American-Eurasian Journal of Scientific Research 11 (2): 79-92, 2016
ISSN 1818-6785

DOI: 10.5829/idosi.aejsr.2016.11.2.22732

Risk Analysis of Radiation Exposes and Sudden Meltdown Condition in Nuclear Power Plant in Kudankulam of Tamilnadu

K. Balasubramanian and M. Kumaran

Department of Civil & Structural Engineering, Annamalai University, Annamalai Nagar, India

Abstract: This study aims at revealing the relationships among risk assessment result, risk perception model and risk acceptance model of the residents near nuclear power plants in KNNP and working staffs. Risk acceptance model is based on the trust of resident to nuclear power plants (NPPs) companies. The risk perception of the residents and staffs is very subtle and is not always based on objective technical knowledge. In addition, there are two models of risk acceptance: i) traditional trust model and ii) salient value similarity model. In order to discuss the risk communication framework between KNPPs with residents, applicability of two modes on the perception of the residents should be investigated. The author collected through the well-structured online questionnaire from local resident near Kudankulam and idinthakarai, Tirunelvei District of Tamilnadu, India. Severity of risk is knowingly affected by the levels of risks, not by amount of knowledge. Radiation relating hazard is normally evaluated difficult risk. Risk acceptance level is significantly related to the factors of social benefits and trust to the KNPPs company, not by regional interest nor amount of knowledge. Furthermore, value similarity model was not significant in this study. The results demonstrated that risk acceptance model of local residents near KNPPs and staffscould be arranged by traditional trust model. In order to establish mutual trustworthy relationships between local residents and KNPPs engineer,technicians expert knowledge in nuclear power, communication skills and expertise in safety are necessary to the engineers and technicians.

Key words: Risk Assessment ・ KNPP ・ Risk Perception ・ Risk Communication ・ Risk Acceptance Model

INTRODUCTION

Kudankulam Nuclear Power Plant is a nuclear power station in Kudankulam Post, RadhapuramTaluk, Tirunelveli district of Tamil Nadu. Construction on the plant began on 31 March 2002, but faced several delays due to the fishermen's and social service organization's objection [2].

Power Generation Unit 1 was synchronized with the southern power grid on 22nd October 2013.The original cost of the two units was INR13,171 crore, but it was later revised to INR 17,270 crore ($2.6 billion). Russia advanced a credit of INR 6,416 crore ($0.97 billion) to both the units.

In 2015, Nuclear Power Corporation of India Ltd (NPCIL) announced a price of 4.29 Rupees/kWh (6.4 ¢/kWh) for energy delivered from Kudankulam Nuclear Power Plant(KNPPs).Now, theconstruction of units 3 & 4 are being prepared to start in 2015-16 [1].

Background: An Inter-Governmental Agreement (IGA) on the project was signed on 20th November 1988 by then Prime Minister Rajiv Gandhi and then Soviet head of state Mikhail Gorbachev, for the construction of two reactors. The project remained in limbo for a decade due to the dissolution of the Soviet Union.There were also objections from the United States, on the grounds that the agreement did not meet the 1992 terms of the Nuclear Suppliers Group (NSG). Dr. M.R. Srinivasan, Atomic Energy Commission (AEC) Chairman from 1987 to 1990, called the project "a non-starter". However, the project was revived on 21 June 1998 [3-5].

Construction: Construction began on 31 March 2002, with Nuclear Power Corporation of India Ltd. (NPCIL) predicting that the first unit would be operational in March 2007, instead of the original target of December 2007.

Corresponding Author: K. Balasubramanian, Department of Civil & Structural Engineering, Annamalai University, Annamalai Nagar, India.

