NUCLEAR SAFETY & TERRORISM: A CASE STUDY OF INDIA

Dr. Shireen M. Mazari & Maria Sultan

Terrorism has become an increasing concern within international society but so far there has been less focus on one particular aspect of the problem – that is nuclear terrorism. Yet, within the context of South Asia this is of special significance, given the number of insurgencies and freedom struggles with transnational linkages, and the nuclearisation of this region since 1998. Of all the South Asian states, India's nuclear facilities are perhaps the most vulnerable to nuclear terrorism, given India's expansive nuclear programme, much of it not subject to IAEA safeguards. In addition, the vulnerability of India's nuclear facilities is further aggravated by its thriving underworld and over a dozen insurgencies going on within the Indian states, as well as the freedom struggle in Indian Occupied Kashmir.

This paper seeks to examine the case of India within these parameters to assess how vulnerable India's nuclear cycle is to nuclear terrorism in terms of acquisition of nuclear material by terrorists. The problem has three dimensions to it: One, nuclear theft; two, leakages at nuclear facilities; three, hazards prevailing at the base of the nuclear cycle, e.g uranium mining.

These issues are not new. In order to deal with these concerns, various conventions and treaties have evolved at the global level. This paper will begin by examining the provisions of these agreements as well as India's accession, or otherwise, to them.

The Treaties

Since India, like Pakistan, is not a party to the NPT, it is not subject to IAEA-NPT safeguards. However, IAEA safeguards, outside of the NPT, are applicable to nuclear facilities with an imported component if the exporter has insisted on such safeguards. In the case of India, not only are most of its facilities with a foreign component unsafeguarded, but its own totally indigenous facilities are also unsafeguarded. Thus, prevailing IAEA safeguard provisions do not impact India's nuclear facilities in any substantive manner.

The Convention on the Physical Protection of Nuclear Material

The Convention was opened for signature on 3 March 1980, and came into force in 1987. By April 2001, sixty-nine states and EURATOM were parties to this Convention.

The Convention obliges parties to ensure that during international transport across their territory, or on ships or aircraft under their jurisdiction, nuclear materials for peaceful purposes (that is, plutonium, uranium 235, uranium 233 and irradiated fuel) are protected at the agreed levels (categorised in Annexures I and II of the Convention and specified in IAEA INFCIRC/2251). Also, under certain conditions, the Convention is applicable to nuclear material used for peaceful purposes while in domestic use, inclusive of its storage and transport.

Parties have to commit that they will not export or import nuclear materials or allow their transit through their territory, unless they have received assurances that these will be protected during international transport in accordance with the levels of protection determined by the Convention. Parties also undertake to share information on missing nuclear materials in order to expedite their recovery.

Robbery, embezzlement or extortion in relation to nuclear materials, as well as acts without lawful authority involving nuclear materials, which cause or are likely to cause death, or serious injury, to any person or substantial damage to property, are to be treated by state parties as punishable offences and are also deemed extraditable offences in any extradition treaty that exists between state parties. Also, state parties undertake to include them as extraditable offences in every future extradition treaty to be concluded between them. India has not signed this Convention.

The Conventions on the Early Notification of a Nuclear Accident & on
Assistance in the Case of Nuclear Accident or Radiological Emergency

The Conventions were adopted by the IAEA General Conference in its special session held in Austria from 24-26 September 1986. The Conventions had been agreed upon in the aftermath of the Chernobyl accident in 1986, confirming the need for international instruments for an early notification of a nuclear and/or a radiological emergency and any assistance to be made available to the affected State. The Conventions aim at the early notification of a nuclear accident and establishment of a mechanism for provision of international assistance in case of an accident. The Convention on the Early Notification of Nuclear Accident deals with providing information by a State to other State parties, either directly or through the IAEA, regarding a nuclear accident, which would have a transborder effect, in order to minimize the radiological consequences for the affected State(s).

Till the end of October 2000, the Convention had more than 86 contracting parties, including India, with certain reservations. The reservations made by India state the Indian disappointment that the Convention does not include all nuclear accidents, with the case being made by the government of India that it should cover all accidents, civil and military – including accidents emanating from nuclear weapons or nuclear weapon tests, 'since transboundary effects of radiological safety have significance from any source whatsoever, like any nuclear facility, vessel, aircraft, space craft, etc'.[2] Nevertheless the Indian government ratified the convention, 'in view of the solemn assurances by the nuclear weapon states to the effect that they undertake to notify all accidents'.[3]

The Convention on Nuclear Safety

The Convention on Nuclear Safety was adopted in an international diplomatic conference in April 1994, and entered into force in October 1996. The objective of this Convention is to ensure the maintenance of a high level of nuclear safety worldwide, through the enhancement of national measures and international cooperation; to establish and maintain effective defences in nuclear installations against potential radiological hazards; to prevent accidents with radiological consequences and to mitigate such consequences, should they occur. The Convention is applicable to the safety of land-based civil nuclear power plants. It places obligations on the contracting parties to take appropriate steps to ensure the safety of these plants. In April 1999, the first review meeting was held, at which each contracting party had reported steps they had taken and a review was carried out of the corresponding respective measures taken by state parties. As of April 2000, there are 65 signatories and 53 parties. India has signed, but not ratified the Convention.

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

The Convention had opened for signature in September 1997, and entered into force in June 2001. As of mid-April 2000, there were 40 signatories and 16 states party to the convention. The Convention aims at the safe and secure storage, use and disposal of separated plutonium and highly enriched uranium, including the treatment of spent fuel and military waste from stored sites and reactors, in addition to the transboundary movement of these materials. The Joint Convention applies to spent fuel and radioactive waste resulting from civilian nuclear reactors and applications and to spent fuel and radioactive waste from military or defence programmes – if and when such materials are transferred permanently to, and managed within exclusively civilian programmes, or when declared as spent fuel or radioactive waste for the purpose of the Convention by the Contracting Party. The Convention also applies to planned and controlled releases into the environment of liquid or gaseous radioactive materials from regulated nuclear facilities.

The obligations of the Contracting Parties with respect to the safety of spent fuel and radioactive waste management are based, to a large extent, on the principles contained in the IAEA Safety Fundamentals document, The Principles of Radioactive Waste Management, published in 1995. They include, in particular, the obligation to establish and maintain a legislative and regulatory framework, to govern the safety of spent fuel and radioactive waste management and the obligation to ensure that individuals, society and the environment are adequately protected against radiological and other hazards. This is to be done, inter alia, by appropriate siting, design and construction of facilities and by making provisions for ensuring the safety of facilities both during their operation and after their closure. The Convention imposes obligations on Contracting Parties in relation to the transboundary movement of spent fuel and radioactive waste based on the concepts contained in the IAEA Code of Practice on the International Transboundary Movement of Radioactive Waste. Also, Contracting Parties have the obligation to take appropriate steps to ensure that unused sealed sources are managed safely.

Measures against Illicit Trafficking in Nuclear Materials and Other Radioactive Sources

A resolution was adopted on 3 October 1997, during the 9th plenary meeting of the General Conference of the IAEA that had focused on the efforts regarding measures against illicit trafficking in nuclear materials and other radioactive sources. The Resolution primarily welcomed the activities in the fields of prevention, detection and response undertaken by the secretariat, and invited all states to participate in the illicit trafficking database programme on voluntary basis.

While India is a party to most of the conventions discussed above, the continuing failure to sign and ratify the Convention on the Physical Protection of Nuclear Weapons adds to the safety fears regarding India's nuclear facilities – especially given the vast geographical spread of its nuclear programme. How far the prevailing treaties and agreements are effective in ensuring the safety of nuclear programmes in countries like India – which are primarily outside IAEA safeguards – can be judged by going through the three dimensions of the problem.

I - Nuclear Theft

Limited access to fissile materials and international safeguards on nuclear facilities are the two main barriers to nuclear proliferation and nuclear terrorism in the world today. The potential effects of a theft of plutonium and uranium go beyond national borders, especially in South Asia with its transnational ethnic and religious linkages and conflicts.

Today, a broad range of factors, from documented seizures of kilogram-quantities of stolen, weapon-usable fissile material to the newly demonstrated capability and will of terrorists to use weapons of mass destruction, makes it critical to ensure security of all weapon-usable material worldwide.[4]

Since the end of bipolarity and the disintegration of the Soviet Union, an issue of concern has been the possibility of theft of nuclear fissile material from the former states of the Soviet Union. Special efforts have been taken by the US and international organisations to properly secure these sites from the possible theft of fissile material. However, beyond the old Soviet states, there have been reported cases of theft of fissile material from states such as India.

In the case of India, the incidences of nuclear theft date back to the seizure of nuclear fissile material as early as the 1980s. However, after the 1998 nuclear testing by India and Pakistan, as well as the rapidly expanding Indian nuclear programme – coupled with the more than a dozen insurgency movements in India – the threat of theft and possible use of nuclear weapons by sub-national groups and terrorists has been aggravated in South Asia. This threat is further multiplied because India has been known to make clandestine purchases of fissile material from private sellers abroad – normally in the old Soviet territories.

The most recent uranium theft case to come to light was reported on 27 August 2001, when police in West Bengal revealed that they had arrested two men with more than 200 grams of semi-processed uranium.[5] According to the press report, Indian intelligence officials believed that a uranium smuggling gang was operating in West Bengal.[6]

While reports of Indian involvement in the theft of nuclear fissile material dates back to the early 1970s, the magnitude of the threat increased manifold in the 1980s and 1990s. In the late 1980s, the CIA had concluded that India was trying to develop a sophisticated Hydrogen bomb. In 1994, on a tip-off, a shipment of beryllium was caught in Vilnius, worth US $ 24 million. The buyer was thought to be either from India or North Korea – though the shipment was caught before it could reach the buyer.[7]

In July 1998, India's Central Bureau of Intelligence (CBI) unearthed a major racket in the theft of uranium in Tamil Nadu, with the seizure of over 8 kg of the nuclear material in granule form and the arrest of three men.[8] The contents of this theft were sent to the Indira Gandhi Centre for Atomic Research (IGCAR) for preliminary analysis and the Centre declared that there were two kinds of substances found in what they said was 6 kg of uranium – natural uranium (U237and U238) and U 235, which is weapons grade uranium. The substances were found in the possession of Arun, a structural engineer, S. Murthy and their associates.[9]

The investigations also led to cases of further seizure of uranium on 31st July 1998, of 31 grams in addition to 2 kg – caught from another accomplice of the two engineers. The approximate abundance of uranium U235 in the samples indicated a 1.40 percent and 2.20 percent of enrichment. This showed that the uranium was neither an ore of uranium nor depleted uranium, but had its existence in an atomic research centre. Meanwhile, the director of the Indira Gandhi Centre for Atomic Research denied the possibility that the uranium could have come from the Madras Atomic Power Station (MAPS) at Kalakkam near Chennai.[10] However, later, when the CBI had vowed to go ahead with the investigation, the leading atomic research centre stated that the substance caught was not uranium but limenite – a non-strategic substance having ordinary applications.[11] The shift in the stance of the research centre, from their initial report of a relatively high level of uranium enrichment to its total absence in the substance, caused a considerable problem for the prosecutors as they could not pursue charges against the persons. Later, as a result of this lead, CBI seized 2 more kilograms of uranium and 31kg of platinum. However, due to the change of statement by the atomic research centre, the case was buried.[12]

Again, on May 1, 2000, Mumbai police seized 8.3 kgs of uranium.[13] The uranium was termed as depleted but radioactive uranium by the Bhabha Atomic Research Centre (BARC). In this instance, the source of this uranium theft – as cited by the police – had been a local hospital, the Leelavati hospital, in Bandra. The fissile material had been found in the custody of scrap dealers who were caught and charged under the Atomic Energy Act. However, the Leelavati hospital authorities maintained that no fissile material/uranium was missing from the hospital. The consistent denial by the hospital authorities and the fact that no material was found missing from the hospital equipment indicated that the source of the material was not the hospital premises. All radioactive materials from the Indian hospitals are technically accounted for and are to be returned to the relevant nuclear research centre. According to this principle, the Leelavati hospital was to return the depleted uranium to Bhabha Atomic Research Centre, after it was rendered as ineffective or had outlived its medical utility. So how could it have found its way to the scrap dealers?

