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June 1, 2007

To
The Member Secretary
Tamilnadu State Pollution Control Board
Chennai

Dear Sir/ Madam,

Re: Submission for the Public Hearing to be held on June 2, 2007 regarding the Koodankulam Nuclear Power Project –KKNPP (establishment of units 3, 4, 5 and 6), Tirunelveli Kattaboman district, Tamilnadu

The environmental public hearing under the EIA notification 1994 for the Koodankulam nuclear power project (units 3, 4, 5 and 6), which was to be held on March 31**,** 2007 has been rescheduled for June 2, 2007. The hearing is based on the *Comprehensive Environmental Impact Assessment for Additional Units 3 to 6 of Nuclear Power Plant at Kudankulam, Dist. Tirunelveli, Tamil Nadu*, prepared by National Environmental Engineering Research Institute, Nagpur, in 2004, and sponsored by the Nuclear Power Corporation of India Limited.

The Environmental Impact Assessment (EIA) has a number of deficiencies, some of which I briefly outline. I discuss some potential environmental and health impacts that the EIA does not deal with in an appendix at the end. I have also tried to provide references wherever possible to back up my submission. Put together, it means that this document cannot be the basis for a serious assessment of the project and should be rejected.

1. The EIA does not identify all the potential impacts related to the project. In particular, it does not discuss the potential environmental contamination that may come from the spent fuel that will have to be necessarily stored on site for several years in order that it may cool. The spent fuel contains the bulk of the radioactivity that leaves the reactor. (For estimates of the quantities involved, see the appendix.) The EIA does not mention what is to happen to this spent fuel, nor does it evaluate the potential environmental impacts of just storing this spent fuel while it is cooling. There are essentially three possibilities. One is that the spent fuel is shipped back to Russia. The

second is that the plutonium content in it is extracted in a reprocessing plant. The third is that it is stored on site indefinitely in either wet or dry storage. Newspaper reports suggest that the chosen option is that of reprocessing the spent fuel on site. But no matter what course is chosen, the environmental impact of the chosen possibility for dealing with spent fuel should have been assessed and included as part of this EIA. By including the environmental impact of the township that is being built to house project personnel, the EIA gives the impression of being ultra-cautious. But in fact it has neglected the much more serious environmental impact due to the infrastructure necessary for dealing with the most radioactive components on site – the spent fuel.

2. The EIA is also seriously deficient in that it does not consider at all the possibility of a beyond design basis accident of the reactor leading to a massive release of radioactivity to the environment. While the probability of such an accident might not be high, it is not zero. As discussed in the appendix, in nuclear reactors it is not possible to know all modes of accident initiation and propagation. Therefore calculations of accident probabilities are unreliable. Further, there are specific concerns about the safety of VVER-1000 reactors, in particular the reliability of the control rod mechanism. (This is discussed further in the appendix.) The EIA shows no evidence of being aware of these problems. In the event of an accident, the EIA does not mention of the likely ranges of radioactive contamination or the emergency preparedness plans that have to be circulated so that people may know how to mitigate the impacts of such a contingency.

3. The EIA estimates (Note that till the reactors are actually built, operated for some years, and all releases are carefully and fully measured, all one has are estimates not actual figures) for the radioactivity released to the atmosphere are not reliable. For example, the values given for atmospheric radioactive discharges from ventilation stacks in Table 3.1.1 on p. 3.9 are much smaller than the corresponding figures for VVER-1000 reactors elsewhere. For example, the I-131 discharge for each KK reactor is given as 2.48 X 10^5 Bq/day, which is 6 times smaller than the discharge rate for Khmelnitsky 1 reactor and 7.4 times smaller than the discharge rate for the Rovno 3 reactor (both in Ukraine). The noble gas release rates are even smaller: 12 and 23 times respectively. These discrepancies between roughly identical reactors suggest that the data used in the Kudankulam EIA are not dependable. No justification has been given for the use of these lower values. Nor is any basis provided for any of these assumptions.