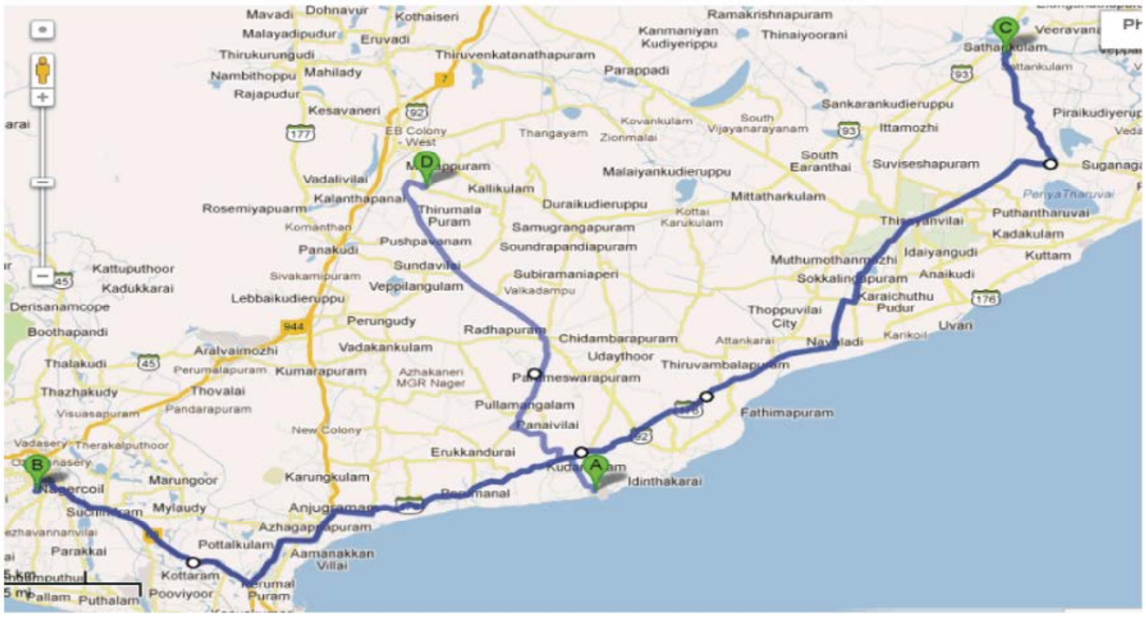

Fig. 1: Location map of KNNP in Kudankulam of Tamilnadu

Fig. 2: Side View of Light water Reactor of KNNP in Kudankulam

A small port became operational in Kudankulam on 14 January 2004. This port was established to receive barges carrying oversized light water reactor equipment from ships anchored at a distance of 1.5 kilometres (0.93 mi). Until 2004, materials had to be brought in via road from the port of Tuticorin, risking damage during transportation.In 2008, negotiations on building four additional reactors at the site began. Though the capacity of these reactors has not been declared and maintain as secret, it was expected that the capacity of each reactor will be 1000 MW or 1.0 GW.The new reactors would bring the total capacity of the power plant to 6800 MW or 6.8 GW. The first reactor of the plant attained criticality on 13 July 2013 at 11:05 pm [6-9].

Table 1: Tamil Nadu may get another 100 MW over its allocation

Beneficiary	Power (MW)
Tamil Nadu	925MW
Karnataka	442 MW
Kerala	266 MW
Puducherry	67 MW
Not allocated	300 MW
Total	2000 MW

Allocation of Power: Our Government of India announced the power allocation from the 2 units of the reactor on 29 August 2013.

Locals say that before the construction of the KNPP[10], no birds had been found around here. *"Before the power plant started to be built, soil in this area had been cracked, with vegetation mainly represented by cacti and thorny bushes. The landscape had been enlivened by huge termite mounds. Birds had hardly lived here"*, – he noted.

The matter is that the construction of the "Kudankulam" NPP had been preceded by the works related to greening the nuclear plant's territory as well as the surrounding area of KNPP. The Indian Atomic Energy Regulatory Board gave clearance for the start-up of the "Kudankulam" NPP. "As a result, rains returned, trees grew up and birds started nesting in the area", – he added.

Anu Vijay - Township of the "Kudankulam" NPP was founded in 2001, on the sea shore, eight kilometres to the west of the plant. The territory of the township is crossed by the bed of the seasonal stream called Uppar. Following the development of the river's bank as well as its realignment, a lengthy pond was created within the area of the township. The pond is nearly two kilometres long and twenty meters wide. Before the development of the river banks, traditional local inhabitants, such as sandpipers, white and gray herons and painted storks, could be occasionally seen in its small delta filled with salted water. As early as in 2007-2008, up to one hundreds of different type of birds could be found in the township. The colony of gray pelicans grew fast enough. In 2006, only six types of birds lived in the area, whereas today there are more than 40 birds nesting here. According to various sources, the total number of gray pelicans in the world ranges between five and twenty thousand birds [22].