When the stolen material was sent for further analysis to establish the exact nature of the radioactive substance, BARC stated that the material found was primarily a shielding material used as counterweight in aircrafts and had no relevance to nuclear weapons technology.[14] Despite the fact that the material was radioactive and could pose health hazards, K. S. Parsatarathy, the secretary of the Atomic Energy Regulatory Board (AERB) stated that the 8.3 kg material seized contained merely 2% of uranium U235, which made the material depleted, having a zero weapon value.[15]

The incident might have been an exception, but on November 5, 2000, the CBI recovered 25 kg of radioactive uranium from a person in the Bibi Cancer Hospital – the material was to be returned back to BARC.[16] The person singled out in this case of uranium seizure was also a scrap dealer. According to the scrap dealer, he had bought a machine from the hospital as scrap and was, therefore, the natural owner of the radioactive substance found in the machine. Yet, according to the restrictions imposed on hospitals by BARC they are not allowed to sell radioactive materials to scrap dealers and the hospital had stated that the material was accounted for.[17] The material once again, according to BARC, was depleted uranium. In this case, as in the earlier case, the Bibi Cancer Hospital in its initial statement denied the charges levelled against the hospital that they had sold a machine with radioactive material to a scrap dealer and stated that there was no material missing from the hospital. However, later the hospital withdrew from its earlier stance and admitted that it had sold parts of the machine.[18] Interestingly, the Bibi Cancer Hospital's record did not show the use of any such machine, which used uranium as a radioactive substance.[19]

On November 13, 2000, the IAEA reported that the Indian police seized three uranium rods and arrested eight persons on charges of illicit trafficking of nuclear material. The critical question here is, where did the rods come from? The suspicion was that the civil nuclear facilities were vulnerable to such thefts. Again, on November 7, 2000, according to the IAEA, the Indian police seized 57 pounds of uranium and arrested two men on charges of illicit trafficking of radioactive material.[20]

Once again, the radioactive material was traced back to a nearby hospital, which denied any reports of missing uranium from its stocks. The fact that the seized radioactive material had been found in the form of three uranium rods reflects the possibility that the origin of these rods may be from a civilian nuclear power plant, or from one of the rapidly expanding Indian nuclear research facilities – rather than from a hospital.

While reviewing the various cases of uranium theft in India, certain questions arise as to how and why in most cases, was the uranium found in the hands of scrap dealers? Other disturbing questions also arise. For instance, why were charges not levelled against the persons who were found in possession of the radioactive material? Why, in a number of cases, did the hospitals change their position on the thefts? Who are the potential buyers for the scrapped radioactive material in India, and is the material intended for internal or international buyers? In fact, one can legitimately wonder whether there is a nuclear mafia present in India. Even more disturbing are the questions raised about the security of the Indian nuclear facilities, including their research facilities.

When one puts all the reported theft cases together, some patterns can be discerned. To begin with, the seizing authority has been either the local police or the CBI. Most of the accused have been scrap dealers who are obviously used as front men, which may well indicate the prevalence of organised crime relating to nuclear materials. Again, in almost all the cases, the charges were dropped against those found in possession of the material, and in most of the cases the initial assessments of the material were later altered. The source of origin, in most case, as stated by the police, have been cancer hospitals – although the nature and quality of the uranium found in the use of the hospitals has differed from case to case. But in all the cases involving hospitals, the latter have denied any material going missing or being stolen. In any case, the amounts supposedly stolen from hospitals are far more than the normal requirements of these hospitals. So, the focus has to shift to Indian nuclear facilities and the whole issue of their safety – especially in relation to theft and nuclear terrorism. This, in turn, raises concerns about the employees of these facilities and their links to possible mafias. Also, the whole issue of safety of transportation of nuclear materials from the mining stages to the spent fuel storage becomes critical in the dynamics of nuclear theft and technical safety of the facilities. While the rising incidents of nuclear theft create the possibility for a lucrative underground market for potential terrorists, unsafe nuclear facilities create risks for the surrounding populace – which has to live in constant terror of a nuclear accident.

II - India's Nuclear Facilities: the Safety Factor

India's nuclear programme has developed at an exceptionally fast pace (see Appendix I). Yet, because few of such facilities are under international safeguards, there is little known about the levels of safety of the various nuclear facilities. Of the ten operational power plants, only four are under IAEA safeguards. According to an Indian parliamentary report, 147 mishaps or safety-related unusual occurrences were reported between 1995-1998 in Indian atomic energy plants.[21] Of these, 28 were of an acute nature and 9 of these 28 occurred in the nuclear power installations.[22]

Thus, the state of Indian nuclear facilities raises serious concerns as they seem to be vulnerable to a high probability of terrorist attacks, thefts and accidents. The scale of the programme aggravates the problems, as there are plans for the building of pressurized heavy water reactors, fast breeder reactors and thorium reactors on a commercial scale.

The Reactors & Other Nuclear Facilities

With regard to the security of the mostly unsafeguarded nuclear reactors, evidence suggests that there is a need for Indian authorities to upgrade physical protection systems at most of these reactors, as well as at other facilities like laboratories, fuel fabrication and reprocessing plants and research institutes. The probability of reactor melt-down as a result of simple sabotage

Source: Compiled from collated information.

– like a truck bomb – cannot be ruled out, given the prevailing inadequate state of safety that exists. Structural, design andoperational problems continue to trouble Indian nuclear facilities.[23]

Given the organised nature of the uranium theft patterns discerned above, the possibility exists of linkages between the organised groups involved in these thefts and insiders working at these nuclear facilities. Hence, it is essential to look for links between the persons caught and the state of security at various Indian nuclear facilities. According to most published information, Indian nuclear reactors and facilities have little or no protection against reactor melt-downs, if initiated through acts of sabotage. Most Indian reactors have been made in India, through a process of replication and with little or no outside help. Though it is claimed that power reactors with containment systems are relatively more resistant to sabotage than research reactors, such an act can wreck the control rooms and essential secondary systems and trigger a core melt-down, with catastrophic radioactive releases.[24]

According to Dr A. Gopalakrishnan, former Chairman of India's AERB, Indian nuclear facilities have had 130 instances of safety-related concerns, including 95 that required urgent action. He reported this in the context of a 3000 page report about India's nuclear facilities, made to the IAEA in 1996.[25] Christopher Pine, a nuclear expert at the Natural Resources Defense Council in Washington, reaffirmed the same facts, stating that the Indian power plants have the lowest capacity factor in the world and one of the poorest safety records.[26] A 1993 UN report states that occupational exposure hazards in India, calculated in proportion to the amount of electricity generated, is six to eight times more than the world average. India has denied the UN figures, terming them as incorrect.[27]

Bhabha Atomic Research Centre (BARC)

Bhabha Atomic Research Centre is India's premier nuclear research laboratory, located in Mumbai. Indian authorities claim that most of the work at this Centre relates to civilian applications. Nevertheless, the dual usage of the material produced here is extremely significant. In fact, many regard BARC as the centre of New Delhi's nuclear weapons programme, with BARC personnel having been instrumental in the designing and building of the nuclear devices that were tested in May 1998.[28]

One of the problems relating to India's civilian nuclear facilities is that, on ground, there is no well-defined boundary separating the peaceful use of these facilities from the weapons programme. Also, most of the civilian facilities are not subjected to IAEA safeguards. The dual use problem is reflected in the fact that the fissile material for the Indian nuclear tests has always come from its civilian nuclear facilities.[29]

Amongst the important units at BARC are CIRUS and DHURVA research reactors. The 40 MW CIRUS is a heavy water, natural uranium research reactor. The reactor is a Candu prototype installed with Canadian assistance, and it went critical in July 1960. This reactor uses natural uranium as a fuel, accompanied by heavy water as a moderator and light water as a coolant and it has a manufacturing potential of producing 10 kg of plutonium annually, as part of reprocessed spent fuel.

Both, Canada and the US had initially given nuclear assistance to India, and the US had supplied India with two boiling reactors, which had begun operating at Tarapur in 1969. Atomic Energy Canada, Limited, had also supplied pressurized heavy water reactors of the Candu type in Rajasthan (RAPS I Kota). RAPS I is a heavy water, natural uranium-based 190-220 MW reactor, which went critical in 1972. This reactor source has often been cited as the front end of the nuclear fuel used by India in its 1974 nuclear explosion in Pokhran. The Indo-Canadian and Indo-US nuclear cooperation apparently ended when India detonated the 1974 device.

Left on its own, India started replicating the Candu reactors within the country, and currently it has a large number of Candu design reactors within India. The focus on Candu type reactors rests on the fact that these reactor types use natural uranium and India has large reserves of this material. Thus, making use of this reactor type was the natural choice for harnessing nuclear energy as a potential source of cheap power and weapons capability.

Nevertheless, the initial line of Candu reactors suffered from design problems. One of the key problems has been that India's Candu clone programme has not kept up with design improvements and the earlier versions of Candu reactors had inadequate emergency cooling systems.[30]

India's Department of Atomic Energy (DAE), had independently improved the cooling system in two pairs of reactors at Kakrapar I & II and Narora I & II which are based on the same design. However, the exact efficiency of the design improvement is debatable, even in the new reactors. The Indian DAE has made no upgrades or improvements in the design of the older reactors at Rajasthan and Madras – all of which have been termed as hazardous and dangerous by the Canadian manufacturers.[31]

Also, equipment problems have resulted in the operation of these reactors at lower levels than their original intended capacity. Coupled with this, the safety problems increased manifold, due to a lack of adequate research in reactor construction and the Indian desire to build the reactors without incorporating adequate safeguards.

On March 1993, a fire in the Narora Atomic Power Station (NAPS), 180 km east of New Delhi, nearly caused a melt-down.[32] The fire, according to reports, had started in a turbine generator, where two blades had snapped from fatigue, causing more blades to break and the whole machine to come to a grinding halt. According to the chronology of events released by the Indian Atomic Energy Regulatory Board to Far Eastern Economic Review,[33] the act of injecting a liquid to stop the nuclear reaction, in an attempt to stop the fire from reaching the reactor door, had activated a secondary shut down and non-radioactive steam had been allowed to blow off. The situation had become alarming, according to this report, when the fire burned through both the regular and the emergency cables. This caused the cooling pump to stop, resulting in a power loss. The account goes on to state that, in order to prevent a reactor melt-down, four crewmen stepped up besides the reactor on an 18-storey platform and cracked open the valves and poured in the boron solution, known as Gravity Addition of Boron (GRAB) system. Had the situation not been contained, it could have been a replication of the Chernobyl incident. According to Gopalakrishnan, the then chairman of AERB, 'it could have been a partial melt-down or localized explosion'.[34]

In addition, the President of the Atomic Energy of Canada, Limited, also stated that the Canadian Candu reactors in India were suffering from hybrid blisters, which could lead to rupture and massive leaks of the heavy water coolant. According to the Canadian Atomic Energy Commission, The position is so bad that there is a real potential for a pressure tube rupture to occur at any time.[35] Canada was the original designer of the Pressurized Heavy Water Reactors (PHWRs) – a design adopted extensively by India, including at the facilities in Rajasthan, Madras, Uttar Pradesh, etc.

