
- These set of coupons are withdrawn at specified interval of reactor operation and subjected to destructive testing to assess change in mechanical properties of RPV material.
- This method provides sufficient lead time for actions, if required.

6. Radioactive Waste and Spent Fuel Management: Principles and Practices (Shri.K.Balu, Former Director, Nuclear Waste Management Group, BARC)

6.1 Waste generation and Treatment

Management of radioactive waste in Indian context includes all types of radioactive wastes generated from the entire nuclear fuel cycle right from mining of uranium, fuel fabrication through reactor operations and subsequent reprocessing of the spent fuel. **Fig. 6.1** depicts the entire activities across the closed fuel cycle adopted in India along with their connectivity. Besides, such wastes are also generated from use of radio nuclides in medicine, industry and research.

FIG 6.1 NUCLEAR FUEL CYCLE



In consideration to the primary objective of protecting human health, environment and future generation, the overall philosophy for the safe management of radioactive waste relies on the concepts of i) Delay and Decay ii) Dilute and Disperse and iii) Concentrate and Contain.

Effective management of radioactive wastes involves segregation, characterization, handling, treatment, conditioning and monitoring, prior to final storage/disposal. Radioactive wastes arise in different forms viz solid, liquid and gaseous with variety of physical and chemical/radiochemical characteristics. Depending on the level and nature of radioactivity, radioactive wastes can be classified as exempt waste, Low & Intermediate level waste and High Level Waste. Low & Intermediate level wastes are further categorized as short lived and long-lived wastes. Radiological hazards associated with

short lived wastes (< 30 years half life) get significantly reduced over a few hundred years by radioactive decay. The high level waste contains large concentrations of both short and long lived radionuclides, warranting high degree of isolation from the biosphere and usually calls for final disposal into deep geological formation (repository).

In tune with international scenario, a coherent, comprehensive and consistent set of principles and standards are followed and practiced for waste management system. Wide range of treatment and conditioning processes are available today with mature industrial operations involving several interrelated steps and diverse technologies. A brief summary of the various radioactive waste management practices followed in India has been presented in Fig.6.2.

FIG. 6.2: SUMMARY OF THE RADIOACTIVE WASTE MANAGEMENT PRACTICES



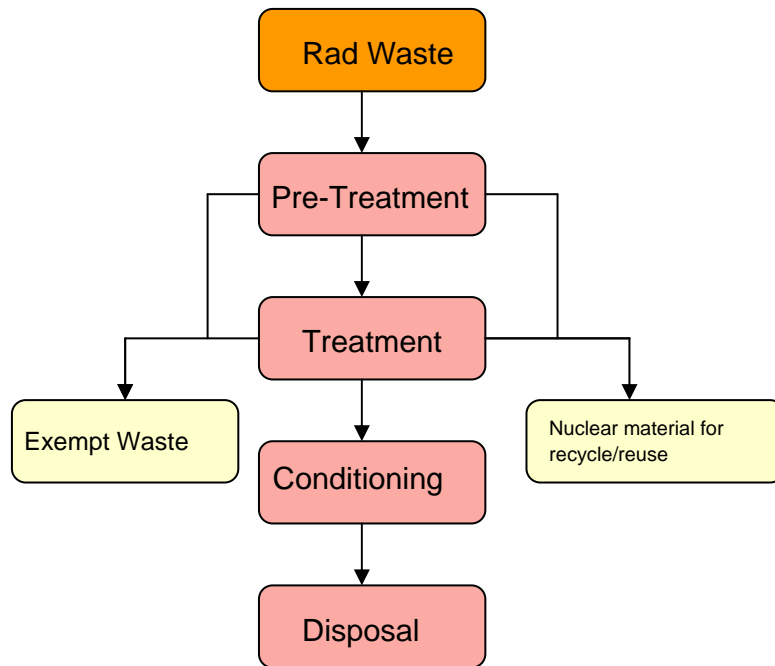
6.1.1 Low & Intermediate Level Wastes

6.1.1.1 Liquid waste

Low & Intermediate level (LIL) liquid wastes have generally high volumes with low levels of radio-activity. Number of processes such as chemical precipitation/flocculation, ion exchange,

evaporation, reverse osmosis etc. is employed either singly or in tandem for the treatment of such wastes. Depending on nature of the waste, radio-nuclides present and level of contamination, the treatment scheme is chosen with the overall view to contain bulk of the activity in process concentrates and the supernatants are discharged after further polishing and monitoring. The relatively small volume of concentrates containing the activity is conditioned towards immobilization in highly durable matrices like cement, polymer etc. Management of such streams is schematically represented in Fig. 6.3.

Fig. 6.3: OVERALL STEPS IN THE MANAGEMENT OF L&IL LIQUID WASTE



Most of the radioactivity present in Low and IL waste is in the form of Cesium(Cs137) and Strontium(Sr90) radioisotopes along with some contributions from Cerium(Ce144), Cobalt(Co60) Ruthenium(Ru106) etc. Chemical precipitation/co-precipitation processes are employed for liquid effluents with higher dissolved solids and varying chemical and radiochemical composition. Copper ferrocyanide and calcium phosphate are used as carriers for co-precipitating Cs 137 and Sr90 respectively and polyacrylamide as flocculating agents. Specific ion exchange resins developed in house have been found to be very effective for treatment of intermediate level radioactive wastes with high concentration of salts (200-250 gms/l) of sodium nitrate. Reverse osmosis method using both cellulose acetate and polyamide membranes is also in use for treatment of L&IL liquid wastes.

With the focus on effective radioactivity reduction (decontamination) and minimization of secondary wastes, up-coming technologies include synthesis and use of specific sorbents (inorganic,

magnetic & bio), adoption of electro-oxidative techniques for organic wastes, cryogenic distillation for separation of radio-nuclides from gaseous wastes, liquid supported membranes etc.

6.1.1.2 Solid waste

Besides the waste forms and residues, containing the bulk activity from liquid waste treatment, relatively larger quantum of solid L&IL wastes of diverse nature gets generated in the different nuclear installations. They are essentially of two types: primary wastes comprising radioactively contaminated equipment (viz. metallic hardwares), spent radiation sources etc. and operational/secondary wastes, resulting from different operational activities, which are as varied as protective rubber & plastic wears, miscellaneous metallic components, cellulosic and fibrous materials, organic ion-exchange resins, filter cartridges and others. Solid waste management plants in India are equipped with facilities for segregation, repacking, compaction, incineration and embedment for radiation sources. Treatment and conditioning of solid wastes are practiced to reduce the waste volume in ways compatible with minimizing the mobility of the radioactive materials contained. Combustible and compactable wastes are generally treated for mechanical compaction and incineration. As appropriate, packaging is usually done in 200l waste drum followed by in-situ grouting. A compactor of 1000-ton capacity as shown in **Fig. 6.4** has been indigenously developed for pelletization of radioactive metallic waste drums. Spent organic ion-exchange resins are immobilized in polystyrene based polymer matrices before disposal.

FIG 6.4: A TYPICAL COMPACTOR



The final packaged and monitored waste is then disposed of in near surface disposal facilities(NSDF), a few tens of meters below the earth's surface. A multi-barrier approach is followed to ensure confinement and isolation of the wastes from biosphere. Various modules of the disposal

facilities are designed to accept different levels of activities in terms of dose rates. While wastes which give out very low doses are disposed off in earth/stone lined trenches, wastes having higher activity are disposed of in reinforced concrete trenches and tile holes. Backfill materials are employed in the design of a near surface repository for prevention of activity migration during off-normal scenario of water ingress into the repository environment. Special emphasis is laid on closure of such modules after it gets full. These include appropriate closure such as clay for the stone lined trench and concrete cover for the other two. Provisions for monitoring & surveillance are incorporated during the design of the near surface disposal facility itself. Provision of Bore holes helps in sampling the ground water for monitoring purposes. Regular environmental monitoring ensures that radioactivity in air, water and soil in and around the disposal facility remains within the safe limits prescribed by the regulatory body.

Fig. 6.5 shows different modules of a near surface disposal facility. India has extensive & varied experience in the operation of near surface disposal facilities (NSDFs) in widely different geohydrological and climatological conditions. As a national policy, NSDF is planned to be co-located at each site of nuclear installations in India.