Reactor Accidents: The nuclear power plant design strategy for preventing accidents and mitigating their potential effects is "defense in depth"- if something fails, there is a back-up system to limit the damage done, if that system should also fail there is another back-up system for it, etc.,. Of course it is possible that each system in this series of back-ups strength fail one after the other, but the probability for that is exceptionally small [11-15]. The Media often broadcast a failure of some particular system in some plant, implying that it was a close call" on disaster; they completely miss the point of defense in depth which easily takes care of such failures. Even in the three mile island accident where at least two equipment failures were severely compounded by human errors, two lines of defense were still not breached--- essentially all of the radioactivity remained sealed in the thick steel reactor vessel and that vessel was sealed inside the heavily reinforced concrete and steel lined "containment" building which was never even challenged. It was clearly not a close call on disaster to the surrounding population. The Soviet Chernobyl reactor, built on a much less safe design concept, did not have such a containment structure; if it did, that disaster would have been prevented.

Risks from reactor accidents are estimated by the rapidly developing science of "Probabilistic Risk Analysis"(PRA). A PRA must be done separately for each power plant (at a cost of $5 million) but we give typical results here: A fuel melt-down might be expected once in 20,000 years of reactor operation. In 2 out of 3 melt-downs there would be no deaths, in 1 out of 5 there would be over 1000 deaths and in 1 out of 100,000 there would be 50,000 deaths. The average for all meltdowns would be 400 deaths. Since air pollution from coal burning is estimated to be causing 10,000 deaths per year, there would have to be 25 melt-downs each year for nuclear power to be as dangerous as coal burning.

Of course deaths from coal burning air pollution are not noticeable, but the same is true for the cancer deaths from reactor accidents. In the worst accident considered, expected once in 100,000 melt-downs (once in 2 billion years of reactor operation), the cancer deaths would be among 10 million people, increasing their cancer risk typically from 20% (the current U.S. average) to 20.5%. This is much less than the geographical variation-22% in New England to 17% in the Rocky Mountain States.

Very high radiation doses can abolish body functions and lead to death within 60 days, but such "noticeable" deaths would be expected in only 2% of reactor melt-down accidents; there would be over 100 in 0.2% of meltdowns and 3500 in 1 out of 100,000 melt-downs. To date, the largest number of noticeable deaths from coal burning was in an air pollution incident (London, 1952) where there were 3500 extra deaths in one week. Of course the nuclear accidents are hypothetical and there are many much worse hypothetical accidents in other electricity generation technologies; e.g., there are hydroelectric dams in California whose sudden failure could cause 200,000 deaths [16].

Nuclear Meltdown Events: This is a list of the major reactor failures in which meltdown played a role:

How Are Radiation Risks Evaluated?: Radiation health risk assessment evaluates how often adverse health effects caused by a given radiation exposure occur in a population (or group). Radiation risk assessment is the process of approximating the type and level of risk to human health from exposure to radiation.

Scientists have learned much about how radiation experience can harm humans. However, scientists still have to make some key assumptions related to radiation-induced health risks because of limited knowledge in some areas [17-18].

Radiation risk assessment is therefore not a precise science. Large doubt can be associated with a given radiation risk estimate.

Radiation risks are usually expressed as a probability. A risk of 0.01 would indicate that 1 out of 100 people would be expected to be affected.

Sometimes a range of probabilities is used rather than giving a single approximation of risk to account for uncertainties. A hypothetical example of risk stated as a range of probabilities follows:

Table 2: List of the major reactor failures in which meltdown played a role

Date	Location of accident	Description of accident or incident	Dead	Cost ($US millions 2006)	INES level
September 29, 1957	Mayak, Kyshtym,Russia	The Kyshtym Nuclear disaster was a radiation contamination incident that occurred at Mayak, a Nuclear fuel reprocessing plant in the Soviet Union.			6
July 26, 1957	Simi Valley, California, United States	Partial core meltdown at Santa Susana Field Laboratory's Sodium Reactor Experiment.	0	32	
October 10, 1957	Sellafield, Cumberland, United Kingdom	A fire at the British atomic bomb project destroyed the core and released an estimated 740 terabecquerels of iodine-131 into the environment. A rudimentary smoke filter constructed over the main outlet chimney successfully prevented a far worse radiation leak and ensured minimal damage.	0		5
January 3, 1961	Idaho Falls, Idaho, United States	Explosion at SL-1 prototype at the National Reactor Testing Station. All 3 operators were killed when a control rod was removed too far.	3	22	4
October 5, 1966	Frenchtown Charter Township, Michigan, United States	Partial core meltdown of the Fermi 1 Reactor at the Enrico Fermi Nuclear Generating Station. No radiation leakage into the environment.	0	132[20]	
January 21, 1969	Lucensreactor, Vaud, Switzerland	On January 21, 1969, it suffered a loss-of-coolant accident, leading to a partial core meltdown and massive radioactive contamination of the cavern, which was then sealed.	0		4
1975	Sosnovyi Bor, Leningrad Oblast,Russia	There was reportedly a partial nuclear meltdown in Leningrad nuclear power plant reactor unit 1.			
December 7, 1975	Greifswald, East Germany	Electrical error causes fire in the main trough that destroys control lines and five main coolant pumps	0	443	3
January 5, 1976	Jaslovské Bohunice, Czechoslovakia	Malfunction during fuel replacement. Fuel rod ejected from reactor into the reactor hall by coolant (CO_2).[21]	2		4
February 22, 1977	Jaslovské Bohunice, Czechoslovakia	Severe corrosion of reactor and release of radioactivity into the plant area, necessitating total decommission	0	1,700	4
March 28, 1979	Three Mile Island, Pennsylvania, United States	Loss of coolant and partial core meltdown due to operator errors. There is a small release of radioactive gases. See also Three Mile Island accident health effects.	0	2,400	5
September 15, 1984	Athens, Alabama, United States	Safety violations, operator error and design problems force a six-year outage at Browns Ferry Unit 2.	0	110	
March 9, 1985	Athens, Alabama, United States	Instrumentation systems malfunction during startup, which led to suspension of operations at all three Browns Ferry Units	0	1,830	
April 11, 1986	Plymouth, Massachusetts, United States	Recurring equipment problems force emergency shutdown of Boston Edison's Pilgrim Nuclear Power Plant	0	1,001	
April 26, 1986	Chernobyl disaster, Ukrainian SSR	Overheating, steam explosion, fire and meltdown, necessitating the evacuation of 300,000 people from Chernobyl and dispersing radioactive material across Europe (see Chernobyl disaster effects)	56 direct; 4,000 to 985,000 cancer[22][23]	6,700	7
May 4, 1986	Hamm-Uentrop, Germany	Experimental THTR-300 reactor releases small amounts of fission products (0.1 GBq Co-60, Cs-137, Pa-233) to surrounding area	0	267	
March 31, 1987	Delta, Pennsylvania, United States	Peach Bottom units 2 and 3 shutdown due to cooling malfunctions and unexplained equipment problems	0	400	

Table 2: Continued

December 19, 1987	Lycoming, New York, United States	Malfunctions force Niagara Mohawk Power Corporation to shut down Nine Mile Point Unit 1	0	150	
March 17, 1989	Lusby, Maryland, United States	Inspections at Calvert Cliff Units 1 and 2 reveal cracks at pressurized heater sleeves, forcing extended shutdowns	0	120	
March 1992	Sosnovyi Bor, Leningrad Oblast, Russia	An accident at the SosnovyBor nuclear plant leaked radioactive gases and iodine into the air through a ruptured fuel channel.			
February 20, 1996	Waterford,Connecticut, United States	Leaking valve forces shutdown Millstone Nuclear Power Plant Units 1 and 2, multiple equipment failures found	0	254	
September 2, 1996	Crystal River, Florida, United States	Balance-of-plant equipment malfunction forces shutdown and extensive repairs at Crystal River Unit 3	0	384	
September 30, 1999	Ibaraki Prefecture, Japan	Tokaimura nuclear accident killed two workers and exposed one more to radiation levels above permissible limits.	2	54	4
February 16, 2002	Oak Harbor, Ohio, United States	Severe corrosion of control rod forces 24-month outage of Davis-Besse reactor	0	143	3
August 9, 2004	Fukui Prefecture,Japan	Steam explosion at Mihama Nuclear Power Plant kills 4 workers and injures 7 more	4	9	1
July 25, 2006	Forsmark, Sweden	An electrical fault at Forsmark Nuclear Power Plant caused one reactor to be shut down	0	100	2
March 11, 2011	Fukushima, Japan	A tsunami flooded and damaged the 5 active reactor plants drowning two workers. Loss of backup electrical power led to overheating, meltdowns and evacuations.[24] One man died suddenly while carrying equipment during the clean-up.	2+		7[25]
12 September 2011	Marcoule, France	One person was killed and four injured, one seriously, in a blast at the Marcoule Nuclear Site. The explosion took place in a furnace used to melt metallic waste.	1		

Our best estimate of the risk of cancer after exposure of those people to radiation is one additional case in 10,000 people, but the risk could be as high as one additional case in 1,000 people, or as low as one additional case in 1,000,000 people.