DHURVA is the second major reactor at Trombay, under BARC. This research reactor is based on a natural uranium, heavy water design of Canadian origin and, like other Indian reactors, also suffers from design problems. The reactor has, since its construction, remained unable to function at full operating potential. This has lead to fuel failures, which have not been rectified to date.

Similarly, another issue causing concern at BARC has been the issue of radiation leakages, which happen regularly, and the directors of BARC have remained unable to control leakage and the spread of radiation underground in and around BARC.[36] In 1991, CIRUS had developed a radiation leak and Cesium 137 was reported to be present in the soil water and vegetation near the discharge lines of CIRUS and DHURVA.[37]

Similarly, according to various news reports, the bed of the Thane creek, which is an extension of the sea at Mumbai port, has also become radioactive because of the nuclear effluents discharged by the research and reprocessing plants at BARC.[38] The added danger of these leakages is that their sources form the basis of the fabrication potential of many of the materials and equipment used in India's military programme – so that the leakages have a very high grade of radioactivity. In addition, the fact that these military facilities are unsafeguarded, implies that there can be theft of weapons grade material.

BARC primarily forms the basis of the Indian requirements for primary fissile material generation method, i.e. it converts uranium into metallic reactor fuel, irradiates that fuel in DHURVA and CIRUS and then reprocesses the spent fuel to extract weapons grade plutonium. The CIRUS reactor has produced an estimated total of 240 to 336 kg of plutonium from 1964 to1999.[39] The larger DHURVA reactor, on a conservative estimate, produced a total of 280 kg of plutonium between 1985-1999. Presently, India's existing fissile material stockpile can produce, according to a conservative estimate, approximately 85 to 120 warheads.[40]

The inadequate safety measures of these expansive facilities continues to plague the Indian nuclear programme. In the mid-1990s, one of six 200,000 litre waste tanks at BARC developed major leaks and had to be emptied. The specific incidents of radiation leakage and design faults in each of the Indian nuclear reactors are grave enough to illustrate that the nuclear radiation levels permissible in India are much higher than what are allowed by international standards. Plans by the Indian DAE to build up to five more research reactors in Trombay, based on the Candu type designs, will increase India's stockpile of unsafeguarded plutonium. The danger lies in the fact that the new power plants will be based on the design of the 100 MW DHURVA reactor, which has been operating at BARC.

The Case of 'Black Diamonds'

In 1992, BARC scientists were allegedly involved in an illegal practice of exporting 'black diamonds' to the international market.[41] According to news reports, the illegal practice had admittedly been going on at BARC for over 20 years. Some senior BARC scientists were making money by using the research reactor, APASRA,[42] to irradiate natural diamonds, thereby making them darker in colour, as well radioactive, and then selling these fake black diamonds on the international market. According to the London-based Diamond Trading Corporation (DTC), these diamonds had dangerously high levels of radioactivity. The DTC warned the government of India not to allow its facilities to be used for these practices.[43] The incident heightened fears regarding the safety of India's nuclear programme, given the fact that its scientists were also prepared to sell nuclear-related material. This also aggravates the suspicion that Indian nuclear scientist can easily fall prey, as well as have access to the underground criminal networks.

BARC is central to India's nuclear weapons infrastructure and its scientists are responsible for designing the country's nuclear arsenal. Although there have been inputs from other laboratories like Terminal Ballistic Research Laboratory, the Institute for Armament Technology, the Armament Research and Development Establishment and the High Energy Materials Research Laboratory, the Trombay complex has been the focus of nuclear and thermonuclear designs since 1980. Today, BARC personnel are working on a variety of tactical and strategic weapons' designs, including boosted weapons small enough to be carried by ballistic missiles.

Madras Atomic Reactor (MAPS)

The Madras Atomic Reactor (MAPS) at Kalpakkam, near Chennai, is primarily a research reactor of 30 KW power generation capacity, with an ability to use Uranium 233. The reactor is, interestingly, in close proximity to the area in which most of the uranium theft cases have been registered and taken place. This reactor is a PHW of Canadian design. It has two units, each of 220 MW, but due to design and safety problems, they were downgraded to 170 MW each. The reactors near Kalpakkam, i.e. MAPS I & II, are not under IAEA safeguards. The two units had run into problems soon after they were commissioned in the mid-1980s. According to reports, the reactors suffered from acute design problems and saw high-scale radiation leakages. It is claimed that, soon after construction, the moderator distribution systems collapsed inside the reactor, leading to a situation where advance robotics had to be developed to remove the debris.[44]

Since the early 1990s, bits of metal from broken manifolds have been lying at the bottom of the chambers of the Unit one and Unit two of MAPS.[45] To date, efforts to retrieve the bits have remained unsuccessful. According to various analysts and reports, the constant flow of uranium fuel inside the tubes, and the pressurized heavy water around them, had caused the detachment of the manifolds, cutting them into several pieces. In the early 1990s, MAPs Unit one also faced a mechanical problem, as a turbine blade broke down.[46]

Similarly, the output of MAPS I and II has dropped below average in recent years because of functional problems in the coolant channels, which are now going to be replaced. In addition to this, there are reports that the temperature in the sea near the facility has remained high due to the radiation leakages.[47] However, in March 1999, due to the malfunctioning of coolant channels, there was a major leak in the heavy water reactor.[48] Under normal conditions, the temperature in the sea at Kalpakkam is 85 degrees F, but when the plants are in operation it rises to 140 degrees F.[49] Such temperature increases can be associated with the presence of the 340 MW reactor in the vicinity and a possible radiation leakage from the plant, as it is believed that the radiation leakage from somewhere within the reactor is causing the water to heat. Increased sea temperatures, as a probable result of radiation leakage, are of grave concern to the population centres, as well as to the marine life.[50]

By 2004-5, India plans to build two new power reactors based on a Russian-design, VVER Pressurized Water Reactors of 1000 MW at Kudankulam in Tamil Nadu. Fears regarding the VVER design stem from the fact that the US Three Mile nuclear power plant was of this design and it suffered a nuclear accident in the early 70s. The potential radiation leakage from these Russian origin, light water reactors, each having a capacity to produce 1000 MW power, therefore, remains a high probability. In such an event, the exact or the full impact of the 2000 MW power reactors in Kudankulam will be catastrophic, especially since MAPS I and II are unsafeguarded reactors and their spent fuel is an attractive source of plutonium for reprocessing plants. The plutonium extracted from these sources would lead to higher reserves of reprocessed plutonium. Without international monitoring, these reserves can be susceptible to theft by potential nuclear terrorists.

Tarapur's Power Reactor Fuel Reprocessing Plant (PREFRE) has also started reprocessing spent fuel from MAPS I & II, since they went critical in the mid-1980s. Though PREFRE supplies plutonium to the Fast Breeder Test Reactor (FBTR) and Tarapur's MOX [51] fuel fabrication facilities, it is not known whether any of the fuel reprocessed and used here can be utilised for the Indian weapons programme. However, the operational capacity of the two reactors leads to the speculation that if minimum production standards are observed in the two facilities, each reactor can have the potential to create approximately 10 kg of weapons-grade plutonium annually for India's weapons programme.[52]

Indian officials have stated that the Kalpakkam reprocessing plants will primarily extract plutonium from spent fuel, irradiated in the country's commercial reactors. Nevertheless, its military usage cannot be ruled out, nor can the chances of radioactive material being stolen from here. Under normal conditions, plutonium extracted from commercial reactors is not fit for use in nuclear weapons, due to its low concentration of plutonium. However, tests in the US have proven that reactor-grade plutonium can be used to produce unstable nuclear devices.[53] In the case of India, to date the plutonium extracted from

MAPS at PREFRE has been used to produce MOX fuel, or to conduct research. Similarly, the Sol-gel pilot plant and electro refining plants, like all facilities for the Kalpakkam nuclear programme, are proliferation concerns. The reason being the presence of reprocessed plutonium, which could be easily diverted or stolen because of the unsafeguarded nature of these nuclear facilities.

Furthermore, since there exists an inherent difficulty in detecting clandestine nuclear activities, India's pursuit of fast breeder reactors can be termed as an attractive source for theft by crime mafias – especially since fast breeders produce more fissile material than they use, thereby adding to the fissile stocks. Because most of this fissile material is intended for military use, so there is the possibility that any material diverted or stolen from these facilities will have a higher degree of enrichment, thereby increasing the potential of radiological terrorism. In addition, various design problems have led to operational failures in Indian nuclear power plants and these pose a constant threat of radiation to those living in the vicinity of these plants.

Indira Gandhi Centre for Atomic Research (IGCAR) Kalpakkam Fuel Reprocessing Plant (KARP)

The Kalpakkam Fuel Reprocessing Plant (KARP) is the third reprocessing plant that is nearing completion. The plant was commissioned on 27 March 1996. Also known as the Kalpakkam Fuel Reprocessing Plant, it reprocesses spent fuel from MAPS, as well as from the Fast Breeder Test Reactors (FBTR) at Kalpakkam, under the Indira Gandhi Centre for Atomic Research (IGCAR).[54] IGCAR is one of India's premier nuclear research and development institutes. Established in 1971, the centre's staff, of approximately 2,300, including 1,000 scientists and engineers, conducts research on fast breeder reactors, sodium technology, plutonium reprocessing, and naval reactors.[55] The facility has a design capacity to reprocess 100 Mt of spent Candu fuel each year using the Purex process.[56] Nevertheless, the plant commissioned in 1985, has suffered for years because of technical delays and financial problems and was unable to begin the scheduled operations in 1990.[57] While most of the plant's components are indigenously developed, some of the technology and components have been imported from the West in general, and Germany in particular.

KARP is one of the several nuclear facilities located at the IGCAR. The FBTR facility at the Centre has experienced numerous shutdowns as a result of technical problems. It was closed between 1987-89, and ran at a mere 1 MW capacity from 1989-92.[58] The reactor has rarely operated at its designed output levels due to an undersized fuel core, and the various unsuccessful attempts of indigenizing the French reactor design to meet Indian needs.

The FBTR, run jointly by IGCAR and BARC personnel, primarily burns MOX fuel developed at BARC. Its initial nuclear fuel core used approximately 50 kg of weapons-grade plutonium. DAE officials have said the reactor is now being fuelled by plutonium extracted from fuel irradiated in the Madras power reactors and reprocessed at PREFRE.[59] To complement the development of advanced research for the FBTR, IGCAR and BARC personnel have built the Kamini 30 KW research reactor. The Kamini reactor is fuelled by U-233 (irradiated thorium) and is instrumental in neutron radiography studies of fuel irradiated in the FBTRs.[60] The reactor was commissioned in 1989, and went critical on 29 October 1996, and reached its full power capacity on 17 September 1997.[61] According to reports, IGCAR has reprocessed U-233 from irradiated thorium, as part of its strategy to eventually use U-233 as the primary fuel for India's nuclear programme.[62] BARC personnel are building a waste immobilization (vitrification) plant at Kalpakkam to handle waste from the Kamini reactor, the FBTR, and IGCAR's reprocessing facilities.[63]

India intends to eventually build commercially viable FBRs. To achieve this goal, New Delhi plans to construct a 500 MW pressurised FBR at Kalpakkam. The initial core load will use MOX fuel, containing 2000 kg of plutonium extracted from spent fuel irradiated in India's commercial reactors.[64] The conceptual design of the FBR was completed in 1996-97 and the construction is scheduled to begin in 2002.[65] This will add to the unsafeguarded fissile stockpiles, and the dangers of theft and radiation that that implies.

