Opinion

RELEVANCE OF FUKUSHIMA NUCLEAR ACCIDENT TO INDIA: NUCLEAR RADIATION RISK AND INTERVENTIONS TO MITIGATE ADVERSE FALLOUT

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ABSTRACT

The environmental radiation release from Fukushima nuclear power following tsunami in Japan has once again highlighted the omnipotent risk of radiation injury in the today's world. India is at a real risk from radiation fallout both due to nuclear power plant accidents and nuclear warfare threat. The risk from nuclear radiation accident in India is further increased by the region being endemic for iodine deficiency as adverse effects following nuclear radiation fallout like thyroid cancer is significantly higher in iodine deficient populations .There is need to institute disaster preparedness measures to mitigate the damage in case of a nuclear accident. Interventions to control adverse fallout of nuclear radiation include evacuation, sheltering and food controls as well as iodine prophylaxis

Keywords: Nuclear accident, radiation risk, mitigation

BACKGROUND

On 11 March 2011, Japan was struck by a high intensity earth quake measuring 8.9 on Richter scale which caused widespread destruction to human life and property. The earthquake was followed by a tsunami which caused catastrophic damage to nuclear power reactors in the region. The failure of the coolant mechanism in the Fukushima nuclear power reactors led to environmental radiation release in the affected Miyagi Prefecture on Japan's east coast. Thousands of people near the reactor site were exposed to nuclear radiation released from the reactor.[1]

This unfortunate incident has once again highlighted the omnipotent risk of radiation injury in the today's world. The event of 11 March 2011 in Japan was not the first of its kind. The world has witnessed many such nuclear accidents. Major nuclear radiation fallout incidents were the nuclear bomb explosions in Hiroshima and Nagasaki in 1942, radiation releases at the Hanford Site in Washington State in the mid-1940s, Three Mile Island reactor leakage in United States of America (USA) in 1979, the Chernobyl nuclear power plant explosion in 1986 in Ukraine and Tokaimura nuclear accident in Japan in September, 1999.[2]

Nuclear radiation fallouts can be unintentional or intentional. Unintentional threats include power plant disasters such as Chernobyl and Fukushima. Intentional threats are associated with military conflict or terrorism. India is at risk of exposure to nuclear radiation both from unintentional and intentional sources. India is a nuclear power state located in one of the nuclear hotbed of world which also happens to be one of the densely populated regions in the world. India also is one of the countries where nuclear power contributes significantly to power generation. Currently nuclear energy constitutes 2.9 percent of India's total energy generation.[3] India has an ambitious plan to increase its nuclear power capacity in near future and is set to overtake USA and China in terms of overall nuclear power generation capacity.

Patho-physiology of risk from radioactive Iodine

In the event of accidents in nuclear facilities, particularly nuclear power plants, several radioactive compounds are released. Isotopes of iodine (I 131, I 132, I 133) are important components of these nuclear release.

Exposure to radioactive iodine during nuclear accidents can occur through many pathways and can be classified into external and internal radiation exposure. Radioactive iodine can enter the body through intake of contaminated water or food as well as through inhalation resulting in internal radiation. The external radiation exposure occurs from radioactive cloud, deposits on the ground and on skin and clothing. Regardless of the route of uptake all radioactive iodine is concentrated in the thyroid. The thyroid concentrates iodine against a strong electro-chemical gradient by an energy-dependent process and is linked to the ATPase-dependent Na+ - k+ pump. The intrinsic plasma membrane transport protein, Na+/I- Symporter (NIS) couples the inward "downhill" translocation of Na+ to the inward "uphill" translocation of I-. [4]

Radioactive iodine, being an unstable atom, emits energy in the form of ionizing radiation in an effort to achieve stability. Ionizing radiation is a type of high-frequency energy that has adverse biologic effects, including damage to DNA, production of free radicals, disruption of chemical bonds, and production of new macromolecules.[5] Nuclear accidents results in both immediate and long term health effects. Immediate effects include acute radiation sickness with a high mortality rate. Long term effects include malignancies like thyroid cancer, leukaemia and breast cancer, cataract, congenital abnormalities, increased risk of cardio vascular diseases and psychological disorders.[6]

The effects of radiation can be either deterministic or stochastic. Deterministic effects are radiation effect for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose. Stochastic effects are radiation effects, generally occurring without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose. Large amounts of ^{131}I results in thyroid-cell death. The deterministic effects from thyroid exposure are hypothyroidism and acute thyroiditis. Hypothyroidism is caused by a radiation dose of the order of more than several Gray (Gy) to the thyroid. A dose that large could be, in practice, be incurred through inhalation only near the point of accidental release. A low dose exposure damages but does not kill thyroid cells and can induce nuclear damage and mutations, which can result in thyroid cancer. Stochastic effects from thyroid exposure are thyroid cancer and benign thyroid nodule. In contrast to high doses required for deterministic effects, a surprising number of children exposed to a relatively low radiation dose (less than 300 mGy) after the 1986 Chernobyl accident developed thyroid cancer within a few years.