Fig. 6.5: MODULES OF NEAR SURFACE DISPOSAL FACILITY



6.1.1.3 Gaseous waste

The off-gas and the ventilation system in nuclear power plants, and other fuel cycle facilities play a vital role in ensuring that the air in the working area and the environment remains free from radioactive contamination. To achieve this goal, the air cleaning systems are designed to handle normal and anticipated off-normal conditions. Various designs of scrubbers are deployed wherein off-gases are intimately contacted with suitable liquid media so as to retain the activity in the liquid phase. Specific

adsorbers are also used to address volatile radio-nuclides like iodine, ruthenium etc. The off-gases are finally routed via high efficiency particulate filters (HEPA) which are designed for an efficiency of > 99.9% for sub micron size particles. Surveillance and monitoring of the off-gases ensure that the discharges are well below permissible limits. Treatment of the secondary solid wastes (filters and adsorbers) is accomplished as described above.

India has achieved self reliance in the management of all types of radioactive waste arising during the operation of the nuclear fuel cycle facilities. Decades of safe and successful operation of our waste management facilities are testimony to the Indian waste management practices being at par with international standards. Apart from having made immense technological progress in this field, a valuable human resource base has been created comprising of scientific and technical man power well versed in the design, construction, operation and maintenance aspects of these facilities. In line with global scenarios, technologies are constantly upgraded for minimization of discharges to the environment.

6.2 Methods Adopted at Kudankulam

The origin of radioactivity in a reactor is the fuel that is undergoing irradiation/ fission. The fuel is clad in a metallic tube so all the radioactivity produced in the fuel stays within the fuel tube or clad. In the unlikely event of any pinhole leak from the fuel tube, radioactivity could come into contact with the circulating coolant water which is constantly being re-circulated through the core of the reactor for removal of heat, produced by fission.

1) If any radioactivity enters the primary cooling water circuit, it is effectively removed by Filters and Ion-Exchange columns provided in the circuit. As the primary cooling water circuit in KKNPP is a closed cycle, any radioactivity that escaped from the fuel gets trapped in Filters and Ion Exchangers and would not pose any hazard to either plant or personnel and there is no way it can find its way to environment. Other liquid process effluents are evaporated for an extremely high decontamination, rendering the condensate with insignificant contamination, considered fit for reuse in the plant and the concentrates are concreted to result in a stable matrix for safe storage and subsequent disposal.

2) Similarly if any solid wastes get contaminated with radioactivity, they are carefully collected and as a first step volume of the wastes produced are reduced to a small fraction by treatment methods like incineration and compaction, apart from size reduction; then the wastes are conditioned by being fixed in cement concrete before they are stored safely for an interim period. They would be considered for disposal in a Near Surface Disposal Facility, in a few years time, giving adequate time for decay of short-lived radioactivity.

3) Any radioactivity, in the exhaust air system from the reactor buildings, though insignificant is invariably treated through a series of off-gas clean up system, before release through tall stacks.

4) Due to the total containment of all radioactivity in the fuel tube, the type of wastes that result from various systems in this reactor are essentially low level wastes, with a small quantity of intermediate level wastes. There are no high level wastes associated with the operation of the reactors at Kudankulam.

5) Thus, as a matter of abundant caution and abiding concern for safety of environment and members of Public, a number of state-of-the art technologies are employed in the Safe Management of Radioactive wastes. The track record of DAE in this regard has been exemplary over the past four decades, and compares favourably with the best in the world.

6.3 Spent Fuel Management

First and foremost it should be remembered that Spent Fuel is not a waste in the Indian Nuclear Programme. A closed fuel cycle is followed, where the valuable fissile materials like Uranium and Plutonium which are present in the Spent Fuel are recovered for reuse.

1) Spent fuel is therefore an asset that needs to be preserved. At Kudankulam, Spent Fuel from the Reactors will be carefully stored in Storage Pools, which are always filled with pure, demineralized, borated water which is constantly recirculated. These pools are high integrity concrete pools which are additionally lined with stainless steel sheets, to ensure effective containment for extended periods of time. The Department of Atomic Energy has long experience and expertise of a high order in the safe management of Spent Fuel.

2) There is no plan to do the reprocessing of the Spent Fuel at Kudankulam site. As such the storage of Spent Fuel at Kudankulam is to be considered only as an interim measure till they are transported to a Reprocessing Facility.

3) Adequate Technology and years of experience are available with Department of Atomic Energy for transporting Spent Fuel from one site to another through both Railways and by roadways, in a safe manner without any public hazard. This is done as per stipulations of AERB, regarding Transport Regulations that govern safety.

7. Ecological Effects

(Prof.N.Sukumaran,Director, School of Life Sciences, VELS University, Chennai, Prof.M.N.Madhyastha, Former Professor, Mangalore University & Dr.A.K.Pal, Professor, Central Institute of Fisheries Education, Versova, Mumbai)

7.1 Marine ecology and fish protection

7.1.1 Base line data collection.

The baseline data of the marine environment of KKNPP has been well established through the studies undertaken by

- a. Manonmaniam Sundaranar University.
- b. Institute of Ocean Management, Anna University.
- c. Engineers India Limited/ CMFRI.

7.1.2 Fish protection in intake facility

Kudankulam project uses sea water for condenser cooling for which water is drawn from intake dykes. To save the fishes from coming into the fore bay / pump house area and getting trapped, KKNPP houses a unique “fish protection system” where in all the fishes which are coming into the intake will be separated by means of a unique air curtain and “Oogee weirs” and are safely returned back into the sea. This is an unique facility to protect the marine organisms, including fish and prawns.

7.1.3 Effect of Condenser cooling water on marine life.

The approximate quantity of coolant water, when the plant is in operation released in sea will be 70 tons per day with a maximum delta T of 7 degree Celsius.

The seasonal variation in surface water temperature of Kudankulam Marine Environment ranged from 23°C during monsoon and winter season to 29°C during summer season, with an annual average of 26.6°C.

The studies on the lethal affects of temperature on selected fishes and prawns of Kudankulam Marine Environment showed that the lethal temperature of fin & shell fishes was found to be between 38.2 and 43.2° C. Considering maximum possible surface sea water temperature of Kudankulam areas as 29°C, during summer months and the rising the temperature as stipulated by MoEF as 7°C, the maximum temperature at discharge point will be 36°C, which may not harm any fish even in the vicinity

of discharge point. But during monsoon and winter season the ambient surface water temperature will be considerably low (23°C) and hence no effect will be envisaged in the discharge area. In fact the mixing will be very fast due to wave action and other water currents. Due to the wave action the mixing of warm water from condenser with ambient sea water will be instantaneous and a possible reduction of ambient sea water temperature will be expected. Considering the fact it is obvious that there may not be any harm to the fishery potential of Kudankulam Marine Environment due to the establishment of KKNPP. It is again supported by the fact that fish, being a cold blooded animal, it can adjust the body temperature with that of environment within the sub lethal temperature and a rise in body temperature will enhance all biological activities, including growth and production. In addition, the fish and prawns will have the capacity to sense the change in temperature in ambient water and try to avoid and move away from the adverse condition, if any, from the point of discharge

The operation of Nuclear Power Plant in the country at the coastal locations at TAPS, Tarapur in Maharashtra and MAPS at Kalpakkam in Tamil Nadu has also not shown any adverse effects on Marine life including the fish.

7.2 Impact on land, agriculture, livestock and food

7.2.1 Impact on Land

Beneficial impacts would be felt on land use pattern and topographical features of the area due to greening of the area through plantation and green belt development. Under operating conditions, there will not be any impact on the land environment as discharges are insignificant as compared to the combined natural background parameters.

As of June 2011, a total of 23890 plants and trees has been developed for green belting, at Kudankulam site (KKNPP). The area covered by lawns and gardens is 16419 Square meters. Hedges accounts for 2467 Running meters and this will help to improve the quality of environment around NPP. The green belt development will be continued in future which will attract more fauna specially avian species resulting in improvement in biodiversity as evident in other nuclear power stations like Kaiga, Kalpakkam, Tarapur etc.

7.2.2 Impact on Agriculture, live stock and food security

National Environmental Engineering Research Institute (NEERI) has prepared the Environmental Impact Assessment (EIA) report and had documented the land use classification in 30 Kms radius of the plant site based on satellite mapping.

The land use/ land cover classification indicates 8.73% area covered by vegetation, 8.73% are covered by Barren land, 23.39% area covered by scrubland, 8.52% area covered by sandy area, 0.08% built-up area, 49.68% water body including sea, river/nala etc.

This is the baseline data. However data from the other nuclear power plants in the country indicate that operation of NPPs do not have any adverse impact on agriculture, live stock and food security.

7.3 Impact on flora and fauna

As such the land acquired has been dry and barren and hence there is no impact on the flora and fauna inside the plant area. NEERI has conducted the base line study of the biological environment in and around KK site and is well documented.