Kalpakkam is also a development site for India's nuclear-powered submarine programme called the Advanced Technology Vessel (ATV), which constructs the structural mechanics of reactors, thermal hydraulics, and components handling, in addition to developing the pressure vessel structure.

This site is also being used by specialists from BARC, who are designing the ATV's reactor, while IGCAR personnel are charged with its construction.[66] If India is able to perfect the technique, it would enable it to manufacture miniaturised reactors which would make their theft easier, especially the theft of fuel rods, etc. Initial tests of the ATV's reactor were reportedly conducted at IGCAR in November-December 1995, but these failed. Nevertheless, it has to be borne in mind that they may perfect the technique in the future.[67] Other facilities have been established at ICGAR to test key components such as the submarine's drive turbines, propellers, and dynamometers.[68]

IGCAR houses additional facilities, including a pilot-scale, ion-exchange, chromatograph facility that can produce Boron-10, presumably for use in control rods for fast breeder reactors. Boron-10 has many nuclear applications, including controlling criticality in nuclear weapons storage sites, reactors, plutonium reprocessing plants, and nuclear materials storage facilities.

Also at Kalpakkam, Indian engineers have completed the design of a Fast Reactor Fuel Reprocessing Plant (FRFRP), which will have a capacity to reprocess up to 1000 Mt of spent fuel per year. A limited number of components, such as ventilation equipment, have also been manufactured.[69] The FRFRP was tentatively scheduled to be cold commissioned in December 2000, but the plant has not gone critical as it still needs work.[70] Given the problems experienced by the DAE with its other reprocessing facilities and a lack of financing, it is doubtful that this facility will actually begin to reprocess significant amounts of spent fuel in the near future. Yet as it stands semi-completed, it becomes a source for acquiring clandestine radioactive material.

Of the nuclear facilities affiliated with MAPS, the tritium extraction plant is the only plant or facility, which is identified as directly related to New Delhi's nuclear weapons programme. It could provide New Delhi with enough tritium to build a large arsenal of boosted fission, or thermonuclear weapons. The tritium production plant would also be the first documented case in which India directly used a commercial reactor for its nuclear weapons programme.[71] Hence the possibility of theft from this plant might not only be possible but is a cause of grave concern, since the actual status of the plant is commercial. When fully operational, the proliferation concern of this facility will be increased. The levels of security at any Indian commercial plant have been found wanting and various accidents at these facilities as well as reported thefts show the vulnerability of these commercial units.

Kakrapar Atomic Power Station (KAPS)

The Kakrapar Atomic Power Station (KAPS), Gujarat, also uses pressurised heavy water (PHW) reactors of Canadian design. It has two units, which went critical in early 1990 – Unit one in 1992 and Unit two in 1993. The reactors experienced a near disastrous fire accident in 1991. Extensive damage was also caused to reactors as a result of the 1994 floods.[72]

The coolant tubes in KAPS are similar to the coolant tubes in RAPS and MAPS and, as of now, all these coolant tubes are at different stage of hydrating and embroilment. The tubes are more prone to becoming weakened by accelerated hydrating and embroilment due to the fact that they can overheat and malfunction easily. This can, in turn, lead to a catastrophic failure that would result in the emission of radioactive material from the core, increasing the probability of a reactor melt-down.

There have also been cases of radiation leaks at these plants. The effects of these radiation leakages are felt by the population around the plant, as they are reported to be suffering from radiation-related health problems.

The Emergency Core Cooling System (ECCS) designed for modern practices and usage in plants, though it has been installed, has not been tested even once. The system is extremely unsafe as it has not been test-proven and the system can suffer a failure similar to that experienced at the Narora plant,[73] which had resulted in a fire. It is still not very clear as to whether the ECCS will function properly.[74] The greatest concern from these reactor types is the plants' ability to produce significant amount of plutonium-bearing spent fuel for reprocessing and use in weapons production.

Kaiga Atomic Power Station

The Kaiga Atomic Power Station at Karnataka, with six units each of 220 MW, is a Canadian design PHWR. Two units of the plant are already under construction and four more are proposed by the Indian government to meet the country's growing energy requirements. The plant suffers from serious design problems. The containment dome of Unit one collapsed in 1994, approximately twenty four hours prior to the plant becoming active.[75] In the more than 50 years of nuclear development around the world, the collapse of the containment dome was unprecedented. Had the dome fallen down when the plant was in operation, then about 130 tons of concrete would have fallen from a height of 30 meters, damaging the automatic control rod drives below the crown of the dome, thereby disabling them. The weight could also have damaged the nuclear coolant pumps and pipes, resulting in the loss of reactor coolant. In turn, this would have led to a melt-down in the reactor core, further resulting in the escape of a large degree of radioactivity in the area. India's difficulties with the Kaiga reactors symbolize its unstable commercial nuclear power programme. Construction has suffered years of delay with high cost overruns. Moreover, the collapse of the Kaiga-I containment dome in 1994 was such a major accident, that it caused New Delhi to re-think its entire commercial PHWR design - which led to the delay of that programme by several years. There have been various arguments forwarded against the plant's construction, such as:

- There has been no government information campaign to tell the people of the hazards of this project to their health.
- Land for the project has been taken over by the Indian government, without compensation for the people living in the area.
- No government health survey has been carried out to monitor the radiation levels and the health levels of the people.
- Upstream of the Kali River (where the Kaiga reactors are located), a number of major dams collect billions of tonnes of water. Local activists have had to alert authorities to cracks in one of these dams, which could cause a nuclear disaster if the dam ever burst.
- The Kaiga reactors and upstream dams on the Kali river are in the earthquake zone within the seismic fault lines.
- A popular people's movement has opposed the Kaiga I reactor for the last twelve years. Village and Taluk (Sub-District) level government bodies have passed various resolutions against the construction of the Kaiga plants.
- The waste material from the Kaiga plants, or a possible radiation leakage, will contaminate the Western Ghats, one of the eight most bio-diverse regions of the world.
- There are no definitive plans of the Indian government, on record, regarding the waste disposal from the plants. An accident involving higher radiation will totally shatter the ecology of the area.
- The energy need of the Uttara Kannada can be met with bio-mass and micro-hydel generators.
- The AERB had specified that before startup, Kaiga should undergo full testing of the ECCS and containment system, and that full scope simulator should be installed to train the operators. However, according to the former chairman of the Indian AERB, these tests have not been conducted.
- The Indian Supreme Court's findings stated that the location of Kaiga should be reconsidered. However, the court's verdict was ignored on the grounds that too much money had already been spent on the project.
- The power generated at the Kaiga plants would not be sufficient to meet the energy needs of the area.[76]

Despite these arguments, the two plants have been under construction, with the aim that between 2004-2007 they will go critical. Nevertheless, there are reports which suggest that Kaiga Unit two went critical in September 1999.[77]

Tarapur Atomic Power Station (TAPS)

The Tarapur Atomic Power Station (TAPS), is among India's oldest commercial nuclear reactors, many of which were provided by the United States in the 1960s. TAPS I and II are boiling water reactors (BWRs) that have maximum design capacities of 210 MW. However, the combined capacity of the two reactors, of 420 MW, has been downgraded to 320 MW.[78] Both units have operated at lower capacity levels and now have maximum net outputs of 160 MW each. The reactors, owned and operated by India's Nuclear Power Corporation (NPC), have operated at 58 percent capacity since the beginning of commercial operations in 1969.[79]

These plants have also had significant radiation problems. In 1995, the radioactive waste from the plant had contaminated the water supply of nearly 3000 villagers living nearby. Though the reactor was shut down, the leak was detected after 45 days.[80] The degree and the intensity of the radiation leakage faced by the Indian nuclear reactors suggests that there is a need to focus on the safety and security of these reactors and the possibility of nuclear thefts. The state of the reactors indicates that the design and maintenance problems have never been addressed properly by the Indian DAE, especially when seen in reference to questions such as what are the radiation levels in the various sub-systems, machinery, pipes and engineering components of the BWR at TAPS? How safe is the adjoining sea from radiation levels?

In 1989, a high dosage of iodine was found in the seawater around TAPS. It was 740 times higher than the normal level.[81] Radiation leaks at these facilities, and in particular at TAPS I have affected innumerable personnel. Hundreds of workers of these facilities have reportedly been exposed to excessive dosages of radiation. They have never been informed about the dangers of radiation. On March 14, 1980, cooling water leaked from reactor I, and 26 workers engaged in repairs had to be rushed to the hospital.[82] For example, in 1992, in Unit one of TAPS II, 94 curies of radioactivity was released into the environment due to a leaking emergency condenser tube in a loop of the unit. The tube failure was attributed to corrosion-assisted thermal fatigue.[83]

Both the reactors suffer from inter-granular corrosion of primary piping. In 1996, a pipe from the waste processing plant in Tarapur was found spilling radioactive liquid waste into a nearby water canal used by the public.[84] Inspectors discovered that a pipe had been incorrectly connected to an external discharge line instead of an internal tank.[85]

The aging reactors are now reaching the end of their planned operational lifespan and at least one former Chairman of the Indian AERB, Dr Gopalakrishnan, has said they are a serious safety hazard.[86] Despite these warnings, Indian officials claim that the TAPS I and II reactors are in good condition and could have their operational lives extended by another twenty years.[87] The potential of having a reactor melt-down in any of these ageing reactors is far too high. Under a 30-year nuclear cooperation agreement, the United States, in addition to building the Tarapur reactors had agreed to providing the low-enriched uranium (LEU) for the BWRs. The agreement had stipulated that the United Sates would supply India with sufficient LEU to fuel the reactors until 1993, but Washington terminated the agreement in 1979, as a result of its 1978 Nuclear Non-Proliferation Act,[88] thereby leaving India to fulfil the reactors' requirements for LEU through indigenous sources.[89]

New Delhi is building two additional reactors at Tarapur that will have design capacities of 500 MW and maximum net outputs of 470 MW. These PHWRs, which would be India's largest indigenously-produced nuclear power plants, are tentatively scheduled to be completed by 2006 and 2007 respectively, by Larsen and Toubro and Walchandnagar Industries, Ltd.[90] Site preparations and excavation for TAPS III and IV had begun soon after the order was placed in 1991, but a delay occurred because of a lack of funding.

These reactors will have the capability to produce large amounts of plutonium through the reprocessing of spent fuel, although the plutonium produced in these reactors will be reactor-grade and, therefore, not ideally suited for use in nuclear weapons due to a low content of the desirable Pu-239 isotope.[91] But its capacity for easy convertibility to weapons-grade plutonium makes it particularly attractive for theft and for the manufacture of a crude nuclear device or an enhanced potential of radiation damage.