4. The theoretical model used on p.3.1 (equation 3.1.1, a Gaussian dispersion model) to predict how radioactivity will spread in the atmosphere, which is then used to calculate health impacts, is not accurate when used in coastal regions, for many reasons, especially the presence of land and sea breezes. The use of such models to predict impacts should be considered a methodological deficiency. Further, the EIA does not mention what values it used for the various parameters that go into calculating the numerical values of the radioactive dispersion. We do not know therefore whether these choices are really representative of the local conditions.

5. In discussing the health impact of radioactive emissions from the reactor, the EIA merely expresses the expectation that the "annual dose of inert radioactive noble

gases, iodine and long-lived nuclides in the form of particulates will be well below the stipulated standards" (p. 3.5). This is completely unjustifiable. The EIA should have started with collecting data on people's milk (since that is a major vehicle for Iodine doses) and food consumption levels. This then should be fed into standard transport pathway analysis in order to predict radiation doses to people consuming local food products. The EIA shows no evidence of having done that analysis. This is corroborated by people living in the vicinity of the site who have said that they have never been surveyed about their food and milk consumption patterns. If that is the case, then how can the EIA suggest that the annual dose will be below stipulated standards? This is yet another area where the EIA is seriously incomplete.

6. One of the impacts of the Koodankulam nuclear stations that local people, especially fisherfolk, are, and must be, concerned about is the hot water discharged by the station. According to the Ministry of Environment and Forests, the temperature of the discharged hot water should not be over 7 °C above the temperature of the receiving water, in this case the sea. If one looks at the plant out fall temperature at various coastal nuclear reactors as given on p. 3.26 of the EIA, the temperature increases vary from 7.65 °C (for 2X 160 MW Tarapur 1&2), 8.4°C (for 2X 220 MW MAPS 1&2), and 9.5 °C (for 2 X 540 MW Tarapur 3&4). At the Koodankulam site, there will be, if the reactors being discussed are constructed, a total of six 1000 MW reactors. Thus, they will be discharging over thirteen times the heat discharged by the MAPS reactors (chosen because it is the intermediate value and because it is on the same coastline as the Koodankulam reactors). There are two possibilities. One is that the temperature increase of the water will be higher than at the MAPS site (Kalpakkam). The other is that the amount of sea water that is circulated will be thirteen times or more as great. In either case, the impact on marine life in that environment will be significant. Though the EIA has mentioned a number of studies of this subject, these are either from other smaller power stations (such as Tuticorin thermal power station and Kalpakkam). Thus, the EIA has not really considered the thermal impact of the proposed reactors on the sea.

7. The EIA does not discuss what would happen in case there is a possible leak in the steam generator resulting in radioactive contamination of the secondary coolant cycle. Would the contaminated water continue to flow to the sea? If so, shouldn't the impact be discussed? If it is not to flow to the sea, then where is it to be stored? What about the potential impacts of such storage?

8. The EIA states that water samples from the sea were collected from different locations and analyzed for fallout radionuclides Cs-137 and Sr-90 (p. 2.45). It goes onto claiming that the values of these in seawater, which varied from 7.4 to 16.6 mBq/l (or Bq/m^3), are in the same range as observed elsewhere. This is not correct. In the case of measurements taken near Iceland, the majority of locations have radioactivity levels well below these values. The Atlantic ocean, for example, had levels of around 2.7 Bq/m^3 while the Artic Intermediate Water had levels of 3.3 Bq/m^3. Both are well below the level mentioned in the EIA. The point is not that the levels near Iceland are relevant to the Koodankulam project but it offers yet another instance of the technical incompetence displayed by those preparing the EIA.

9. The Executive Summary of the EIA claims that "nuclear power is the economical option as compared to costlier thermal power for this area and there is no scope for hydropower in this area." This is not true. The estimated cost of power from the Koodankulam reactors I & II is about Rs. 3.08 per unit (Business Correspondent, 2001). The tariff for electricity from the relatively nearby Neyveli Thermal Power Station as approved by the Central Electricity Regulatory Commission on September 26, 2006 for 2008-09 (when Koodankulam 1 & 2 are expected to be commissioned) is Rs. 1.74 per unit if it is operating at even a 70% capacity factor and Rs. 1.66 if it is operating at 85% capacity factor (CERC, 2006). Thus, clearly thermal power is much cheaper. This result is also consistent with my own research that compared the cost of generating electricity at the Kaiga Nuclear Reactor and Raichur Thermal Power Station and found that the latter is cheaper only for relatively unrealistic parameters (Ramana *et al.*, 2005).