As stated earlier, a total of 23890 plants and trees has been developed for green belting, at KKNPP. The area covered by lawns and gardens is 16419 Square meters. Hedges accounts for 2467 running meters.

The Green Belt programme will be continued to develop a green belt in the vacant land, after assigning the plant structures of KKNPP 3 to 6. Because of the green belt developed, the area around plant and township has become a hub for migratory birds.

7.4 Bio-sphere considerations

7.4.1 Gulf of Mannar Biosphere reserve

- The nearest biodiversity richness region of Gulf of Mannar biosphere reserve is located north of Tuticorin which is more than 80 Kms from the plant site.
- CMFRI while preparing the marine EIA had conducted exhaustive sampling covering 60 Sq Kms of the site. They have clearly stated that “the marine ecosystem of the KKNPP region has characteristics of an oceanic region which is different from the productive ecosystems of the west coast , gulfs and bays.”
- Another significant ecological feature of KKNPP Site is the absence of sensitive habitats like mangrove and coral reefs in KKNPP coast. The CMFRI have confirmed that there are no formations of coral reefs south of Tuticorin and along the Kanyakumari coast (including the Plant neighborhood).

7.4.2 Western Ghats

- The EIA document confirms that there is no forest area within 15 km of the plant site.
- As such there is no impact on the Western Ghats due to setting up of KKNPP.

8. Earthquake and Tsunami

(Prof. Harsh K.Gupta Panikkar, Professor,NGRI, Hyderabad & Prof. C.V.R.Murthy, Dept. of Civil Engg, Earthquake resistant design of structures)

8.1 Earthquake design methodology

Structures, systems and components (SSC) of Indian nuclear power plant (NPP) are designed for two levels of earthquakes which are estimated according to safety requirements laid down by the Atomic Energy Regulatory Board (AERB) which are in line with the IAEA (International Atomic Energy Agency) guidelines (IAEA Guide 50-SG-S1):

- 1) S1 level of ground motion or OBE (Operating Basis Earthquake).
- 2) S2 level of ground motion or SSE (Safe Shutdown Earthquake).

S1 level corresponds to the maximum ground motion which can be expected to be experienced at the Site during the life of the NPP i.e. once in a 100 years. All SSC necessary for power generation are designed for this level of ground motion.

S2 level corresponds to the conservatively estimated level of ground motion which can be expected to occur once in 10,000 years. All SSC important to safety are designed to remain functional during a S2 level earthquake.

SSE is derived on the basis of maximum earthquake potential associated with the tectonic structures and seismotectonic province in the region and takes into account:

- I. the maximum earthquake potential inside the seismic tectonic province of the site associated with specific tectonic structures
- II. the maximum earthquake potential inside the seismic province of the site not associated with specific tectonic structures
- III. the maximum earthquake potential for the adjoining seismotectonic provinces associated with specific tectonic structures and
- IV. the maximum earthquake potential for the adjoining seismotectonic provinces not associated with a specific tectonic structure.

8.2 Earthquake Design Basis for KKNPP

(Reference: "Earthquake Design Basis for Kudankulam Site" report prepared by Dr. A.K.Ghosh, BARC & Shri D.C. Banerjee, AMD)

Kudankulam Nuclear Power Plant is located in Indian Seismic Zone II which is the least seismic potential region of our country. (ref. IS 1893). However, for designing of the Plant, detailed studies are conducted to conservatively estimate extent of ground motion applicable to the specific Site with

reference to Seismotectonic and Geological conditions around it so that NPPs are designed for a SSE level earthquake which has a very low probability of being exceeded (return period of 1 in 10,000 years).

For Kudankulam NPP, the following tasks were undertaken for detailed evaluation of Site specific conditions as below:

- a) Study of the seismotectonic and geological setup of the region.
- b) Selection of a set of recorded accelerograms with source and site conditions resembling those at Site for computing response spectra.
- c) Generation of response spectra of the selected time-histories for various values of damping and statistical analysis of the ensemble of response spectra.
- d) Collection of additional information on earthquakes, regional and local geology and tectonics pertinent to evaluating fault activity and design basis ground motion parameters.
- e) Integration of the above information to arrive at the Earthquake Design Basis (EDB). This involves the generation of peak ground acceleration and response spectral shapes for various components of ground motion for both S1 and S2.
- f) Generation of spectral compatible accelerograms.

All potential, active and non-active faults, lineaments and seismic history within a radius 300 kms have been analyzed to arrive at the SSE and OBE levels of earthquake. As per above data, there are no faults / lineaments in the near vicinity of the site. The most intense earthquake experienced in this 300km region is the earthquake that occurred at Coimbatore (307 km) on 08/02/1900 which had an epicentral intensity of VII on the MMI scale (6.0 in the Richter scale).

Towards enhanced conservation, the high intensity earthquakes that occurred in this seismotectonic region have been assumed to act at the closest faults/ lineaments near the site in arriving at the SSE level. The Site specific response spectra for SSE at KKNPP has been derived from the envelope of these hypothetical events.

Considering the above events, a rock-site-specific formula for the maximum peak ground acceleration valid for the range of magnitude and distance of interest has been derived.

The peak ground accelerations thus evaluated for KKNPP are as follows.

Peak ground acceleration (g)		
Level	Horizontal	Vertical
<i>SSE</i>	<i>0.15</i>	<i>0.11</i>
<i>OBE</i>	<i>0.05</i>	<i>0.036</i>

In conclusion, the seismic parameters for the design of SSC of KKNPP have been arrived at in a highly conservative manner following the AERB stipulations and thus the seismic safety of the plant is assured with a large safety margin.

8.3 Volcano and Tsunami

The overall passive tectonic of the peninsular India and Sri Lanka is reflected by the moderate and mature continental topography of Precambrian cratons, which is among the oldest and most stable landforms on the earth. This stable cratonic landmass of Indian peninsula is separated from the Gondwana landmass during Late Cretaceous period (Laughton et al., 1973; McKenzie & Sclater, 1971). This stable landmass has experienced several volcanic activities during its lifespan of more than three billion years (>3 Ga) with youngest being during 90.0 ± 1.0 and 87.5 ± 0.9 Ma ago (Kumar et al., 2001; Fig. 8.3.1), which coincides with the timing of breakup of India from Madagascar. It is therefore obvious to find volcanic rocks in peninsular India, but they do not suggest any volcanic activity in recent past or foreseeable future. The spatial occurrence of volcanoes on the earth is not random but follows a tectonic regime and the same is observed in the present day distribution of active volcanoes in the world as well as Indian subcontinent e.g. Barren Islands to the east of Andaman Nicobar Island chain. It is therefore not appropriate to assume active volcanism just by finding volcanic rock at a location. Further, any parallel from the Yucca Mountains in USA cannot be drawn as the Indian peninsula is a stable shield whereas the Yucca Mountains is tectonically active region.



Fig. 8.3.1: Google image of part of Indian peninsula overlaid with the locations of volcanic rocks of respective ages.

The bathymetry of the Gulf of Mannar [Anonymous, 1975] is reminiscent of an amphitheater with an approximately 1 km high outer lip. Along the deeper central portions of the basin (depth from 2600 to 2800 m) is a submarine canyon with a NNW trend. The maximum depth within the canyon is ~ 350 m. Two suites of submarine slumps from opposite margins of the Gulf of Mannar, namely East Comorin slide and Colombo slide originating on respective continental slopes between southern India and Sri Lanka [Vestal & Lowrie, 1982; Anonymous, 1976; Figure 8.3.2]. They are large rotational slides with very little internal deformation in the East Comorin side but the Colombo slides show complex internal deformation. To the south, an enlarging and deepening submarine canyon marks the area of slump coalescence. The Eastern Comorin Slump is the more coherent with a length of 70 to 100 km whereas the Colombo slump consists of two to four blocks 15 to 35 km in length. A paleoslump underlies the western toe of the East Comorin Slump at a depth of some 800 meters is also observed [Vestal & Lowrie, 1982].