In addition to the use of plutonium in these facilities, India seeks to burn MOX fuel, as part of its nuclear power production programme stocked quantities. The MOX contains a mixture of uranium and plutonium. India has loaded a total of at least 70 kg of MOX fuel in TAPS I in 1994 and in TAPS II in October 1995.[92] New Delhi has processed MOX despite international objections, especially from the US, on using plutonium in civilian reactors due to proliferation concerns. According to Indian sources, the use of MOX fuel is considered necessary, despite the proliferation challenges, because of the fact that Washington and Paris cut-off the promised supplies of LEU fuel for the Indian civilian reactors.[93] India has fabricated four of the MOX cores for TAPS I and II at its Advanced Fuel Fabrication Facility, which is run by BARC personnel.[94]

This facility has a design capacity to manufacture 10-20 Mt of MOX fuel per year, using plutonium extracted at Tarapur's PREFRE.[95] In future, India may use a sol-gel pilot plant that is being developed at Tarapur to fabricate MOX fuel or to reprocess plutonium.[96] PREFRE, one of the three Indian facilities that extract plutonium from spent reactor fuel, has a design capacity to reprocess as much as 100 Mt of Candu spent fuel each year, using the Purex process.[97]

Since PREFRE began operations in 1979, technical problems and a lack of spent fuel availability are believed to be the cause of the plant's inability to operate at its maximum levels.[98] These problems have led the DAE to revamp the plant's design and construction programme. The facility, which was expected to become operational in 1998-99, has still to be fully operational and its complete functions are not yet clear.[99] To date, the plutonium extracted at PREFRE is not known to have been used for any activity other than producing MOX fuel or for research. Nevertheless, the military implications of the plant's capabilities cannot be ignored. MOX fuel is particularly worrisome because it involves the use of plutonium in the civilian power reactors and greatly increases the danger that plutonium could be diverted or stolen.

Nuclear Fuel Complex, Hyderabad (NFC)

The city of Hyderabad is home to three government-owned facilities that conduct nuclear-related activities. The Nuclear Fuel Complex (NFC), established in the early 1970s, is geared to making nuclear fuel and reactor core components for India's atomic power programme. The site has a vast array of imported and domestically produced nuclear-related machinery, including a slurry-extraction system for uranium-oxide production, high-temperature pellet sintering furnaces, vacuum annealing furnaces, cold reducing mills, bearing pad welding machines, and specialized welding equipment.[100] The complex's primary function is to fabricate nuclear fuel, uranium purification and related materials. The facility has units, which are capable of uranium purification - that is, it can convert yellow cake (U308) into uranium oxide (U02). This facility has been operational since 1971. This plant has the ability to produce 250 Mt of UO2 per year and is currently being expanded to a level where it will be able to produce up to 600 Mt per year.[101]

After converting yellow cake into uranium oxide, the NFC fabricates the UO2 into nuclear fuel. The New Uranium Fuel Assembly plant can make 300 Mt of heavy water reactor fuel per year. This facility has been operating since 1971, and now its capacity is being expanded to 600 Mt per year.[102] The NFC also has a smaller 25 Mt per year facility that makes fuel for light water moderated reactors such as those at Tarapur.[103] None of these facilities are subject to IAEA safeguards unless they are handling imported enriched uranium or using safeguarded fuel.

Facilities to support the production of nuclear fuel are also located at the Hyderabad site. These include a zirconium metal production plant, which has a capacity of 210 Mt per year. This facility began operations in 1972, with a titanium production plant, and a plant that separates zirconium and hafnium – using what a DAE report described as a "pyrochemical" process.[104]

The Hyderabad site has additional facilities to produce special materials, used to advance the weaponisation potential of fissile material into atomic bomb cores. One plant produces high-purity titanium oxide, a chemical which is resistant to corrosion by liquid actinides, such as plutonium nitrate, and therefore, can be used to line hot cells for reprocessing plutonium, or crucibles, for casting weapon cores.[105] Although, titanium is not on the Nuclear Suppliers Group (NSG) Trigger List of controlled goods, it is listed in an IAEA memorandum on dual-use technology.[106] The availability of such material can lead to situations where material may be subject to theft or nuclear terrorism, as the biggest problem faced by nuclear terrorists remains that of protecting the core and maintaining the critical mass so that the destructive potential of a crude device can be enhanced.

The output of most of the NFC's facilities, such as nuclear fuel and zirconium components, has contributed indirectly to New Delhi's nuclear weapons programme. The threat of theft from these places cannot be ruled out. While there is no overt evidence that such thefts have occurred, the possibility cannot be completely precluded because most of the fuel and power reactors are not under IAEA or any other kind of safeguards. In addition, there is no international supervisory inventory control of the fissile materials.

Rajasthan Atomic Power Station (RAPS)

Rajasthan state is home to the Rajasthan Atomic Power Station (RAPS) and the Kota Heavy Water Production Plant. RAPS, which is owned by the DAE and operated by the government-owned Nuclear Power Complex (NPC), consists of two Candu type PHWRs with maximum design capacities of 220 MW.[107] Both RAPS I and II are under IAEA facility-specific safeguards. RAPS I was constructed by Canada's General Electric and it began commercial operations in 1973.[108] Canada provided half of the initial nuclear fuel cores load as well as 130 Mt of heavy water. However, later the agreement was terminated, and the Russians stepped in to provide the remainder of the requirements. New Delhi has reprocessed up to 20 Mt of spent fuel from the RAPS I reactor at its Power Reactor Fuel Reprocessing Plant at Tarapur till the 1980s.[109] Both RAPS have suffered numerous technical problems and shutdowns throughout their functioning history. However, RAPS I has suffered from more technical problems than any other Indian nuclear reactor and the magnitude of these problems is so long and persistent that it is India's least productive reactor. In the 1980s, a crack in the end shield of RAPS I 's Unit one had caused a reactor shut down for several years and, in 1994, the Unit had to be shut down for about three and a half years due to recurrent technical and functional problems. Since the reactor is based on the earlier design of PHWR reactors from Canada, it suffers from severe design faults, and there have been reported cases of radiation leaks in the area surrounding these reactors. Cancer and leukaemia cases have been on the rise in the area, as well as among the workers of these facilities. Efforts to repair the damage were hampered by the cessation of Canadian nuclear assistance following India's 1974 atomic blast. As a consequence, the reactor's estimated production capacity has been down-rated from 220 MW to 100 MW, while RAPS II remains at 200 MW. To date, the reactor has not achieved even the down-rated output since restarting operations in late 1997. The reactors have operated at full capacity for just 21 percent of the time, which is lower than both the India-wide average of 49 percent and the world average of 70 percent.[110]

Other reported problems include shortages of heavy water, cracks in the reactor's turbines, and a 1994 heavy water leak, all of which have resulted in numerous shutdowns of the reactor facilities.[111] These problems have became so common that India's Parliamentary Standing Committee on Atomic Energy recommended that the reactor's status be changed from a commercial plant to a research facility, which would be run by the DAE.[112] RAPS II has had technical problems, which have led to frequent shutdowns. For instance, following repeated heavy water leaks, the reactor was shutdown from September 1994, till May 1998, to replace its 306 coolant channels.

Though the reactor has been restarted, it is not expected to reach full capacity anytime soon. Throughout its life span, RAPS II has operated at full capacity just 46 percent of the operational time of the reactor.[113]

India is building two additional PHWRs at RAPS that will have design capacities of 235 MW and maximum net outputs of 220 MW, respectively.[114] Construction of the reactors by India's Walchandnagar Industries had began in 1990, using an indigenous design, but work was halted after the Kaiga I reactor's containment dome collapsed in 1994. The reactors, with a design similar to Kaiga I, went critical in September 1999 and early 2000 respectively. These plants use natural uranium 238 and indigenously produced heavy water.[115] The unsafeguarded reactors burn natural uranium mined in India and fabricated at the NFC. The spent fuel from these reactors is reprocessed at Tarapur or at Kalpakkam. New Delhi hopes to eventually build four additional, heavy water, natural uranium reactors of a capacity of 500 MW by 2004.[116]

The Kota heavy-water production plant, operated by the DAE's Heavy Water Board, formerly used steam generated by RAPS I and II. Canada started construction of the plant, but ceased its cooperation after India's 1974 nuclear test. BARC then completed the design of the plant, which can produce up to 100 Mt of heavy water per year using a hydrogen sulfide water-exchange process.[117] Operations were originally expected to begin in 1976, but were delayed until 1985 due to problems associated with the accumulation of toxic chemicals created during the production of hydrogen sulfide gas.[118] Inadequate and unreliable supplies of power and steam from the adjacent RAPS reactors have also plagued the plant and contributed to its low output.[119]

RAPS I and II have a long history of technical difficulties, making them uneconomical for commercial use. Moreover, the frequent shutdowns adversely affected production at Kota's heavy-water production plant. These problems supposedly have been resolved and the Indian officials claim that the Kota facility is operating efficiently. Nevertheless, in view of the past record and the oft repeated technical problems, it is not clear how satisfactorily these problems have been dealt with.[120] Similarly, for much of its existence, the heavy water plant's history of low output, huge cost overruns, and frequent shutdowns have made the plant a financial burden on India's struggling nuclear power programme.

In addition, and most importantly, despite RAPS problems, the reactors have been kept in operation because they provide indirect benefits to the nuclear programme, such as giving the Indian nuclear scientists and engineers experience working with Candu technology. More recently, it is also claimed that the experience gained by changing the coolant channels of RAPS II, will be applied to India's other PHWRs to increase their operating proficiency.

The RAPS reactors have contributed to the country's fissile material stockpile as well. To date, at least 25 kg of reactor-grade plutonium have been extracted from the unsafeguarded spent fuel of RAPS I, and much more could be reprocessed, if needed. When completed, RAPS III and IV will have the capability to produce significant amounts of unsafeguarded plutonium through reprocessing of spent fuel.

Kudankulam Atomic Power Reactors

The structural problems of design in Indian facilities have been so significant and so many that India has to look to foreign suppliers for nuclear power reactors. New Delhi signed a deal with the Soviet Union in the late 1980s for the supply of two 1000 MW power plants. Although the original deal was suspended in the early 1990s, it has been revived and is proceeding forward. In June 1998, Indian Atomic Energy Commission Chairman Rajagopal Chidambaram and Russian Minster of Atomic Energy Yevgeny Adamov signed a contract under which Russia agreed to build two 1000 MW light-water reactors (LWRs), at Kudankulam in southern India.[121] India has signed the agreement to build two Russian VVER-1000 type power plants with a total installed capacity of 2000 MW of power. As part of the nearly $ 3 billion agreement, Russia also agreed to extend $ 2.6 billion in long-term soft credits and will provide the plants with 30 Mt of LEU fuel per year.[122] The original contract called for the reactors to be provided by the Soviet vendor Atomstroiexport on a turnkey basis, operated by Indian technicians, trained in the then Soviet Union.[123] After years of being deadlocked in negotiations, the then Russian President Boris Yeltsin, convinced Indian officials that the deal could be revived, during a visit to India in late 1993.[124] This deadlock was broken in December 1997.