10. Finally, one basic flaw with the EIA is that while it gives fairly trivial and unimportant information in great detail (examples are the pollution attenuation factors as a function of green belt width for different atmospheric stability classes or the noise level due to the cooling water pump at a distance of 2 metres), it does not give far more vital information that will be needed for reliable evaluation of the environmental impact. Some examples are the expected inventories of different fissile materials on site at any given time, the over-pressure that the containment dome is designed to withstand, and the expected volumes or masses of radioactive effluents that flow out into the sea under routine or accidental circumstances. It is the latter category of information that might actually reveal what kind of an impact the proposed project might have on the health and well being of the people and communities who live nearby. Decision making without such crucial information will be without basis and the project should not be given clearance.

On the above grounds, I urge the Tamilnadu State Pollution Control Board, the Department of Environment, Tamil Nadu, and the Central Ministry of Environment and Forests to reject the current Environmental Impact Assessment as flawed and not offering a basis for approving the project. Further, the government's EIA notification states that "Concealing factual data or submission of false, misleading data/reports, decisions orecommendations would lead to the project being rejected." The EIA has clearly concealed factual data about the potential impacts of the project, either intentionally or unintentionally. Thus, this should lead to the project being rejected.

Sincerely yours,

M. V. Ramana

Fellow, CISED

Appendix: Accidents at the Spent Fuel Pool, Reactor, or Reprocessing Plant

As mentioned earlier, one of the major deficiencies of the EIA is that it does not consider the possibility of severe accidents. There are several scenarios that could lead to large scale releases of radioactivity. One standard accident scenario whose impact should have been studied as part of the EIA is that of a LOCA (Loss of Coolant Accident) coupled with a loss of electric power ("station blackout"). Station blackouts have occurred in Indian reactors; the most dangerous situation was at the Narora reactor in 1993 (NEI, 1993). Anther dangerous combination could be a LOCA and a failure of the Emergency Core Cooling system. In addition to this, other less severe possibilities that could potentially lead to release of radioactivity should have been considered in the EIA. This has not been done.

Likelihood

Among all electricity generating technologies, nuclear power alone is vulnerable to catastrophic accidents, as illustrated by Chernobyl. It is often stated that safety issues have been adequately addressed after the Chernobyl accident. However, the basic features of nuclear reactors remain the same. It is a complex technology involving large quantities of radioactive materials where events can spin out of control in a very short time. In studying the safety of nuclear reactors and other hazardous technologies, sociologists and organization theorists have come to the pessimistic conclusion that serious accidents are inevitable with such complex high-technology systems (Perrow, 1984; Sagan, 1993). The character of these systems makes accidents a "normal" part of their operation, regardless of the intent of their operators and other authorities. In such technologies, many major accidents have seemingly insignificant origins. Because of the complexities involved, all possible accident modes cannot be predicted and operator errors are comprehensible only in hindsight. Adding redundant safety mechanisms only increases the complexity of the system allowing for unexpected interactions between subsystems and increasing new accident modes. All of this means that it is not possible to ensure that reactors and other nuclear facilities will not have major accidents. It also implies that calculations of probabilities of accidents are necessarily unreliable.

There is an experiential basis for concern about such accidents within India. Practically all the nuclear reactors and other facilities associated with the nuclear fuel cycle operated by the Department of Atomic Energy (DAE) have had accidents of varying severity (Chanda, 1999; Rethinaraj, 1999). A few examples are the unexplained power surge at the Kakrapar reactor in 2004, the 1993 fire at Narora, and the collapse of the containment at Kaiga in 1994. Because of the reasons mentioned above, many of these accidents could well have become the basis for a major radioactive release.