Fig. 8.3.2 Slump Zones in Gulf of Mannar

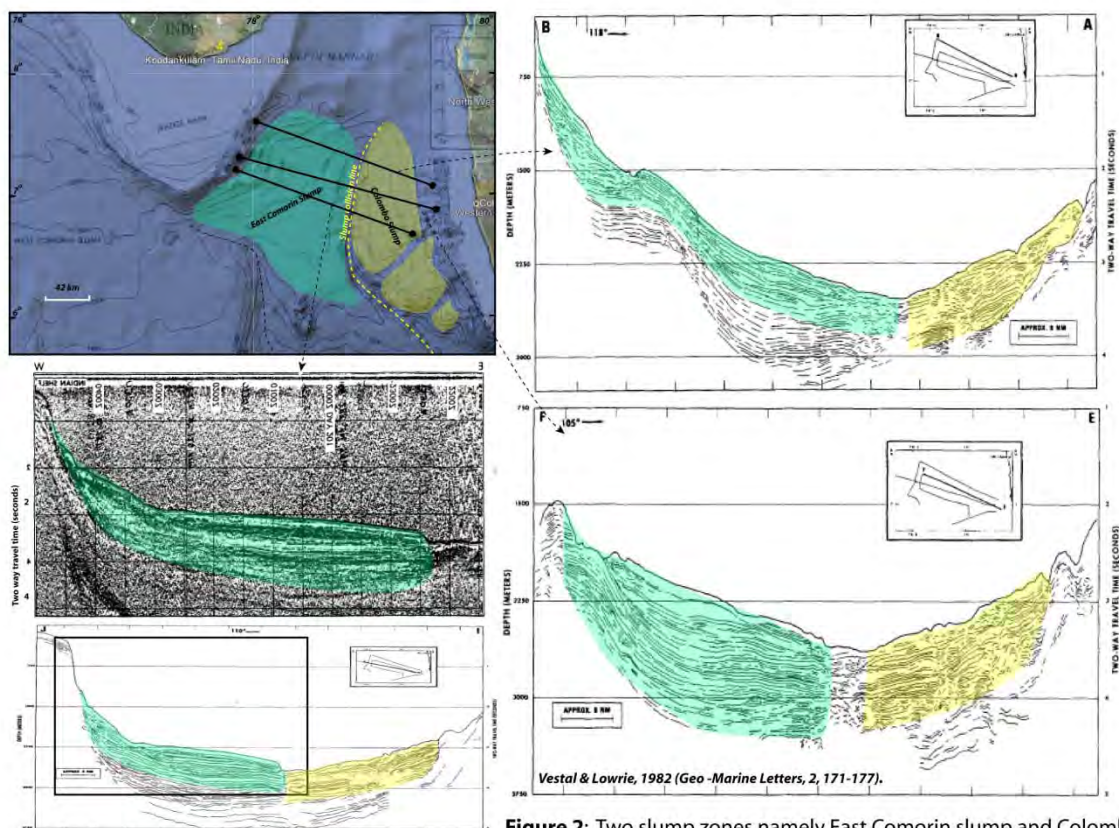


Figure 2: Two slump zones namely East Comorin slump and Colombo

slump are mapped along the passive margin in Gulf of Mannar. These are rotational slump on the continental slope and upper continental rise off Cape comorin with minimal internal deformation within the block and rotation along failure surface. The East Comorin slump with 70-100 km length is more coherent whereas the Colombo slump is constituted of two to four blocks of 15-30 km segments and show internal deformation.

It is suggested that large sub-marine landslides can generate Tsunami and may cause coastal hazard. An attempt has been made to quantify the amount of possible water displacement from the above slump belts in Gulf of Mannar that may occur during the worst case scenario. The hypothetical catastrophe affecting the entire sub-marine landslide (length x width = 100 x 70 Km²) may produce an apparent slip of the order of ~100 m in down slope direction along a slope of ~30°. This will displace an amount of <2.5 Km³ of water per kilometer length of landslide along the coast parallel length of ~100 km. This is very small amount of water displacement to produce a serious tsunami that can cause any damage to the surrounding region. Further, only the Colombo slide, which is fragmented and small in size with 15-30 km length with several internal deformation may not have enough potential to even displace a fraction of volume calculated above to generate any damaging tsunami that will have directivity towards NW i.e. Indian Peninsula (the area of interest).

In conclusion, it can be seen that there has been no volcanic activity in the peninsular India for several million years. Also, there is no possibility of Tsunami affecting KKNPP due to landslip in the Indian Ocean.

8.4 Flood design of KKNPP

8.4.1 Design Basis Flood Level

The safe grade elevation of KKNPP site has been kept at 7.5 Mtr above MSL and a shore protection bund is constructed all along the shore to a height of + 8.0 Mtr to MSL.

The details of arriving at the safe grade elevation, considering either tsunami or storm surge is listed in the table below.

SI No	Rise Water level Due to (m)				Total (w.r.t CD)
	Wave Run up	Max. Tide	Storm Surge	Tsunami	
1	2.0	1.42	2.46	---	5.88
2	2.0	1.42	---	2.50	5.92
Therefore the maximum water level = 5.92 – 0.481 = 5.439m with respect to MSL.					
Keeping a further safety margin of 2.0m, the safe grade elevation is kept as 7.44m (say 7.5m) w.r.t MSL					

8.4.2 KKNPP Building elevations

In addition to the safe grade elevation, sufficient margins are available in each building. Elevations and locations of important safety buildings are given in the table below.

Description	Elevations in meters above MSL	Margin available meters
Pump house grade elevation	+7.65 m	2.21
Reactor Building grade elevation	+8.7 m	3.26
Safety DG building (sealed building)	+9.3 m	3.86
Diesel tanks in DG building	+13.8 m	8.36
Battery Banks (sealed building)	+16.5 m	11.06
Passive Heat Removal System Heat exchangers	+ 52.2m	46.76
Main control Room	+26.0	20.56

In addition, having a higher grade elevation, all the safety related buildings are closed with double gasket leak tight doors.

8.4.3 Shore stability

No potential of shore instability exists at Kudankulam site area, as protruding rock outcrops are present all along the coast protecting the shore from erosion. Also, no historical shore erosion has been recorded in the area.

8.4.4 Tsunami warning systems

Possible Tsunami occurrence can be known as alerts come from the following agencies:

- KKNPP is registered with INCOIS, Hyderabad (Indian National centre for ocean information service). In case of any Tsunami warnings, information in the mobile numbers of the station management will be received.
- Madras Atomic Power station, Kalpakkam has established PC based Earthquake Notification System (ENS) which gives alarm in the control room in case of an earthquake. ENS is an application which scans USGS (US Geological survey) and EMSC (European Mediterranean Seismic Centre) sites. Immediate alert will be given to KKNPP control room from Kalpakkam in case of any alarm.

9. Regulatory and Statutory Clearances

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9.1 Introduction

Regulatory and statutory clearances are to be obtained from the relevant authorities before and during the various stages of construction and commissioning of a Nuclear Power Plant. NPCIL submits the required information to these authorities for obtaining the clearances.

Regulatory clearances are accorded by **Atomic Energy Regulatory Board** where as other statutory clearances are obtained from different Central and State government bodies like **Ministry of Environment and Forest, State Pollution Control Board, Petroleum and Explosives Safety Organization, Central Electricity Authority and Director of Boilers, Tamil Nadu, etc.**

9.2 Nuclear Regulatory Clearances

9.2.1 Guide for consenting process

The AERB guide AERB/NPP&RR/SG/G-1 published in the year 2007 give in detail the CONSENTING PROCESS FOR NUCLEAR POWER PLANTS. The guide details the important stages for obtaining consent in respect of Nuclear Power Plants (NPPs) and the nature of submissions to be made by the applicant at each stage. This regulatory guide is available in AERB web site www.aerb.gov.in .

9.2.2 Major stages of AERB's consenting process for NPPs are as follows:

- Siting
- Construction
- Commissioning
- Operation
- Decommissioning

9.2.3 Brief details of stage wise consenting process and the consents obtained for KKNPP 1&2

9.2.3.1 AERB siting clearance for KKNPP 1&2

NPCIL submitted a detailed **Site Evaluation Report** to AERB along with the proposal for locating KKNPP 1&2 in 1988. Further a supplementary report was made in February and March 1989. Layout of the two units of KKNPP as well as an overall plant layout with the exclusion zone marked was submitted. These were reviewed by AERB in three levels of committees.

Based on the above reviews, AERB granted clearance for Kudankulam site for locating 2 X 1000 MWe VVER's vide their letter no: CH/AERB/KK/8486/89 dated 10th Nov 1989.

9.2.3.2 Construction Consent

For construction clearance the following stage clearances were to be obtained, viz.