India hoped that the agreements with Russia would help India meet its goal of creating 10,000 MW of installed nuclear power capacity by the year 2000. Though the reactors have been constructed, their exact power capacity has still to be verified as they are yet to become operational. One of the major reasons for the Indian investment in these Russian type reactors has been her desire to overcome design problems in reactor construction, with the added belief that these reactors will not be prone to Chernobyl-like disasters. The reason cited is that since VVER-type PWRs use ordinary water as a coolant and a moderator therefore, these reactor types are different from the RBMK type graphite moderator reactors used in Chernobyl. However, according to Dr Yablokov, Chairman of the Russian Federation's National Ecological Security Council, the VVER types reactors are highly unsafe.[125] The IAEA has also expressed doubts about the safety of these plants.[126]

Apart from the facilities discussed above, India also has a number of research reactors – all of which are unsafeguarded and thereby susceptible to becoming sources of theft. Additionally, there are problems of safety and security relating to the mining of uranium.

III - Uranium Mining: Jaduguda

The Uranium Corporation of India Ltd. (UCIL), headed by J L Bhasin, is based in Jaduguda. All of the uranium for the 10 power plants in India comes from this single plant in Jaduguda. Thus, this plant, or complex, is the foundation of the Indian nuclear fuel cycle. The corporation owns and operates three uranium mines in the Singhbum east district of Bihar State. India's first and largest mine, the Jaduguda Uranium Mine, has been in operation since 1967 and can produce up to 200 Mt of yellowcake per year, although actual production has averaged 115 Mt per year.[127] The second mine in Bhatin, which started operations in 1986, is located 4 km northwest of Jaduguda,[128] while the third mine, the Narwarpahar Uranium Mine and Mill, is located 10 km from Jaduguda, which began operations in 1995.[129]

Also located near Jaduguda is the Turamdih Uranium Mill. This facility can process up to 170 Mt of yellowcake per year, and is currently being expanded to 230 Mt per year in order to handle additional uranium from the Narwapahar mine.[130] The mill processes all of India's indigenously mined uranium, most of which is then shipped to the Nuclear Fuel Complex in Hyderabad. Despite efforts to expand New Delhi's uranium production capacity, the mines and the mill have suffered financial difficulties, and resulted in lower than scheduled output due to the low-grade of uranium located there.[131]

UCIL has come under increasing pressure from local leaders and environmental groups over the reported radiation leaks and health hazards from the facilities, as well as from the tailing ponds – as the waste dumps are called.[132] Interestingly, India's Department of Atomic Energy refuses to accept charges relating to the improper discharge of effluents from the plants, although the villagers maintain that radioactivity has resulted in genetic mutations and other disorders. The reason for this is the fact that reportedly UCIL has constructed unshielded and unfenced tailing ponds in gross violation of international safety norms. Since the UCIL has not fenced the tailing ponds, people from nearby villages and their cattle have an easy access to the pond bases. Most of these illiterate villagers are unaware of the effects of radiation.[133] Similarly, the UCIL's open ventilator is neither fenced nor guarded, thus polluting the air with uranium dust, which contaminates the adjacent areas with radioactivity.[134]

Nearly 30,000 people living in the area are affected by the lack of safeguards and effective security mechanisms. Besides dumping radioactive waste from the mines and the plant, Jaduguda has become a dumping ground for radioactive waste from plants all around India.[135] Furthermore, the DAE has stated that India does not have the amount of nuclear waste that requires the formulation of a comprehensive plan.[136]

According to UCIL figures, Jaduguda mines have an approximate daily capacity of 1000 tonnes. The mill processes yellow cake, which is transported to Hyderabad via trucks.[137] The possibility of theft from trucks en route cannot be ruled out. As of early 2001, the UCIL is fighting a court battle in the Indian Supreme Court with regard to irregularities observed in waste disposal at the complex. The residents of the adjacent villages, most affected by the radiation leaks have filed the petition.

The uranium mines and the mill, located near Jaduguda are India's primary source of indigenously produced uranium. As such, at least some of these facilities' output contributes to the country's nuclear weapons programme - whether by fuelling the plutonium production reactors at Trombay or by being enriched at the Rattehalli uranium enrichment plant in Mysore. Sanctions were imposed on the Jaduguda, Narwapahar, and Turamdih mines in November 1998, by the United States because of American suspicions that nuclear weapons-related activities were being undertaken at these facilities.[138] The bulk of the uranium mined and milled at Jaduguda is fabricated into fuel for the country's commercial power reactors. Production at the mines between 1994-2000 has been lower than expected, causing a shortfall in uranium needed for the commercial power plants. With the expected completion of at least two new indigenously built reactors,[139] demands for uranium will increase and the challenge of meeting them will become more difficult. But, most difficult, is going to be the safety issue which, unless conceded to and addressed by the concerned authorities, will continue to present a hazard to the people of the surrounding areas. Already, the Indian Dalits (the 'untouchable' caste) have organised themselves to counter what they regard as a deliberate mass destruction of Dalits by the Hindu Brahmins, through this unsafe mining facility.[140] In fact, the battle between the victims of the uranium mining operations in Jharkhand on the one side and the UCIL, DAE and the Government of India on the other, is now centred around the Supreme Court of India through a Public Interest Litigation (PIL) Petition filed in 1998 (The Jadugoda Case). This Petition has been filed under the principle of Right to Life of the Indian Constitution.

While the present uranium mining project continues to be a source of threat to the lives of the people working and living in the area, India has discovered more uranium reserves and plans to develop these resources to meet the needs of its growing nuclear programme.

Conclusion

It is clear that India's nuclear programme has developed too quickly, without being assimilated within proper safeguards. The problem has been further aggravated because of India's rejection of IAEA safeguard mechanisms. The fact that foreign partners like the US and France allowed India to bypass these safeguards has meant that even for imported components there was little accountability. Other than the factor of a nuclear state's lack of accountability, the wide dispersal of unsafeguarded nuclear facilities within India, exposes that many population centres to the hazards arising out of radiation leakages from faulty structures and mechanisms, in addition to the willful misuse of stolen nuclear material and crudely made nuclear devices, for sabotage purposes.

The lack of safety features in the uranium mining ventures has endangered a whole chunk of Indian citizens. The fact that they happen to be Dalits is highly destabilizing within the Indian political context.

Again, the lure of financial rewards seems to have allowed some in the nuclear scientific community to be led astray – hence the threat of saleable expertise in India, to any group or country willing to pay the price, has become acute.

Within such an environment, India may become the first country to give concrete form to the threat of nuclear terrorism. Given the on-going insurgencies within the Indian state – especially in the northeast – and the political violence in states like Bihar, the nuclear cycle components in these regions become prone to becoming accessible to terrorists – not only as sources of theft of radioactive materials but also as targets of sabotage.

What needs to be done? As a beginning, India really needs to go in for IAEA safeguards on its civilian facilities. It also needs to take stock of the prevailing problems it has faced in its nuclear installations and mining enterprises, so that a more viable system of protection from terrorism is put in place, before it embarks on future ventures. This is especially critical because the Indian nuclear industry's Vision 2020, given out in 1998, is extremely expansive. It involves setting up of additional power plants including five fast breeder reactors.[141] Since these will be developed indigenously, with no international safeguards, the threat of their becoming vulnerable to design faults and theft of radioactive material will make India an even more attractive hunting ground for potential nuclear terrorists.

Besides, India's nuclear plans are often extremely unrealistic. For instance, the IGCAR at Kalpakkam had declared in 1998 that they were developing the prototype for a 500 MW fast-breeder reactor, which they stated would begin construction in 2002 and go onstream by 2008.[142] While the programme is still on, how far it will work out remains to be seen because there is no fast-breeder reactor on the 500 MW scale anywhere in the world yet. Such new plans also add to the vulnerability of the Indian nuclear programme, since without proper safeguards, they become ideal targets for potential terrorists – as well as themselves being a source of threat in terms of safety. Given that most of the nuclear facilities built, and those under development, are almost all located near major urban centres, the Indian population also faces an ever-present threat to their lives. Also, the location of the Indian nuclear facilities is such that the neighbouring states are all susceptible to radiation from leakages and threats of reactor melt-down from the Indian nuclear facilities. Therefore, these states need to question the safety of India's nuclear programme development at bilateral and multilateral fora. The disaster of Union Carbide in Bhopal should be a constant reminder to the Indian state of the scale of what can go wrong in its accelerated and over ambitious nuclear programme, which has no international safeguards to ensure safety standards.

Finally, it is also becoming increasingly evident that the existing international conventions on nuclear safety do not deal with problems of safety, of the design of reactors, of minimum safety conditions to govern mining of radioactive substances, and the possibility of nuclear theft. Yet it is these issues that may add to the threat of international terrorism becoming ever more lethal. In the case of India, the danger to the region from its unstable, unsafeguarded nuclear facilities makes the nuclear threat more acute – not only in terms of a nuclear exchange between Pakistan and India, but also in terms of nuclear terrorism from sub or transnational groups based in India and relying on clandestine material stolen from these Indian facilities.

References

1. INFCIRC refers to IAEA's information circulars on various issues.
2. Declarations/reservations: IFCIRC/336; see for example, www.iaea.org/worldatom/documents/Infcircs/others/inf336s.html
3. Ibid.
4. Mathew Bunn, 'Ensuring security of weapon usable nuclear materials worldwide: expanding international cooperation, strengthening global standards', The proceedings of Global 99 Nuclear Technology- Bridging the Millenia, a conference held in Jackson Hole , Wyoming, 30 August - 2 September, 1999. p. 16.
5. 'Uranium smugglers caught in India', news.bbc.co.uk/hi/english/world/south_asia/newsid_1512000/1512077.stm
6. Ibid.
7. Zimmermann & Cooperman, 'Beryllium deal, Russian Mafia' in US News & World Report, October 23, 1995.
8. 'Uranium racket unearthed', Press Trust of India, July 24, 1998, www.expressindia.com.
9. The Indian Express, 4 August, 1998.
10. Ibid.
11. Press Trust of India, 30 July, 1998, The Times of India, 6 May, 2000.
12. Ibid.
13. The Times of India, 6 May, 2000.
14. Ibid.
15. Ibid.

16. Mainstream, Vol. XXXVIII, No. 48, November 18, 2000, pp. 33-35.
17. The Hindu, November 7, 2000.
18. The Hindu, November 8, 2000.
19. Ibid.
20. www.iaea.org, November 14, 2000.
21. Ritu Sarin, 'Hunt for yellow cake', The Indian Express, June 4, 1998, see e.g., www.expresidia.com
22. Ibid.
23. Paul Leventhal & Brahma Chellaney, 'Nuclear Terrorism: Threat, Perception and Response in South Asia', paper presented at the IDSA, New Delhi, October 10, 1988.
24. Ibid.
25. Nayan Chanda, 'The perils of power', 4 January, 1999, see e.g. www.wsj.com
26. Ibid.
27. Ibid.
28. Andrew Koch, 'Resources on India and Pakistan: Selected Indian Nuclear Facilities', July 1999, Monterey Institute of International Studies, Centre for Non Proliferation Studies.
29. Buddhi, Kota & Subbarao, 'India's Nuclear Prowess: False claims and tragic truths'. www.freespeech.org/manushi/109/nukes.html.
30. 'India: Near Miss in 1993', www.antenn.nl/wise/506/4978.html
31. Ibid.
32. Ibid.
33. www.fareasterneconomicreview.com
34. Ibid.
35. 'Candus in India in bad condition', The Financial Post, Canada, 20 September, 1994.
36. www.freespeech.org
37. Ibid.
38. Ibid.
39. 'Resources on India and Pakistan', op cit.
40. George Perkovich, India's Nuclear Bomb: The impact on global proliferation. (California: University of California Press, Ltd., 1999), pp. 400-442.
41. 'Indian black diamonds', www.freespeech.org.com. Black diamonds are found naturally and considered to be very rare. However, the Indian sciencetists have been trying to create them artificially through radioactive processes.
42. It is a light water, medium enriched-uranium, pool type, I MW research reactor, operational since 1956.
43. www.freespeech.org
44. www.freespeech.org
45. 'India: Near Miss in 1993', The Indian Express, 30 August, 1993.
46. Ibid.
47. The Madras reactors, like Rawathbhata plants and RAPS I suffer from weld cracking, leaks, steam tube failure and the lack of high pressure emergency core cooling system, which can save a reactor from exploding in the event of a loss of cooling accident (LOCA). India has at times tried to share the emergency cooling system between the two reactors in Tarapur, a dangerous violation of international safety standards, as such the new techniques for system to work effectively have not been test proven. These can in the case of an accident lead to a reactor melt-down. There are unconfirmed reports that the Indian government may think of replicating the

design technology system of the Tarapur reactors to other reactors of similar design throughout India.