A further source of concern is that the Atomic Energy Regulatory Board (AERB), which is supposed to oversee the safe operation of all civilian nuclear facilities, is not independent of the DAE. The AERB reports to the Atomic Energy Commission (AEC), which is headed by the head of the DAE. The Chairman of the Nuclear Power

Corporation (NPC) is also a member of the AEC. Thus, both the DAE and the NPC exercise administrative powers over the AERB. (This lack of independence is in direct contravention of the international Convention on Nuclear Safety, of which India is a signatory.)

Further, as the former chairman of the AERB has observed, “the AERB has very few qualified staff of its own, and about 95% of the technical personnel in AERB safety committees are officials of the DAE whose services are made available on a case-to-case basis for conducting the reviews of their own installations. The perception is that such dependency could be easily exploited by the DAE management to influence the AERB’s evaluations and decisions” (Gopalakrishnan, 2002). Elsewhere, Gopalakrishnan has pointed to an example of direct interference from the AEC. “When, as chairman, I appointed an independent expert committee to investigate the containment collapse at Kaiga, the AEC chairman wanted its withdrawal and matters left to the committee formed by the [Nuclear Power Corporation’s Managing Director]. DAE also complained to the [Prime Minister’s Office] who tried to force me to back off” (Pannerselvan, 1999).

There are also specific safety concerns about both the VVER-1000 reactors. Experience at various reactors has raised questions about the reliability of the control rod mechanism. Both at the Temelin reactor in the Czech Republic and at the Kozludoy reactor in Bulgaria numerous control rods did not move as designed (Schneider, 2007). We describe the latter case in some detail. On 1 March 2006 Kozloduy unit 5 was operating at full power. At 06:08 AM due to electrical failure, one of the four main circulation pumps tripped. Following this initiating event, to enable rapid power reduction the system automatically reduced the power to 67% of nominal capacity. In the process of power reduction the operators identified that three control rod assemblies remained in upper end position. The follow-up movement tests of remaining control rod assemblies identified that in total 22 out of 61 could not be moved with driving mechanisms. The number of control rod assemblies, unable to scram (to drop due to the gravity only) remains unknown. Control rod insertion failures are considered very serious and lead to a severely degraded state of safety in case an accident-initiating event occurs.

Similarly there is concern that in the event of loss of cooling water at spent fuel pools, the radioactive spent fuel could heat up relatively rapidly to temperatures at which the fuel cladding could catch fire and the fuel’s volatile fission products could be released (Alvarez *et al.*, 2003).

Potential Consequences

The Koodankulam VVER-1000 reactors use Low Enriched Uranium (LEU) with an average equilibrium enrichment of 3.92% of U-235 and the average discharge burn up is 43000 MWd/tU. Therefore the annual fuel requirement is about 21.9 tonnes for each 1000 MWe reactor operating at 85% capacity factor. After discharge, the spent fuel is cooled in the spent fuel pool for a minimum period of 5 years. At equilibrium, therefore, there will be at least about 110 tonnes of spent fuel in the spent fuel pool for each 1000 MW reactor. Since the project currently envisages having six reactors on site, the total inventory of radioactive spent fuel on site will be at least 660 tonnes.

This is independent of what the Nuclear Power Corporation and their Russian counterparts decide to with the spent fuel after it has cooled sufficiently. If the decision is made to permanently store the spent fuel on site, as is the case with the Tarapur I&II reactors, then the inventory will be much higher. If the decision is to reprocess it, then there will be routine releases of radioactive effluents into the atmosphere and water.

In order to estimate the potential environmental and health impacts of an accident, I first calculate the radionuclide inventory of the reactor core and the spent fuel pool on the basis of Origen-2 (a standard computer programme) calculations performed at the Oak Ridge National Laboratory in the USA (Gehin *et al.*, 2004). I focus on three radionuclides which have the greatest impact on human health: Iodine-131, Cesium-137, and Strontium-90. Iodine is readily absorbed by the human body after inhalation or ingestion and is concentrated in the thyroid; Cesium-137 and Strontium-90 are long-lived, with half lives of about 30 years. They are the important contributors to the radiation dose received by people because of the penetrating gamma rays associated with Cesium-137 and the efficient way Strontium enters the food chain.