The Steps in Risk Assessment: A radiation risk assessment often consists of four steps.

Radiation Hazard Identification: Here, the potential health hazard from exposure to radiation is identified.

Radiation Exposure Assessment: Scientists evaluate the levels of radiation exposure that could arise. There is usually hesitation to how much radiation a given individual could be exposed.

Radiation Toxicity Assessment: Scientists also evaluate the type and degree of harm that different amounts of radiation would be expected to cause in humans. There is usually uncertainty associated with the amount of harm (e.g., number of radiation-induced cancer cases).

Radiation Risk Characterization: Scientists evaluate the risk posed by radiation for a given exposure scenario. Often, computer models are needed to estimate radiation doses to humans.

In risk characterization, scientists combine information from radiation exposure assessments and radiation toxicity assessments to estimate the type and magnitude of risk faced by the exposed population. The risk characterization usually states important uncertainties.

Risk Assessment vs. Risk Management: Risk assessment is distinct from risk management. Risk assessment is a scientific process of examining phenomena to estimate the level of risk. Risk management is an effort to reduce the risk through education, regulation, etc.

Risk managers use the results of risk assessments, plus economic, social and legal considerations to make regulatory and policy decisions. While economic, social and legal considerations have a legitimate place in risk management, they have no place in the scientific process of risk assessment.

Risk Assessments and Judgments: Risk assessment is not completely devoid of judgments. Sometimes the decisions are based on the scientist's best judgment. Such decisions can affect the outcome of the risk assessment.

Risks Associated with Small Radiation Doses: Cancer is the major risk associated with exposure of humans to low radiation doses. Two types of models are usually used for evaluating the risk of radiation-induced cancer in humans: (1) absolute-risk models and (2) relative-risk models.

Absolute-Risk Models: With absolute-risk models, the excess risk due to exposure to radiation does not depend on the usual risk that would arise when there is no radiation exposure. Absolute risks are evaluated on a scale from 0 to 1. A risk of 1 corresponds to 100% of the exposed individuals being affected.

Absolute risks are usually based on the assumption of a linear risk vs. dose relationship that passes through zero excess risk at the origin. This represents what has become known as the linear, no-threshold (LNT) model.As an example of how absolute risk is applied, if the normal risk over the lifetime is 0.001 for a specific type of cancer and radiation adds an additional risk of 0.02, then the absolute risk of cancer over the lifetime is 0.001 + 0.02 or 0.021 [19].

Relative-Risk Models: With relative-risk models, the relative risk is a multiple of the normal risk. Unlike absolute risks, relative risk values range from 1 to very large numbers. A value of 1 for the relative risk means that there is no excess risk.

The relative risk considers how the normal risk changes with age. For example, if the normal risk of developing a given type of cancer between age 50 and age 51 years is 0.001 and radiation exposure leads to a relative risk of 2, then the relative risk is used to multiply the normal risk, so one has to calculate the product 2 x 0.001 or 0.002. Thus, instead of having a normal risk of 0.001 for cancer in the age interval 50 to 51 years, the risk is increased to 0.002 because of the radiation exposure.

Similar calculations are carried out for other age intervals depending on the age of the person at the time of exposure and the latent period for the cancer type of interest.The tumor latent period is the time it takes for a tumor to develop. The latent period is different for different types of cancer [20].

To determine the lifetime risk, the risks for the different age intervals are added. However, no radiation-related risks would be counted during the latent period.Effects other than cancer that could be caused by low radiation doses include genetic effects and effects on the unborn embryo or fetus carried by a pregnant mother. Small radiation doses could also cause temporary suppression in sperm counts in males.

Risks Associated with Large Radiation Doses: In addition to cancer and genetic effects, the risk associated with large radiation doses includes a change of other effects that necessitate killing large numbers of cells in an organ or tissue. For effects that require killing large numbers of cells, a threshold dose occurs below which the effect would not be expected to occur. The shape of the dose-response curve for such effects is generally S-shaped (sigmoidal).