48. 'Heavy water leakage at Kalpakkam', The Hindu, 27 March, 1999, 'A Panel Set up to Probe MAPS Leakage', The Hindu, 21 April, 1999.
49. Ibid.
50. MAPS I & II are operating 30 km from Madras (Chennai), India's fourth-largest city.
51. Mixed uranium–plutonium oxide (MOX).
52. 'Heavy water Leakage at Kalpakkam', The Hindu, 27 March, 1999, 'A panel set up to probe MAPS Leakage', The Hindu, 21 April, 1999; see also, http www.cns.miiss.edu.
53. Perkovich, op. cit.
54. V.L. Kalyane, ed., BARC Progress Report – 1995 (Mumbai, India: Bhabha Atomic Research Centre, 1996), p. 120; 'Third Reprocessing Plant Starts Up', Nuclear Engineering International, May 1996, p. 8; 'Third Reprocessing Plant Opened at Kalpakkam,' Nuclear News, May 1996, p. 43.
55. Department Of Atomic Energy Annual Report 1996-1997, Government of India, 1997; 'Atomic Energy', http://www.meadev.gov.in; 'Indira Gandhi Centre for Atomic Research', see www.igcar.ernet.in
56. Neel Patri, 'Nuclear R & D Budget Rises Slightly in India for Coming Fiscal Year', Nucleonics Week, 14 March, 1996, pp. 15-16.
57. G. Sudhakar Nair, 'Efforts for Self-Sufficiency in N-Energy Reviewed', Telegraph, 8 January, 1985, p. 7; Worldwide Report, 13 February, 1985, pp. 77-81.
58. 'India's Test Breeder Reactor Was Restarted May 11', Nuclear News, July 1989, p. 67; Department Of Atomic Energy Annual Report 1996-1997, Government of India, 1997; 'Reactor Group', see www.igcar.ernet.in.
59. Mark Hibbs, 'Tarapur: First Separation Line at Kalpakkam Slated to Begin Operations Next Year', Nuclear Fuel, 1 December, 1997, p. 8; David Albright, Frans Berkhout and William Walker, Plutonium And Highly Enriched Uranium 1996 (New York: Oxford University Press, 1997), p. 268.
60. Ibid.
61. Ibid, Neel Patri, 'India Starts Up Research Unit Using Fuel Made from Thorium', Nucleonics Week, 7 November, 1996, p. 2; 'Reactor Group', http://www.igcar.ernet.in.
62. Ibid.
63. 'Delhi Acquires Nuclear Waste Management Technology', Financial Express, 23 March, 1998.
64. Maya Ranganathan, 'New Reactor at Kalpakkam by 2007', Indian Express, 24 January, 1997.
65. Department Of Atomic Energy Annual Report 1996-1997, Government of India, 1997; Maya Ranganathan, 'New Reactor at Kalpakkam by 2007', Indian Express, 24 January, 1997.
66. 'Submarine's N-Power Plant Getting Ready', Times of India, 29 December, 1995; in Strategic Digest, March 1996, pp. 440-441.
67. Vivek Raghuvanshi, 'Technical Snags Frustrate Indian Nuclear Sub Programme', Defense News, June 24-30, 1996, p. 40.
68. Ibid.
69. Department of Atomic Energy Annual Report 1996-1997, Government of India, 1997.
70. 'N-Safety Research Facility Near Chennai', The Hindu, 21 February, 1999.
71. Perkovich, op. cit.
72. Ibid, see also www.freespeech.org
73. On March 31, 1993, the turbine building at the Narora atomic Power Station caught fire and burned out of control for two hours. The power to the Reactor was cut for 17 hours, and three diesel backup generators failed when their power cables burned out. The plant was shut down when smoke had entered the control room and even in the shutdown state a coolant was needed

to keep the reactor core from tearing itself apart. It has been one of the closet cases in which a reactor could have faced a core melt-down. It was later discovered that the DAE and the contractor responsible for machining the turbine components was aware of a design fault which led to the fire but had chosen not to act on the information provided by the turbine designer, GE Corporation of UK.

74. Ibid.
75. Ibid. Following the collapse, Unit one is still under construction. The containment dome is designed to withstand intense radiation, earthquakes, and anything up to an explosion within the reactor or a terrorist bombing. Owing to the design fault, about 40% of the entire structure caved in during the last stages of the construction.
76. Scott Ludlam, 'Energy for People: Planning, Conservation and Sustainable Alternatives', A report on the nuclear accidents of India, presented on 22 November, 1999, Bangalore, India, at No Nukes-Asia Forum 1999. See, www.anawa.org.au/india/download.html.
77. The authorities had delayed the connection of the plant electricity in 2000, due to potential attack of Y-2k bug, nevertheless it is still not clear whether the plant has gone critical as yet or not.
78. Nuclear Engineering International, World Nuclear Industry Handbook 1996, (London: Reed Business Publishing, 1995), p. 22.
79. Ibid.
80. Rahul Bedi, 'Indian nuclear plant leak hits village's water', The Electronic Telegraph, World News, 4 July, 1995.
81. Ibid.
82. Ibid.
83. Ibid.
84. Nayan Chanda, 'The perils of power', Far Eastern Economic Review, 4 January, 1999.
85. Ibid.
86. S. A. Gopalakrishnan, 'Of the Shortcomings, the Risks', Frontline, 8-21 May, 1999.
87. 'Aging Tarapur Atomic Power Station to Live Longer', Indian Express, 25 April, 1999.
88. The Act puts a ban on providing US assistance to those counties which might get involved in harnessing nuclear energy for military purposes. India had conducted a nuclear explosion in 1974, which had been seen as a cause of concern by the nuclear powers, therefore an attempt was made to stop the assistance of those countries which could become a proliferation concern.
89. The Act required that all recipients of US nuclear technology permit full-scope IAEA safeguards. New Delhi declined to do so and the agreement was terminated well before 1993.
90. Ux Weekly, 14 September, 1998; in Uranium Institute News Briefing, 9-15 September, 1998, see also http://www.uilondon.org
91. There is considerable scientific research which indicates that, reactor-grade plutonium can be used effectively for making a crude nuclear device, or can be used for high dispensation of radiation in case the material is used for carrying out radiological terrorism. However, the effectiveness of using this material for high precision nuclear devices is questionable.
92. Mark Hibbs, 'Tarapur-2 to Join Twin BWR in Burning PHWR Plutonium', Nuclear Fuel, 25 September, 1995, pp. 18-19; Mark Hibbs, 'China Will Supply U, SWU to India', Nuclear Fuel, 24 October, 1994, p. 6.
93. Mark Hibbs, 'Tarapur-2 to Join Twin BWR in Burning PHWR Plutonium', Nuclear Fuel, 25 September, 1995, pp. 18-19.
94. Nuclear Engineering International, World Nuclear Industry Handbook 1996, (London: Reed Business Publishing, 1995), p. 113; V.L. Kalyane, ed., BARC Progress Report – 1995 (Mumbai, India: Bhabha Atomic Research Centre, 1996), p. 3.

95. Mark Hibbs, 'Indian Reprocessing Programme Grows, Increasing Stock of Unsafeguarded PU', Nuclear Fuel, 15 October, 1990, pp. 5-7; 'The Bomb Behind Nuclear Power', Plutonium Investigation, 10 December, 1998, pp. 1-6.
96. The sol-gel process uses a glass-like substance to fabricate nuclear fuel that is easier and less hazardous to handle than standard nuclear fuel.
97. David Albright, Frans Berkhout and William Walker, Plutonium And Highly Enriched Uranium 1996 (New York: Oxford University Press, 1997), p. 181; Nuclear Engineering International, World Nuclear Industry Handbook 1996 (London: Reed Business Publishing, 1995), p. 116; Frans Berkhout and Surendra Gadekar, 'India', Energy And Security, February 1997, p. 12.
98. Department Of Atomic Energy Annual Report 1980-81, Government of India, 1981; in David Albright, Frans Berkhout and William Walker, Plutonium And Highly Enriched Uranium, 1996 (New York: Oxford University Press, 1997), p. 267.
99. G. Sudhakar Nair, Telegraph, 8 January, 1999, p. 7; in Worldwide Report 13 February, 1999, pp. 77-81.
100. . 'Three N-Centres to Be Commissioned Near AP', Financial Express, 7 August, 1995, p. 5.
101. Shahid-ur-Rehman Khan, 'India and Pakistan Exchange Lists of Nuclear Facilities', Nucleonics Week, 4 January, 1992, p. 10.
102. 'Three N-Centres to Be Commissioned Near AP', Financial Express, 7 August, 1995, p. 5, the plant is called the New Uranium Fuel Assembly Plant, work on this facility has been completed and trial production has begun; 'NFC Gearing to Double Uranium Output', The Hindu, 15 July, 1996, p. 6.
103. 'World Light Water Reactor Fuel Fabrication Facilities', see http://www.antenna.nl
104. India's Department of Energy's Annual Report 1999.
105. Department Of Atomic Energy Annual Report 1996-97, Government of India, 1997; 'Atomic Energy in India: Nuclear Fuels and Structural Components', http://www.barc.ernet.in
106. 'Communications Received from Certain Member States Regarding Guidelines for the Export of Nuclear Material, Equipment, and Technology', International Atomic Energy Agency Information Circular, 24 February, 1998, INFCIRC/254/Rev.3/Part 2.
107. 'On Line, Off Line in India,' Nuclear Engineering International, May 1994, p. 8.
108. 'RAPP I for Scrap', Nuclear Engineering International, October 1986, p. 11.
109. The plant reprocesses most of Indian reactor spent fuel since it went operational. The spent fuel reprocessed in Rajasthan atomic power stations is believed to have yielded 25 kg of plutonium for India's nuclear weapons programme. See e.g. A. Abraham, 'Plutonium Missing in Tarapur Plant', Sunday Observer, 16-22 October, 1983.
110. See Eric Arnett, ed., Nuclear Weapons and Arms Control in South Asia after the Test Ban (New York: Oxford University Press, 1998), p. 8.
111. 'India's N-Power Development Crosses Another Milestone', Deccan Herald, 24 December, 1997, http://www.deccaanherald.com; 'Indo-Russian Reactor Deal On: AEC Chief', Deccan Herald, 15 June, 1998, http://www.deccanherald.com; The Hindu, 19 June, 1986, p. 9; in Worldwide Report, 11 August, 1986, p. 33.
112. 'Committees Consider Indian Programme', Nuclear Engineering International, May 1996, p. 8.
113. Ibid.
114. Nuclear Engineering International, World Nuclear Industry Handbook 1996, (London: Reed Business Publishing, 1995), p. 23.
115. Department Of Atomic Energy Annual Report 1996-97, Government of India, 1997; 'Kaiga-2 to Go Critical on Aug. 25', The Hindu, 9 August, 1999.
116. World Nuclear Industry Hand book 1996, (London: Reed Business, 1995), p. 22.