In epidemiological studies investigating the relationship between thyroidal radioiodine exposure and risk of thyroid cancer, the estimation of thyroid radiation doses is a critical and complex aspect of the analyses. The Chernobyl reactor accident of April 1986 provides the best-documented example of a massive radionuclide release in which large numbers of people across a broad geographical area were exposed acutely to radio-iodines released into the atmosphere. Following the accident at the Chernobyl nuclear power plant in 1986 a significant rise in thyroid cancer cases in the exposed children has been observed in Belarus, the south-western part of the Russian Federation (oblast of Bryansk) and the northern part of the Ukraine. About 1,800 thyroid cancer cases have occurred up to 1998 in those who were children or adolescents at the time of the accident.[7] In these regions, for the first 4 years of the accident, a striking increase in the incidence of thyroid cancer among children and adolescents was seen. Observed cases of thyroid cancer among children aged 0 through 4 years at the time of the accident exceeded expected number of cases by 30- to 60-fold. During the ensuing years, in the most heavily affected areas, incidence is much as 100-fold compared to the pre-Chernobyl rates.[8] Following the Chernobyl accident there were thousands of children who accumulated a dose to the thyroid of several Gy. However, the majority of cases occurred in the children who apparently received less than 300 mGy to the thyroid.[9] There has been an excess thyroid cancer incidence even in areas where the mean dose to the thyroid in children was estimated below than 100 mGy.[8]The physical half life if iodine -131 is 8 days but the biological half life is 23 days in five year old whereas 80 days in an adult. Hence, the efforts in case of nuclear calamity should not only be concentrated for few days but many weeks altogether.[10]

Iodine Deficiency and Radiation Risk following nuclear accidents:

It has documented in various studies that iodine sufficient individuals/populations are at lesser risk of damage to thyroid gland from nuclear radiation. If the dietary intake is 150 micrograms a day for children and adults and

250 micrograms a day for pregnant and breastfeeding women, there would be minimal absorption of radio-active iodine in case on nuclear accidents in that population.

International Council of Iodine Deficiency Disorder (ICCIDD) has stated that iodine sufficient population has no increased risk of thyroid cancer; hence the emphasis should be on promoting universal iodations salt and procuring iodine rich naturally available food rather than opting for other iodine supplements at the time of radiation disaster.[11]

Survey for iodine deficiency in areas near nuclear power plant need to be undertaken to and appropriate measures to increase iodine intake by increasing the coverage of iodized salt in the deficient areas should be adopted.

Relevance to Indian scenario:

Nuclear power is the fourth-largest source of electricity in India after thermal, renewable and hydroelectric sources. India currently has 20 nuclear reactors located in six nuclear power plants in Kaiga, Kakrapur, Kalpakam, Narora, Rawatbhata and Tarapur. Three new nuclear power plants are under construction.[12] In October 2009 India's safeguards agreement with the IAEA became operational. Following agreement with IAEA government announced that it plans to significantly increase its capacity of power generation using nuclear reactors. This commitment to exponentially increase the number of nuclear power reactors has been reiterated even after the nuclear radiation fall out in Fukushima. Hon’ble Prime Minister himself recently stated that India will quadruple its total electricity production using nuclear energy from current 5,000 megawatts to 20,000 megawatts by 2020.

Table 1: Recommended dose of Potassium Iodide for prophylaxis as protective measure against nuclear radiation exposure

Group	Exposure Gy (rad)	KI Dose (mg)
Above 40 years	5 (500)	130
18 to 40 years	0.1 (10)	130
12 to 17 years	0.05 (5)	65
4 to 12 years	0.05 (5)	65
1 month to 3 years	0.05 (5)	32
Birth through 1 month of age	.05 (5)	16
Pregnant or lactating women	0.05 (5)	130

India has had its share of nuclear accidents and they are fairly common occurrence. About 124 hazardous incidents have occurred at various nuclear plants in India between 1993 and 1995. The few well known nuclear accidents in India are the Kalpakkam, Tamil Nadu incident in 1987; Tarapur, Maharashtra in 1989; Kota, Rajasthan in 1995 and many more.[13]

Most of the nuclear power plants in India are situated in low earthquake prone Zone of II and III.[14] These plants had operated safely in many low intensity earthquakes that have occurred over the year. But, as most of the nuclear plant lie in the coastal areas, they are more prone to be affected by tsunami like event similar to that occurred in Japan. The plant at Kalpakam was in fact affected by the tsunami that hit the eastern cost of India in 2004.