Radionuclide	Half Life	Average Quantity in One 1000 MW Reactor Core (MCi)	Average Quantity in Spent Fuel Pool (MCi)
Sr-90	28.78 years	3.3	63
I-131	8.04 days	36	140
Cs-137	30.17 years	4.6	88

Of these, the greatest long term effect is likely to come from Cs-137. It is relatively volatile with an expected release fraction of about 30% in a reactor accident or a spent fuel pool fire, and is a potent land contaminant because 95% of its decays are to an excited state of Barium-137, which de-excites by emitting a penetrating (0.66-MeV) gamma ray (Alvarez *et al.*, 2003).

The extent of these inventories are significant. In the event of an accident which could lead to the release of significant fractions of these radionuclides, depending on the weather conditions, somewhere between 10,000 and 25,000 square kilometres of land will be contaminated with levels of Cs-137 that would necessitate relocation of people. Contamination at this level could reach as far away as 400 km from the reactor site. Lest these assertions seem far fetched, one can compare with what resulted from the Chernobyl accident.

The VVER-1000 reactor is different in design from the RBMK reactor that went prompt critical (exploded) at Chernobyl. This means that the potential sequences of events that lead to a major accident would be different. But as we have emphasized earlier, all nuclear reactors are susceptible to catastrophic accidents with non-calculable probabilities. Further, once there is an accident involving a major release of radioactivity, the consequences will be somewhat similar. The differences would mainly be in the slightly different radioactive product inventories and how much of that is released into the atmosphere. Therefore, the April 1986 accident of the Chernobyl reactor would actually be a good model for the consequences of a major reactor accident at Koodankulam.

Following Chernobyl, more than 100,000 residents from 187 settlements were permanently evacuated because of contamination by Cs-137. Strict radiation-dose control measures were imposed in areas contaminated to levels greater than 15 Ci/km2 (555 kBq/m2) of Cs-137. The total area of this radiation-control zone is huge: 10,000 square kilometres.

The greatest short term radiation related damage came from the ingestion or inhalation of I-131, which leads to thyroid cancer, especially in young children. Indeed, this is this most acute health impact of the Chernobyl accident. In 2000, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), recorded that there were an "unusually high numbers of thyroid cancers observed in the contaminated areas during the past 14 years" and went on to observe that "the number of thyroid cancers (about 1,800) in individuals exposed in childhood, in particular in the severely contaminated areas of the three affected countries, is *considerably greater* than expected based on previous knowledge. The high incidence and the short induction period are unusual… If the current trend continues, additional thyroid cancers can be expected to occur, especially in those who were exposed at young ages" (UNSCEAR, 2000). These "form the largest number of cancers of one type, caused by a single event on one date, ever recorded" (Williams, 2002).

In the longer term, there would also be a large number of cancer deaths due to increased radiation doses. The estimated collective radiation dose to the entire world from Chernobyl is 600,000 person-Sv (UNSCEAR, 1993, p. 23). The most recent estimate of risk from radiation exposure is 0.057 cancer deaths per Sv (National Research Council, 2006). Therefore, the collective radiation dose mentioned above would result in roughly 34,000 deaths over a long period of time.

Accidents involving loss of cooling at a spent fuel pool would be no less devastating. In 1997, a study done for the United States Nuclear Regulatory Commission estimated the median consequences of a spent-fuel fire at a pressurized water reactor (PWR) that released 8–80 MCi of Cs-137, roughly 10-90% of the inventory of Cs-137 that I have estimated for the Koodankulam spent fuel pools (Alvarez *et al.*, 2003). The consequences included 54,000–143,000 extra cancer deaths, the contamination of 2000–7000 square km of agricultural land leading to condemnation, and the economic costs due to evacuation of $117–566 billion. The first of these figures is clearly an underestimate for Indian conditions because of the much higher population density.