- **clearance for excavation,**
- **clearance for first pour of concrete and**
- **Clearance for erection of major equipment.**

9.2.3.2.1. AERB Consent for Excavation of KKNPP 1&2

NPCIL submitted Detailed Project Report and Preliminary Safety Analysis Reports (PSAR) to AERB in June 2000. The submissions covered the following:-

- details of the VVER type reactor, its various safety and design features,
- layout of the two units
- Philosophy of the safety classification of the buildings, systems and components, List of all the building and their classification
- Results of the various Site investigations carried out and site specific design parameters such as Design Basis Ground Response Spectra, Safe bearing capacity of the ground, Safe grade elevation of the site considering coastal flooding etc
- Details of the back ground radiation survey carried out all around the site within a radius of 30km
- Demographic details around the site
- Meteorological data of the site

- Report on Plant Layout which included the layout of the buildings and structures, roads within the Main plant boundary, movement of personal, equipment, and spent fuel and fresh fuel. The report also addressed the underground networks (pipelines and tunnels), Radiation zoning and contamination control philosophy, movement of heavy cargo within the plant site, overall plant drainage scheme etc.

The studies were carried out by various government agencies working in these fields and through experts in those fields.

After review of the submissions, AERB accorded clearance for excavation of the site for the main plant buildings of Kudankulam Nuclear Power Project vide their letter no: CH/AERB/199/KK/2001/8134 dated 9th Oct 2001.

9.2.3.2.2 AERB consent for First Pour of Concrete (FPC) of KKNPP 1&2

NPCIL had submitted all the relevant PSARs and other related documents for obtaining AERB clearance for “First pour of concrete” of the main plant buildings and these were reviewed by AERB.

After review of the submissions in different levels by Specialist Groups and committees constituted by AERB , **AERB gave clearance for FPC vide the following:-**

- 1. Clearance for FPC for Reactor Auxiliary Building of KKNPP 1&2 vide letter no: CH/AERB/199/KK/2002/2501 dated 22nd March 2002,**
- 2. Clearance for FPC of Reactor Buildings of KKNPP 1&2 vide letter no: Ch/AERB/199/KK/2002/3035 dated 9th April 2002.**

9.2.3.2.3 AERB consent for major equipment erection for KKNPP

NPCIL had submitted all the relevant PSARs and other related documents for obtaining AERB clearance for major equipment erection.

All the documents were reviewed in three levels by Specialist Groups and committees constituted by AERB.

After review of the documents, AERB gave the following clearances:-

- **Clearance for equipment erection in KKNPP 1 vide letter no: CH/AERB/199/KK/2006/8531 dtd 30th Aug 2006.**
- **Clearance for equipment erection in KKNPP 2 vide letter no: CH/AERB/199/KK/2007/6808 dtd 22nd June 2007.**

9.2.3.2.4 AERB Consent for Commissioning

The clearance for commissioning is to be obtained in the following sub stages as given below:-

- Hot Run
- Fuel loading
- First approach to criticality
- Power raise and connection of generator to grid
- Power raise to 75%
- Power raise to 100%

AERB grants the clearance for each stage after the review of the reports commissioning activities and tests carried out up to the preceding stage.

NPCIL submitted application to AERB for obtaining clearance for hot run for KKNPP Unit -1 vide letter dated 30th April 2010. Based on review of the **results of various tests, including primary and secondary steam generator hydraulic tests, containment strength and leak rate tests, by specialist committees and their recommendation, AERB granted clearance for Hot-Run of KKNPP-1 vide letter No CH/AERB/KKNPP/199/2011/39 dated June 30, 2011.**

The hot run was completed in July, 2011. All the required tests for hot run were completed successfully. The next stage is permission for opening of pressure vessel, removal of dummy fuel and in-service inspection of vessels and piping. NPCIL has submitted all the documents related to completion of Hot Run and requested AERB for clearance for the next stage.

For obtaining consent for fuel loading, some of the important submissions required are

- results of commissioning and tests pertaining to hot run
- Results of inspection of reactor pressure vessel and other major equipment
- fuel loading pattern and loading procedures
- radiological zoning and commissioning of radiation monitoring system
- availability of health physics facilities
- Commissioning of startup instrumentation

For obtaining consent for first approach to criticality and low power physics experiments, submissions are required on

- tests results of regulating, protection and safety systems
- establishment of exclusion boundary
- onsite and offsite emergency procedures & plans

For obtaining consent for various stages of power operation, results of operation and tests carried out during the respective previous stage are required to be submitted progressively.

The documents and further stage clearance is under review by AERB specialist groups.

9.2.4 AERB Regulatory Inspections

AERB carries out regular Regulatory Inspections (RIs) at KKNPP site to verify compliance to regulatory requirements. Regulatory inspection is carried out twice in a year.

9.3 Statutory Clearances

Statutory clearances applicable to other major industries are also required to be obtained before start of construction/operation of an NPP. These are obtained from different Central and State Government agencies that are specifically authorized for granting permission.

9.3.1 Environmental Clearance

As per the then prevailing norms (as per environment protection act 1986) when KKNPP was initiated in 1989, the applicant was required to apply to the State Ministry of Environment and Forests. The state government used to issue environmental clearance after studying the project details. Further, the same would be forwarded to central MoEF and they would issue a final environmental clearance.

9.3.1.1 KKNPP 1&2 Environmental clearance details

Application in the standard format to Tamilnadu State Department of Environment and Forests/ Tamilnadu Pollution Control Board for setting up of 2 X 1000 MW Nuclear power plants in Kudankulam, Tamilnadu was submitted by NPCIL on 12.12.1988 as per the environmental protection act 1986.

Based on the submissions and verification thereof, Tamilnadu State Environmental Committee which is under the State Environment and Forests Department vide their letter no: 6264/A3/89-1 dated 13.02.1989 gave clearance and forwarded to Central MoEF.

Further the central Ministry of Environment and Forests considered the environmental clearance application and gave environmental clearance to NPCIL for setting up of 2X 1000 MW nuclear plant in Kudankulam vide their letter dated 9th May 1989 with stipulations(Ref letter no: 14011/1/88-IA dt 09-05-1989).

In 1994 Environmental Impact Assessment (EIA) notification was introduced for the first time in the country stipulating EIA document to be submitted for getting environmental clearances. Subsequent amendment was issued in 1997 stipulated additional requirement of public hearing.

However, the 1994 EIA notification gave an exception for the projects which had commenced the pre project stage activities. This exception clause (clause 8) stated that "if the project land has been acquired and all relevant clearances of the State Government including NOC from the respective State Pollution Control Boards have been obtained before 27th January, 1994, a project proponent will not be

required to seek environmental clearance from the Impact Assessment Authority (IAA). However those units who have not as yet commenced production will inform the IAA.”

Accordingly, the matter of environmental clearance of KKNPP and its applicability as per the 1994 notification was referred to MoEF by NPCIL.

- The details of completion of the land acquisition for the project, the state government environmental committee clearance and the work carried out in the project site since 1991, was submitted to MoEF.
- Based on the submissions, MoEF revalidated the environmental clearance issued in May 1989 vide their letter dated 6th September 2001 to KKNPP and mentioned that there is no need to conduct public hearing and seek fresh environmental clearance.

Note: The comprehensive EIA for Units 1 & 2 was made through NEERI in the year 2003, and during the Environmental clearance for Units 3 to 6, a comprehensive EIA including the impacts of Unit 1 & 2 was made, and submitted to MoEF in the year 2006, for which MoEF accorded environmental clearance (the EIA documents are available in NPCIL website).

9.3.2 CRZ clearance of KKNPP 1&2:

As per the norms prevailing in vogue in the year 1989 when KKNPP 1&2 obtained environmental clearance, there was a ban for constructing structures within 500 metres of High Tide line (HTL). Application for obtaining the environmental clearance for KKNPP 1&2 was submitted giving the project details and location and the details of condenser cooling system as sea water in December 1988. Considering the application, MoEF issued environmental clearance in May 1989, with a permission to locate structures within 500 Mtrs of HTL.

Subsequently 1991 notification for CRZ was issued and as per clause 2(i) (b) of 1991 CRZ notification projects of Department of Atomic Energy (DAE) are permissible activities. Also as per clause 3 (2) (i) of the 1991 CRZ notification, the projects of DAE shall require to obtain environmental clearance from MoEF.

While considering the applicability of all the notifications issued after 1989 on the environmental clearance issues, MoEF vide their letter 6th September 2001 has reconfirmed the environmental clearance issued to KKNPP 1&2 (in 1989) which provides exemption for constructing plant structures within 500 Mtr of HTL .

Even as per clause 3(i)(b) of the latest 2011 CRZ notification , projects of Department of Atomic Energy are permissible activities in the CRZ area. The regulation of the permissible activities as per this notification also stipulates that the permissible activities need to obtain environmental clearance from MoEF.