In addition, India is nuclear power state with a stockpile of fissile nuclear war heads and shares border with two other nuclear power states. Thus, the country is under a constant threat with regards to occurrence of both unintentional as well as intentional nuclear events.

The risk from nuclear radiation accident in India is further increased by the region being endemic for iodine deficiency. As per the surveys by Directorate General of Health Services (DGHS) and Indian Council for Medical Research (ICMR), 263 districts out of total surveyed 324 districts in India are endemic for iodine deficiency disorder.[15] The risk of adverse effects following nuclear radiation fallout is significantly higher in iodine deficient populations. In light of above facts, there is a need for setting up an expert group to assess the nuclear radiation risk in Indian population and devise appropriate guidelines and plan of action in event of an nuclear accident.

Interventions to mitigate damage from radiation injury

In emergencies involving a release to the environment of radioactive iodine there is a need for an early warning and rapid response so that measures that prevent or mitigate exposure can be implemented. Interventions to control adverse fallout of nuclear radiation include evacuation, sheltering and food controls as well as iodine prophylaxis. The optimum response will often involve the combined use of these countermeasures. It should be noted that while the other countermeasures protect against most radionuclide and external exposure, iodine prophylaxis protects only against inhaled or ingested radioiodine. The brief details of individual countermeasures are as follows:

1) Evacuation- Evacuation is most effective when implemented before the passage of the radioactive cloud.

2) Sheltering- Inhalation of radioactive iodine from a passing cloud will be reduced to some degree by sheltering indoors with closed windows and any forced ventilation shut off, but sheltering is not completely effective in avoiding inhalation doses.

3) Food Control- The principal protective measures against internal exposure through ingestion are firstly, agricultural countermeasures (such as putting grazing animals on stored feed) followed by the banning of potentially contaminated foodstuffs or locally produced agricultural products.

4) Stable Iodine prophylaxis as a protective measure- Stable iodine administered before, or promptly after, intake of radioactive iodine can block or reduce the accumulation of radioactive iodine in the thyroid.

4.1 Exposed group Populations- It is important to consider potentially exposed population groups separately when deciding on plans for stable iodine prophylaxis. In general, the potential benefit of iodine prophylaxis will be greater in the young, firstly because the small size of the thyroid means that a higher radiation dose is accumulated per unit intake of radioactive iodine. Secondly, the thyroid of the fetus, neonate and young infant has a higher yearly thyroid cancer risk per unit dose than the thyroid of an adult and, thirdly, the young will have a longer time span for the expression of the increased cancer risk. The stable iodine prophylaxis is warranted for following population groups; pregnant and lactating women, neonates, infants, children and adolescents (1 month to 18 years), adults under 40 years. The risk of radiation induced thyroid cancer in adults *over 40 years* this group is probably extremely low and may even be zero.[16] The risk of side effects from stable iodine increases with increasing age as the incidence of thyroid diseases is higher. Stable iodine prophylaxis is not indicated for this group, unless doses to the thyroid from inhalation rise to levels threatening thyroid function, that is of the order of about 5 Gy. Such radiation doses will not occur far away from an accident site. The recommended dosage of prophylaxis in different age group is given in table 1.[17]

4.2 Timing of iodine prophylaxis: For optimal protection against inhaled radioiodine, KI should be administered before or immediately coincident with passage of the radioactive cloud, though KI may still have a substantial protective effect even if taken 3 or 4 hours after exposure. The protective effect of KI lasts approximately 24 hours.

4.3 Side effects- Thyroidal side effects may result from stable iodine administration, especially in iodine deficient regions. There is an increased risk of thyroid disorders, such as auto-immune thyroiditis, Graves’ disease and nodular goitre. The Polish experience showed the risk of severe side effects from single doses of stable iodine to be minimal (less than 1 in 10 million in children and less than 1 in a million in adults).[18]

4.4 Logistics- Stable iodine can be used either as potassium iodide (KI) or potassium iodate (KIO3). KI is the preferred alternative, since KIO3 has the disadvantage of being a stronger intestinal irritant. Stable iodine can be given in either doubly scored tablet or liquid form. Tablet form causes less gastrointestinal irritation. As there is only limited time for implementation of prophylaxis, prompt availability of the tablets to individuals has to be ensured if they are to be at their most effective. In the vicinity of nuclear reactors, pre-distribution to households should be seriously considered. Countries using nuclear power or at risk from nuclear radiation fall out should stock iodine at national level.

CONCLUSIONS

The risk of radiation hazards, especially thyroid cancers, is high after a radioactive accident. India is at a real risk from radiation fallout both due to nuclear power plant accidents and nuclear warfare threat. There is need to institute disaster preparedness measures to mitigate the damage in case of a nuclear accident. Also, the iodine status of the Indian population as whole should be improved as iodine sufficient population are at minimal risk from nuclear radiation induced thyroid cancer.

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