Reprocessing: Potential Environmental Consequences

In case the spent fuel from Koodankulam is to be reprocessed, then the potential environmental impact of that has to be considered. Reprocessing, in many ways, is the dirtiest part of the nuclear fuel cycle producing large amounts of solid, liquid and gaseous radioactive waste. This is because reprocessing essentially separates out the large amount of radioactive substances contained in the spent fuel into three waste streams: low level, intermediate level, and high level. The low level waste is released into the biosphere and is therefore a conduit for various fission products to potentially reach human beings. The amount of low level waste produced could be about 8000 cubic metres per year for reprocessing the spent fuel from each of the Koodankulam reactors.

Such radioactive discharges can be transported for long distances in the oceans. Radioactivity levels in the oceans near Norway, for example, have shown increases due to reprocessing activity at Sellafield in the United Kingdom (NRPA, 2002). Ireland in fact sued the United Kingdom at a European Union Tribunal at the Hague, Netherlands, over pollution of the Irish sea.

In addition to routine releases of radioactive materials, reprocessing plants are also susceptible to a wide spectrum of credible accidents because of the complicated nature of the chemical processes involved. Broadly speaking one can classify the more serious accidents into fires, explosions and criticality accidents.

Fires: There are a number of inflammable materials in a reprocessing plant, in particular organic solvents and zircaloy (the zirconium-based alloy used to clad the radioactive fuel elements in reactors). Some of the materials used for packaging radioactive waste are also inflammable. Any of these could catch fire, potentially leading to the release of radioactivity. One instance was the 1997 fire at the Tokai reprocessing plant in Japan. The fire started in the section where low level wastes from reprocessing were fixed in asphalt (bitumen). After ten hours of burning, the fire triggered an explosion. Thirty-seven workers received varying radiation doses, mostly from internal exposure to radioactive cesium. Radioactivity levels increased measurably up to tens of kilometers from the site of the accident.

Explosions: Some of the chemical reactions that take place during reprocessing produce explosive mixtures. The high radiation levels also cause the disintegration of chemicals that can sometimes produce hydrogen, which is again explosive. The last major explosion occurred at Russia's Tomsk reprocessing plant in April 1993 when reactions between the nitric acid and organic solvents produced large volumes of a gaseous mixture that eventually exploded. Radioactive fallout from the explosion spread widely and was detected even as far away as Alaska.

Explosions could also occur in tanks that store high level radioactive waste from reprocessing. Due to the heat produced by radioactive decays, such tanks have to be constantly cooled and loss of cooling could cause drying out and creation of an explosive residue. One prominent example occurred in September 1957 at the Mayak facility in the Soviet Union when a tank containing high level waste underwent a large explosion (estimated to be between 25 and 100 tons of TNT equivalent) and ejected 70-80 tons of highly radioactive waste with a total radioactivity of 20 million curies into the atmosphere. Radioactive fallout settled along a 400 km long swath of land, covering an area of over 20,000 square kilometers, much of which still remains uninhabitable. The collective radiation dose to the resident population before it was permanently evacuated was nearly 6000 person-Sv. This collective dose would be expected eventually to result in about 340 cancer deaths according to standard estimates of mortality from radiation induced cancer.

Criticality: Also serious are criticality accidents where fissile materials like enriched uranium and plutonium are allowed to reach a concentration where an uncontrolled chain reaction like that in a nuclear bomb results (but with much less energy produced). An example is the accident that occurred in 1999 at the Tokaimura fuel fabrication facility in Japan. The accident occurred because workers put fuel enriched to 16 per cent uranium-235 in a container meant to hold fuel for light water reactors, which is usually only enriched to 3-5 per cent. This set off a chain reaction, resulting in elevated radiation exposures to several hundred workers and members of the public, including three workers who received large exposures, one of whom subsequently died from acute radiation sickness following a radiation dose of about 16 Sv (1600 rads). Similar events have occurred in reprocessing plants, for example at the Idaho Chemical Processing Plant, USA in 1959.

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