9.3.3 Consent from TNPCB

Consent to establish KKNPP 1&2.

Application for consent to establish KKNPP 1&2 under air and water act was applied to District Environmental Engineer, Tirunelveli vide application dated 30.12.2001 with relevant documents. The documents were verified by DEE and the same was forwarded to TNPCB, Chennai.

TNPCB Board vide their board resolution number 202-1-10 dtd 19-02-2004 resolved to issue consent. The consent for establishing vide TNPCB letter no nil dated 25.02.2004 to KKNPP 1&2 under air and water act.

Consent to operate KKNPP 1&2

Application enclosing all the details including additional facilities were submitted to DEE in year 2010. Based on the discussion with TNPCB chairman with KKNPP 1&2 management, the plant was inspected by DEE and the queries raised by DEE have been responded. The application is under consideration of the TNPCB.

9.4 Other statutory clearances obtained by KKNPP 1&2

9.4.1 Statutory clearances obtained for storage of diesel oil at site

Clearance for storage of High Speed Diesel fuel oil Storage from Petroleum and Explosives safety organization (PESO) Nagpur, (Formerly department of explosives) has been obtained for storage of High Speed Diesel fuel oil used in emergency diesel generators of KKNPP at each location under the **Petroleum Rules 2002.**

PESO granted following licenses to KKNPP for storage of HSD:

- License No. P/HQ/TN/15/4818/(P26894) dated 19/1/2010 for storage of 3800 KL of High Speed Diesel (HSD) at Central Diesel Storage Facility 06 UEJ.
- License No. P/HQ/TN/15/4855/(P251898) dated 21/6/2010 for storage of 100 KL of HSD at 05UEJ. (Common DG sets building) (Diesel storage Facility of 05 UKD)
- License No. P/HQ/TN/15/4856/(P251850) dated 21/6/2010 for storage of 100 KL of HSD at 01UEJ. (Unit 1 11 UKD Diesel Storage Building)
- License No. P/HQ/TN/15/4859/(P251860) dated 21/6/2010 for storage of 100 KL of HSD at 02UEJ. (Unit 1 12 UKD Diesel Storage Building)
- License No. P/HQ/TN/15/4820/(P244402) dated 21/1/2010 for storage of 100 KL of HSD at 03UEJ. (Unit 1 13 UKD Diesel Storage Building)
- License No. P/HQ/TN/15/4857/(P251890) dated 21/6/2010 for storage of 100 KL of HSD at 04UEJ. (Unit 1 13 UKD Diesel Storage Building).

9.4.2 Clearance for storage of compressed gas cylinders from Petroleum and Explosives safety organization (PESO)

Nitrogen, oxygen, hydrogen, acetlyne, argon and carbon dioxide gases are used for various processes in KKNPP and need to be stored .

Based on KKNPP application, **Deputy Chief Controller of Explosives**, PESO, Sivakasi sub circle, Sivakasi , Tamil Nadu granted following licenses to KKNPP for storage of compressed gases as per **Gas Cylinders Rules -2004**:

- License No. G/SC/TN/06/1801/(G21512) dated 11 August 2010 for storage of 1400 argon and 1680 oxygen compressed gas cylinders at 0 USK.
- License No. G/SC/TN/06/1802/(G21795) dated 11 August 2010 for storage of 320 carbon dioxide, 3680 nitrogen, 3360 hydrogen and 560 acetylene compressed gas cylinders at 0 USK

9.4.3 Approvals from Director of Boilers, Tamil Nadu , Chennai

Auxiliary boiler is used for producing auxiliary steam during start up of plant. Applications were submitted to the Director of Boiler (DOB), Chennai for design approval, erection approval and license for operation. Following are the licenses granted to KKNPP w.r.t auxiliary boilers:

- Provisional order No. Tech-I/ 4660-M/2008 dated 18-06-2008. Design drawings approval.
- Provisional order No DB/7729/7982M/2009, DB/7730/7982M/2009, DB/7731/7982M/ 2009 dated 22-02-2010. (Three boilers) Pipe line drawings approval, inspection of the boilers, provisional order to boilers, pass order to pipe lines issued.
- Provisional order No 43/DB/09-10, 44/DB/09-10, 45/DB/09-10 dated 20-02-2010 granting permission for operation of the boilers. Provisional order is renewed every six months.

9.4.4 Clearance from Central Electricity Authority, Electrical Inspectorate Division

For energizing and operating any electrical installation in the installations, clearance from Central electricity authority (CEA) has to be obtained. Application was submitted to CEA and on satisfaction of the documents and site inspection of the installations, CEA gave approval.

- Energisation of 6.6 KV and 220 KV GIS: Vide letter dated 24-10-2008.
- Approval for energisation of HV/MV equipment: Vide letter dated 09.06.2010.
- Approval for energizing GT,UAT,ICT, DG 400 KV GIS: Vide letter dtd 16.12.2010
- Approval for energisation of **all electrical equipment** of UNIT-1: Vide letter dated 26-08-2011.

10. Other Topics

Dr.A.E.Muthunayagam, Nurul Islam University, Nagercoil, Tamil Nadu & Dr.S.M.Lee, Raja Ramanna Fellow, Safety Research Institute, Kalpakkam)

10.1 Fuel Supply

10.1.1 Nuclear Fuel

Fuel for initial and reload of Unit-1&2 of KKNPP is procured as per Fuel Contract signed between Russian Federation and DAE, GOI. The fuel is supplied in the form of finished fuel assemblies of designated enrichment to be loaded in to the core. The quality of fuel fabrication at the fuel fabrication plant in Russia is inspected by DAE/NPCIL fuel experts at different stages of fuel

fabrication as per approved Quality Assurance Plan.

The finished fuel assemblies are packed in specially designed casks and transported by special air craft from Russia to India. From Airport to the KKNPP facility, the transportation is done by road. The entire transportation, starting from fabrication plant in Russia to KKNPP facility, strictly adheres to the safety regulations of International Atomic Energy Agency (IAEA) and AERB of India. Security arrangements are followed as per the DAE Security norms.

10.1.2 Dummy Fuel

Dummy Fuel has no radioactive material and is used to simulate the Nuclear Fuel Assembly, both by geometrical and by weight consideration. Dummy Fuel is made of lead encapsulated in steel tubes.

These are required to be installed in the reactor during commissioning, to study hydraulic characteristics like pressure and temperature variations, flow pattern with various combinations of Reactor Coolant Pumps, temperature etc., in the Primary Coolant System. The Dummy Fuel assemblies have no problems of disposal as they are non-radioactive, but in fact are preserved and re-used in subsequent new reactors during commissioning test.

10.2 IAEA Safeguards

Government of India has entered into an agreement with International Atomic Energy Agency for the application of Safeguards for the nuclear fuel to be supplied for KKNPP by the Russian Federation. The agreement entered into force on 27th September 1988 and follows the guideline available in 'INFCIRC/360' available on IAEA website. We have long experience in implementation of safeguards on nuclear fuel in some of our NPPs and the procedures to be followed at KKNPP will be no different. Hence there are no problems in implementation of IAEA safeguards for the nuclear fuel in KKNPP.

10.3 Fresh Water Supply and Desalination Plants

Desalination plant, based on Mechanical Vapour Compression technology, at KKNPP site has been designed to meet the process requirements of Unit # 1&2 and the potable water requirements.

The plant water requirement is 5664 m³/day and the potable water requirement is 1272 m³/day. Against this, the installed desalination plant capacity is 7680m³/day. This is met by three units, each of capacity 2560 m³/day, with one additional unit of 2560 m³/day unit, as a standby. The output water from the desalination plant is further purified by de-mineralizing and used for industrial purpose. The product water is treated further for making it potable water.

The provision of water storage and inventory available in various tanks are adequate for cooling requirements of Reactor Plant for at least ten days, in case of power failure from the Grid (even though the regulatory requirement is only 7 days).

The desalination plants have been designed for sufficient capacity and have been erected and commissioned. Hence, the question of water utilization from other sources such as Pechiparai dam and Tamirabharani river does not arise.

Desalination Plant at KKNPP site is based on thermal desalination i.e Mechanical Vapour Compression (MVC) system. The system draws sea water from the main cooling water intake channel provided for the power plant. The brine reject from the desalination plant will be mixed with the condensed cooling water discharges, diluted and released into the sea through the existing outfall channel.