117. Ibid.

118. S. P. Mukherjee, 'Heavy Water: Surplus Output for Export', The Hindu; also see, Survey of Indian Industry 1998, pp. 87-89.

119. Ibid.

120. Ibid.

121. Vladimir Radyuhin, 'Project Report: Contract for Koodankulam Signed', The Hindu, 21 July 1998.

122. Ibid.

123. Ibid.

124. Ibid.

125. See for example, www.freespeech.org

126. Dhirendra Sharma, 'Hazards of nuclear power' The Hindustan Times, March 6, 1997. See also, George Perkovich, India's Nuclear Bomb: The Impact of Global Proliferation, (New Delhi: Oxford University Press, 2000).

127. Nuclear Engineering International, World Nuclear Industry Handbook 1997, (London: Reed Business Publishing, 1996), p. 117.

128. 'Uranium: Resources, Production and Demand', Nuclear Energy Agency, Organization for Economic Co-operation and Development, 1995; p.195.

129. Ibid.

130. Ibid.

131. Ibid.

132. See, for example, Soutik Biswas, 'Nuclear Fallout', Asia week, 25 June, 1999; see http://www.pathfinder.com/asiaweek; Kalpana Sharma, 'The Other Side of Security'; The Hindu, 27 January, 1999. http://www.hinduonline.com

133. Pallavi Ghosh, 'How the waste is treated', The Electronic Telegraph, New Delhi, 4 July, 1995.

134. Ibid.

135. Aarti Dhar, 'The price for nuclear facilities', The Times of India, April 6, 1999.

136. Julian West, 'Thousands at risk of poisoning from India's Chernobyl', The Sunday Telegraph, 25 April, 1999.

137. Ritu Sarin, op. cit.

138. Soutik Biswas & Kalpana Sharma, op.cit.

139. Kaiga I & II were to go critical in 1999 but so far the completion has lagged behind because of lack of funds and technical problems. The Indian government claims that Kaiga I went critical in 1999, however other sources do not confirm this.

140. 'India's Cernobyl: The Final Brahmin Annihilation of Dalistan', see e.g., http://dalistan.org/journal/recthist/ nuclear/i_chern.html

141. 'Nuclear power to boost power generation', Indian Express, September 22, 1998.

142. Ibid.

Appendix I
INDIAN NUCLEAR FACILITIES

NAME/LOCATION OF FACILITY	TYPE AND CAPACITY – GROSS DESIGN (NET) OUTPUT	COMPLETION OR TARGET DATE	IAEA SAFEGUARDS
POWER REACTORS – OPERATING			

Tarapur 1	Light-water, LEU and MOX 210 (150) MWe	1969	Yes
Tarapur 2	Light-water, LEU210 (160) MWe	1969	Yes
Rajasthan, RAPS-1 Kota	Heavy-water, natural U 220 (90) MWe	1972	Yes
Rajasthan, RAPS-2 Kota	Heavy-water, natural U 220 (187) MWe	1980	Yes
Madras, MAPS-1 Kalpakkam	Heavy-water, natural U 235 (170) MWe	1983	No
Madras, MAPS-2 Kalpakkam	Heavy-water, natural U 235 (170) MWe	1985	No
Narora 1	Heavy-water, natural U 235 (202) MWe	1989	No
Narora 2	Heavy-water, natural U 235 (202) MWe	1991	No
Kakrapar 1	Heavy-water, natural U 235 (170) MWe	1992	No
Kakrapar 2	Heavy-water, natural U 235 (202) MWe	1995	No
POWER REACTORS - UNDER CONSTRUCTION			
Kaiga 1	Heavy-water, natural U 235 (202) MWe	1998	No
Kaiga 2	Heavy-water, natural U 235 (202) MWe	1998	No
Rajasthan, RAPP-3 Kota	Heavy-water, natural U 235 (202) MWe	1999	No
Rajasthan, RAPP-4 Kota	Heavy-water, natural U 235 (202) MWe	1999	No
POWER REACTORS - PLANNED AND PROPOSED			
Tarapur 3	Heavy-water, natural U	2006	No

	500 (450) MWe		
Tarapur 4	Heavy-water, natural U 500 (450) MWe	2005	No
Rawatbhata 4 Rajasthan	PHWR 220 MWe	July 2001	No
Kaiga 1	Heavy-water, natural U 235 (220) MWe	Re-construction	No
Kaiga 3	Heavy-water, natural U 235 (202) Mwe	-	No
Kaiga 4	Heavy-water, natural U 235 (202) Mwe	-	No
Kaiga 5	Heavy-water, natural U 235 (202) Mwe	-	No
Kaiga 6	Heavy-water, natural U 235 (202) Mwe	-	No
Rajasthan, RAPP-5 Kota	Heavy-water, natural U 500 (450) MWe	-	No
Rajasthan, RAPP-6 Kota	Heavy-water, natural U 500 (450) MWe	-	No
Rajasthan, RAPP-7 Kota	Heavy-water, natural U 500 (450) MWe	-	No
Rajasthan, RAPP-8 Kota	Heavy-water, natural U 500 (450) MWe	-	No
Koodankulam 1	Russian VVER Light-water, LEU 1000 (953) MWe	-	Yes
Koodankulam 2	Russian VVER Light-water, LEU 1000 (953) MWe	-	Yes
Koodankulam 2	Russian VVER Light-water, LEU 1000 (953) MWe	-	Yes

RESEARCH REACTORS			
Apsara BARC, Trombay	Light-water, medium-enriched Uranium, pool type - 1 MWt	1956	No
Cirus BARC, Trombay	Heavy-water, natural U 40 MWt	1960	No
Dhruva BARC, Trombay	Heavy-water, natural U 100 MWt	1985	No
Kamini IGCAR,	Uranium-233 30 KWt	1996	No
Kalpakkam	Fast Breeder Test Reactor (FBTR), Plutonium and natural U, 15 MWe: operating	-	No
Zerlina BARC, Trombay	Heavy-water, variable fuel 100 Wt – decommissioned	1961	No
Purnima 1 BARC, Trombay	Fast neutron, critical assembly zero power – decommissioned	1972	No
Purnima 2 BARC, Trombay	Uranium-233 .005 KWt – dismantled	1984	No
Purnima 3 BARC, Trombay	Uranium-233	-	No
BREEDER REACTORS			
Fast Breeder Test Reactor (FBTR) IGCAR, Kalpakkam	Plutonium and natural U 40 MWt	1985	No
Prototype Fast Breeder Reactor (PFBR) IGCAR, Kalpakkam	Mixed-oxide fuel 500 MWe – planned	2008	No
URANIUM ENRICHMENT			
Trombay	Pilot-scale ultracentrifuge plant operating	1985	No

Trombay	Laser enrichment research site	early 1980s	No
Rattehalli (Mysore)	Pilot-scale ultracentrifuge plant operating	1990	No
Center for Advanced Technology, Indore	Laser enrichment research site	1993	No
REPROCESSING (PLUTONIUM EXTRACTION)			
Trombay	Medium-scale - 50 tHM/y operating	1964/1985	No
Tarapur (Prefre)	Large-scale - 100 (25) tHM/y operating	1977	Only when safeguarded fuel is present
Kalpakkam	Laboratory-scale -operating	1985	No
Kalpakkam	Large-scale, two lines - 100 tHM/y each- under construction	1998/2008	No
Kalpakkam	Fast breeder fuel reprocessing plant	-	No
URANIUM PROCESSING			
Rakh, Surda, Mosaboni	Uranium recovery plant at copper concentrator; operating.	-	N/A (Not Applicable)
Jaduguda, Narwpahar, Bhatin	Uranium mining and milling; operating	-	N/A
The Singhbhum district (Bihar), West Khasi hills (Meghalaya), the Bhima Basin area (Gulbarga district of Kamataka), and the Yellapur – Peddagattu area of Nalgonda district (Andhra Pradesh)	Promising uranium mining areas If enriched UF6 supply for India's BWRs is cut off, they may fuel with UO2-PuO2	-	N/A
Hyderabad	Uranium purification	-	No

	(UO_2); operating.		
Hyderabad	Fuel fabrication; operating.	-	Partial
Trombay	Uranium conversion (UF_6); operating; Fuel fabrication.	-	No
Tarapur	Mixed uranium-plutonium oxide (MOX) fuel fabrication; operating.	-	Only when safeguarded fuel is present.
HEAVY WATER PRODUCTION			
Trombay	Pilot-scale; Operational?		-
Nangal	14 t/y; Operating	1962	-
Baroda	67 t/y; Intermittent operation	1980	-
Tuticorin	71 t/y; Operating	1978	-
Talcher phase 1	62 t/y; Operating	1980	-
Talcher phase 2	62 t/y; Operating	1980	-
Kota	100 t/y; Operating	1981	-
Thal-Vaishet	110 t/y; Operating	1991	-
Manuguru	185 t/y; Operating, under expansion	1991	-
Hazira	110 t/y; Operating	1991	-

Abbreviations:

HEU = highly enriched uranium
LEU = low-enriched uranium
nat. U = natural uranium
MWe = millions of watts of electrical output
MWt = millions of watts of thermal output

KWt = thousands of watts of thermal output
tHM/y = tons of heavy metal per year
PHWR = Pressurized Heavy Water Reactor

ABBREVATIONS

AERB	Atomic Energy Regulatory Board
ATV	Advanced Technology Vessel
BARC	Bhabha Atomic Research Centre
BWR	Boiling Water Reactor
CBI	Central Bureau of Intelligence (India)
DAE	Department of Atomic Energy, India
DTC	Diamond Trading Corporation, London
ECCS	Emergency Core Cooling System
EURATOM	European Atomic Energy Community
FBTR	Fast Breeder Test Reactor
FRFRP	Fast Reactor Fuel Reprocessing Plant
GRAB	Gravity Addition of Boron system
IAEA	International Atomic Energy Agency
IGCAR	Indira Gandhi Centre for Atomic Research
INFCIRC	Information Circular (IAEA)
KAPS	Kakrapar Atomic Power Station
KARP	Kalpakkam Fuel Reprocessing Plant
LEU	Low-Enriched Uranium
LWRs	Light-Water Reactors
MAPS	Madras Power Station, Kalpakkam
MOX	Mixed Uranium—plutonium oxide
NFC	Nuclear Fuel Complex, Hyderabad, (India)
NPC	Nuclear Power Corporation, (India)
NPT	Nuclear Non-proliferation Treaty
NSG	Nuclear Suppliers Group
PHWRs	Pressurized Heavy Water Reactors
PIL	Public Interest Litigation
PU	Plutonium
PREFRE	Power Reactor Fuel Reprocessing Plant
RAPS	Rajasthan, Atomic Power Station
TAPS	Tarapur Atomic Power Station, Maharashtra
U	Uranium

UCIL	Uranium Corporation of India Ltd.
VVER	Russian designed Pressurized Water Reactors