A base line environmental assessment and mathematical modeling study on flow, dispersion of brine reject and extent of mixing in the sea has been done by Indomer Coastal Hydraulics Pvt Ltd, Chennai, who is a certified consultant by Ministry of Agriculture, Department of Animal Husbandry & Dairying, New Delhi and also a certified 'A' grade hydrographic surveyor by Inland Waterways Authority of India, Noida.

The brine reject volume is 350 m³/ hour and it gets diluted with sea water discharge through the outlet canal which is 2,50,000 m³/hour during plant normal operation. This will give an initial dilution of the order 700. This pre-dilution would reduce the brine concentration from 69 ppt to an ambient value of 35.1 ppt.

The brine reject will not have any impact in the marine environment while joining the sea.

The brine reject does not contain any toxic or organic pollutant.

10.4 Construction QA

Nuclear Power Corporation of India Limited has a corporate quality management program which gives assurance of quality in all activities undertaken.

Based on the observations and perusal of documents available at site it is concluded that adequate quality standards are incorporated in all stages of works in the project. The assurance of quality is accorded highest attention in all fields i.e. in design, manufacturing and procurement, construction, erection, commissioning and operation.

The components manufactured in Russia and supplied to KKNPP 1&2 from Russian Federation are subjected to undergo the stringent checks as detailed in the quality assurance plans developed jointly by NPCIL and Russian Nuclear authorities.

The construction works are carried out in accordance with QA manual especially in respect of civil construction, the materials used are tested for every batch at the concrete testing lab at site. The construction QA personnel inspect the works as per the QA plan and the works are carried out as per approval of QA staff. The records of testing and inspections which are extensive are well documented. The regular reviews of the quality are carried out by internal audits within NPCIL and audits on specific systems by AERB.

The reactor building containment has withstood a structural integrity and leak rate test at the test pressure, which is much higher than the design pressure. The hydrotests, non-destructive tests (radiography, ultrasonic test) etc were carried out and records are maintained. Hot run has been carried out to validate the design.

All the relevant documents pertaining to quality are kept properly for ready reference.

10.5 Emergency Preparedness

NPPs are designed and operated following the principle of defense-in-depth. This principle requires that there be successive barriers against release of radioactivity and several layers of protection be provided for each of the safety functions.

The first level of defense-in-depth is achieved by ensuring that the plant is designed in such a way that all safety parameters like pressure, temperature, flow etc. are maintained within the specified limits.

The second level corresponds to upset operating conditions that can be expected during plant operation, like, failure of grid power supply. The design ensures that safety is not jeopardized on account of such upset conditions.

The third level relates to the situation where plant parameters exceed the prescribed safety limits. The safety design of the NPP ensures that the reactor is promptly shut down automatically and cooling of fuel is adequately maintained to prevent it from overheating and cause any release of radioactivity.

The fourth level corresponds to a situation where adequate cooling of the fuel cannot be maintained for some reason whereby the reactor gets into the accident mode. Even for such accident conditions, the NPP design provides the means to be able to control the progression of the accident and prevent any major release of radioactivity to the environment such that there are no significant adverse radiological consequences in the public domain.

The fifth level of defense-in-depth assumes, in a hypothetical manner that due to unforeseen reasons or due to any failures in design or operating procedures or in their implementation, radioactivity release takes place. Towards this an emergency preparedness plan is in place which can be executed, if required, to mitigate the consequences of such a release.

The emergency preparedness plans should therefore be viewed in the overall context of the safety philosophy of defense-in-depth. Needless to mention that for any plan to be effective, it must be tested periodically. The emergency exercise including the off-site emergency exercise that may require evacuation of a section of the population, are carried out accordingly. It must, however, be reiterated that the possibility of an emergency situation arising is extremely remote and the exercises are done only to be in a state of preparedness, should the need arise.

In India, NPPs have been in operation over the last more than 40 years and there has never been any accident of the need for any emergency actions in the public domain. Even in the entire world where over 430 NPPs are in operation, the need for emergency action in the public domain has arisen only twice; once in 1986 from the Chernobyl accident and the other in 2011 from the Fukushima accident.

It may be noted that in KK reactor design, many advanced safety features are deployed. These include the passive heat removal system, which ensures cooling of the fuel even if power is not available and other safety provisions like the double containment and core catcher that strengthen the plant safety such that any intervention in the public domain outside the plant exclusion zone will not be required even in case of an accident. However, as a matter of abundant caution following the defense-in-depth safety philosophy, emergency plan for actions to be taken in public domain during any off-site emergency plans were prepared and provided to District Authorities for implementations.

These procedures are accordingly included in the “Emergency Preparedness Plans” Vol-1 and Vol-2 duly approved for Kudankulam Nuclear Power Project. Volume- 1 covers Plant Emergency and Site Emergency conditions which have been prepared by the KKNPP Site, reviewed and approved by Atomic Energy Regulatory Board. The document no. is I01.KK.0.0.TM.MN.WD001. Volume -2 is for the Off-site Emergency Preparedness which has been prepared by NPCIL in consultation with the State authorities, concurred by Atomic Energy Regulatory Board and approved by the District Collector, Tirunelveli District. Document No. is I01.KK.0.0.TM.MN.WD002. Both of these documents are in place.

These emergency preparedness plans brings out the conditions at which plant, site and off site emergencies may be declared by the respective authorities. They also bring out in detail the roles and responsibilities of various agencies involved. The plants are tested periodically by conduct of emergency exercises such that any deficiency can be observed and corrected and to keep the plant updated. Plant emergency exercise is conducted once in 3 months, site emergency is conducted once in a year. The off-site emergency is conducted once is two years. Prior to first criticality, plant, site and off-site emergency exercises have to be conducted once.

For the plant and site emergency, all the KKNPP employees and the CISF personnel have been trained. First plant emergency mock exercise has been conducted involving KKNPP personnel and contract personnel.

Implementation of offsite Emergency plan involves various State Government Departments like District Revenue, Social Welfare, Fire, Health, Horticulture & Agriculture, Fisheries, Irrigation, Forest, Animal Husbandry, Electricity Board, Transport, Local Administration & Police Departments. A detailed training programme was conducted as per the schedule provided by the District Collectorate for the officials from all the above departments in the month of August 2011 about the roles and responsibilities of the respective departments. Around 600 officials from these departments have been trained on off-site emergency preparedness.

10.6 Decommissioning

The objective of decommissioning is to release the NPP site for reuse or for unrestricted use, depending on the requirement, ensuring safety of members of the public and occupational workers as well as protection of the environment. Provisions for facilitating decommissioning in KKNPP-1&2 have been made in the design.

Decommissioning strategy consists of de-fuelling of reactor and removal of all radioactive fluids from the systems, at the end of its operating life. The SSCs are then kept in a safe storage mode for a period of time to allow for natural decay of radioactivity for ease of dismantling of components and their packaging and transportation for disposal. The necessary machinery, components, structures and the building are left intact for such safe keeping. Some of the conventional SSCs may be dismantled at this stage.

The cost of decommissioning of NPPs in India has been worked out through a detailed exercise. The estimates indicate that decommissioning cost can be met by a decommissioning levy of 2 paise per KWh to be charged along with tariff to create a corpus to be used at the time of decommissioning. The levy will be reviewed periodically to ascertain its adequacy to meet the decommissioning fund requirements and may be revised if necessary.

In this context, it may be noted that some of the Indian NPPs have undergone significant renovation and modernization activities. These included replacement of components like pressure tubes end fittings, feeder pipes etc. This experience has demonstrated that technology for such dismantlement activities, which are similar to decommissioning, is available in the country. The experience also shows that costs involved are within the estimated values. The radioactive waste arising from decommissioning is not significantly different than the waste generated from normal operation of the NPP, except that its volume will be comparatively large. In India we have good experience in handling and disposal of such waste and therefore no difficulty is foreseen for handling and disposal of waste arising from decommissioning work.

11. CONCLUSIONS

EG observes that KKNPP is designed and engineered to the state of art of nuclear reactors in line with the current international safety requirements and principles. KK site related aspects such as seismic, tsunami, tropical storms are taken into consideration at design stage. More than 20 VVER-1000 are operating in Russian Federation and in other countries. While finalizing the contract for KKNPP, additional safety features were specified which have been incorporated and their functionality is being established during commissioning. The radiological releases during the plant operation are expected to be well below prescribed limits. This fact is borne out by the experience from operating NPPs in India and abroad. Based on the national and international studies and experience, such radiological releases have no adverse effects on public health, environment and plant personnel. Safety of KKNPP was examined in relation to the TMI, Chernobyl and Fukushima accidents. It is seen that based on the advanced design safety features, safe grade level and high elevation of safety related equipment and the fact that all key operating personnel are graduate engineers who also receive intensive training, it is not conceivable that any accident of these types can take place at KKNPP.

EG also notes that clearances for various stages of the project are given by the Atomic Energy Regulatory Board after an elaborate and exhaustive safety review at each stage. Similarly, other statutory bodies have also conducted detailed and in-depth reviews before according clearances

pertaining to areas relevant to their purview. This clearly indicates that all applicable safety aspects of the project have been subjected to careful scrutiny by the concerned statutory bodies in the country.

In particular, safety of KKNPP has been thoroughly evaluated against external events of natural origin, viz., earthquakes and possible flooding of the site from cyclonic storms and tsunamis. It is seen that the seismic design of its SSCs and location of safety related components provide high level of safety against such events. Possibility of volcanic eruptions in the vicinity of the site has also been examined and no active volcanism has been identified. The magnitude of any possible tsunami that can be generated from submarine landslides in the Gulf of Mannar has been found to be much smaller than tsunamis that may get generated from the submarine active seismic faults, which has already been taken into consideration.

In view of the above, the EG would like to conclude that the fears of the local population are unfounded and design of KKNPP meets the current safety standards.

1. BRIEF PROFILE OF Dr. A. E. MUTHUNAYAGAM



Mechanical Engineer who has contributed significantly over 35 years in Indian Space Research Programmes and Oceanography in various capacities. He was former Vice Chairman for Intergovernmental Oceanographic Commission, former Secretary to Government of India, Department of Ocean Development, Chairman Board of Governors of IITM and Executive Vice President of Kerala State Council for Science, Technology & Environment. Since April 2009 he is with Nurul Islam University as Pro Chancellor / Advisor.

2. PROFILE OF DR. M.R.IYER



A senior scientist associated with work on radiation safety for more than 50 years. He was a professional with International Atomic Energy Agency (IAEA) in Vienna. A veteran in the area of radiation health risks, Dr. Iyer can be expected to clear any doubt on the subject.

3. BRIEF PROFILE OF DR. M.N. MADHYASTHA



Formerly Chairman, Dept. of Biosciences, Dean Faculty of Science & Technology, Mangalore University, Mangalore. Currently Visiting Professor, National Institute of Technology, Karnataka offering course for M.Tech in Environmental Engineering. 40 years experience on coastal marine biology, ecological issues and resource conservation. Coordinator National Biodiversity Strategy and Action Plan [NBSAP] for West-coast region. Principle Investigator & Monitoring Committee Integrated Action Plan on River Kaveri. Principal Investigator Thermal ecology of benthic organisms of Kaiga Atomic Power Plant. Handled many research projects. Visited many countries for research activities. Was visiting Professor at Salford University, UK, Fulbright Research Fellow. Visited USA for 1 year for Research. Training in Environmental Master Plan at Denmark. Expert member, Committee of Environmentalists and Sociologists, inter linking of rivers GOI.

4. BRIEF PROFILE OF DR. SUKUMARAN



Former Professor and Head Sri Paramakalyani centre for Environmental Sciences, Manonmaniam Sundaranar University, Alwarkurichi-627 412. Had a Ph.D in Biology from Madurai Kamaraj Univesity. 35 years of teaching and research experience in Fisheries, Biotechnology, Environmental Sciences and Thermal Ecology. Is a member in several committees at State and Central Government. More than 30 students got their Ph.D under his guidance. He has produced. Had more than 300 research publications in National and International Journals. Had travelled many foreign countries for attending international conferences and workshops. He was honoured with TANSA Award for his research in Environmental Sciences by Government of Tamil Nadu.

5. BRIEF PROFILE OF DR. A.K.PAL



He is Principal Scientist and Head Division of Fish Nutrition Biochemistry and Physiology, Central Institute of Fisheries Education Deemed University, ICAR. His principle area of specialization is Thermal Eco-physiology & And Radio Ecology. He has received many awards and honors in his area of specialization and has authored many research papers in his field.


6. BRIEF PROFILE OF DR. V.SHANTA




V. Shanta born to an illustrious family and raised in a world of books, ideas, and high achievement executive chair of Chennai's Cancer Institute (WIA).She studied medicine at Madras Medical College and came under the spell of Muthulakshmi Reddy, a social reformer and India's first woman medical graduate. In 1954, under Dr. Reddy's leadership, the Women's Indian Association Cancer Relief Fund founded the Cancer Institute (WIA) in Madras, now Chennai. Drawn to Reddy's vision, young Dr. Shanta spurned a more lucrative post to join the Institute. Shanta conducted groundbreaking research on oral, cervical, and breast cancer and pediatric leukemia, publishing the results in international journals and establishing the Institute as India's first Regional Cancer Research and Treatment Center in 1975. In 1984, the Institute added a postgraduate college where Shanta proceeded to train cancer specialists, more than 150 of whom now practice throughout the subcontinent. Eighty-four year-old Shanta still sees patients, and is still on call

	twenty-four hours a day. She was honoured in year 2005 by Ramon Magsaysay Award for Public Service
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7. BRIEF PROFILE OF DR.C.S.PRAMESH

	Dr.C.S.Pramesh is the head of thoracic surgery at the Tata Memorial Hospital, the largest cancer centre in the country. He is an expert in cancer diagnosis and treatment. He is an experienced researcher and has conducted several large research studies in cancer causation, diagnosis and treatment. He has over 100 peer-reviewed publications in several international journals and books.
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8. BRIEF PROFILE OF DR. HARSH K GUPTA PANIKAR

	He is a noted seismologist and former Secretary to Government of India, Department of Ocean Development. After the tsunami, he led design and commissioning of Tsunami Warning System for India. He has published over 150 scientific papers in reputed journals, and has authored four books. His first book titled “Dams and Earthquakes” published in 1976. Recently (2011) he edited the encyclopaedia of Solid Earth Geophysics (Springer, 1600 + pages). He is President, International Union of Geodesy and Geophysics.
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9. BRIEF PROFILE OF DR. KANNAN IYER

	Ph.D. Purdu University in the area of nuclear reactor safety in 1985. Joined IITB in 1986 and has continued experiments and analysis in the area of nuclear reactor safety. He specialises in reactor safety and his assessment of the construction and functioning of the Koodankulam plant will convince the protestors regarding the safety of the centre.
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10. BRIEF PROFILE OF PROF C.V.R. MURTY



A Specialist in earthquake structural engineering. His areas of research are non-linear behaviour of structures under strong earthquakes shaking and development of seismic design codes. He has been a member of Bureau of Indian Standards Committee on earthquake engineering. Currently he is a Professor in Department of Civil Engineering at Indian Institute of Technology, Madras.

11. BRIEF PROFILE OF DR. S.K. MEHTA



He is a retired Director, Reactor Group at Bhabha Atomic Research Centre [BARC] with long experience in nuclear reactor design and development, safety research and safety analysis. Nuclear Reactor design analysis and review is his area of specialisation.

12. PROFILE OF DR. S.K. SHARMA



Chairman of Atomic Energy Regulatory Board (AERB) from January 2005 to January 2010. Vice Chairman of AERB for about one and half year before this. Before joining AERB, he worked as Director of Reactor Group in the Bhabha Atomic Research Centre. He is a member of the prestigious International Nuclear Safety Group (INSAG) of IAEA since the last about 8 years.

13. BRIEF PROFILE OF DR K. BALU



He is a retired Director of Nuclear Waste Management Group at Bhabha Atomic research Centre [BARC]. A specialist in spent fuel management, Dr. Balu has developed methods & set up facilities for safe treatment and disposal of radioactive wastes in the various nuclear facility sites in the country.

14. BRIEF PROFILE OF DR.S.M.LEE



He is former Director, Safety Research, Health Physics, Information services, Instrumentation and Electronics Groups of Indira Gandhi Centre for Atomic Research, Kalpakkam and presently Raja Ramanna Fellow, Safety Research Institute, Kalpakkam.

15. PROFILE OF DR. W. STEPHEN ARULDASS KANTHIAH



Dr. W. Stephen Aruldass Kanthiah is a former Director of Heavy Water Board, Govt. of India. He is a noted specialist in Industrial safety. He is well known for his extensive experience in establishing highest standard of industrial safety in chemical industries. A winner of National Safety award 2006 and 2009. He has 36 years of Industrial experience in industrial operations. He is an outstanding Scientist, Department of Atomic Energy, Govt. of India.