The steepness of the sigmoid curve usually depends on the radiation dose rate and the degree of uniformity of the radiation dose to local tissue. Risk is evaluated based on a sigmoidal dose-response curve that accounts for dose rate effects, the type of radiation and how radiation dose is distributed over a given target (organ/tissue) in the body.

Separate risks can be evaluated for radiation effects associated with different organs. Examples follow:

- Risk of erythema from skin damage
- Risk of hypothyroidism from irradiation of the thyroid
- Risk of severe lung damage from irradiation of the lung
- Risk of lethal damage to the bone marrow
- Risk of lethal radiation damage to the small intestines

Some risks can be increased by wounds (e.g., risk of death from radiation induced damage). Risks can also be influenced by exposure to other agents (biological and/or chemical agents) in addition to radiation.

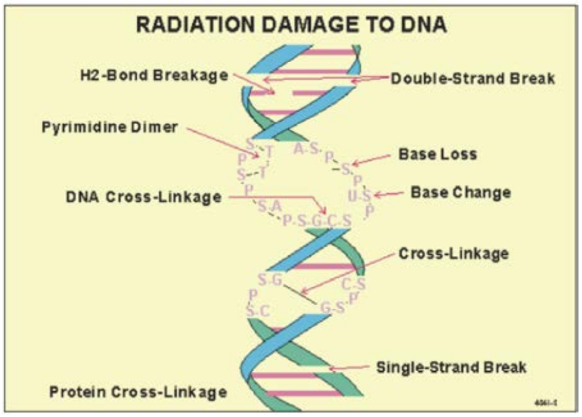

Fig. 3: Radiation Damage to DNA

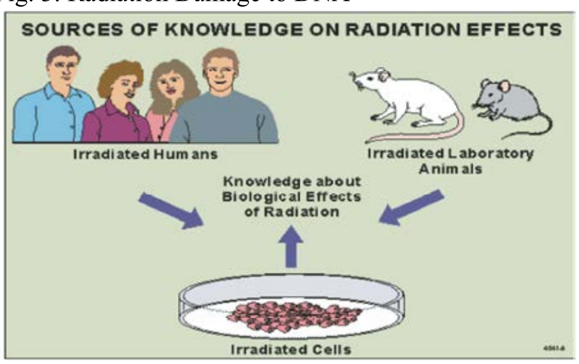

Fig. 4: Sources of knowledge on Radiation Effects

How Can Radiation Exposure Harm People?: Harm to people from radiation exposure starts with damage to cells in the body. The cell damage get up from damage to constituents of the cell, especially DNA. Figure 3.1 shows different types of damage to DNA produced by radiation (including ultra violet).

Radiation damage to cells may occur directly from a radiation hit on the critical target or indirectly from free radicals (reactive chemicals) that are produced by radiation. Key sources of knowledge on radiation effects are resented in Figure 3.2 and include knowledge gained from cell, animal and epidemiological studies.

Harm from Small Radiation Doses

Radiation Effects in Somatic and Germ Cells: Most of the cells in the body are somatic cells. Somatic cells are cells other than the germ cells.Germ cells are involved in reproduction (i.e., producing babies). Skin and lung cells are examples of somatic cells and are not complicated in reproduction.

Small radiation doses can disturb cells biologically. The belongings depend on the type and amount of radiation. These effects include cell killing, altered genes, injured chromosomes and cells being temporarily held (arrested) at specific places in the cell cycle called checkpoints.

DNA is checked for damage while cells are detained at checkpoints and the damage is most often correctly repaired. However, on infrequent occasions, the damage is not correctly repaired.

Misrepair (incorrect repair) of DNA damage can lead to unhinged DNA in the cell nucleus. Unstable DNA in living cells is called genomic instability.

Cells that survive with genomic instability can, over time, cause big problems for people. Two such problems are cancer in irradiated persons and genetic effects in children of irradiated parents. Genetic effects arise from genomic instability in germ cells of the irradiated parents.Cancer arises from genomic instability in somatic cells in the irradiated person [21].

Genetic Effects: Small doses of ionizing radiation can permanently damage DNA in germ cells as formerly indicated. One type of permanent damage is gene mutation. A mutation can be transmitted from one generation to another and therefore characterizes a genetic effect of irradiation.

Two specific germ-cell stages are considered important in evaluating the effects of radiation on the heredity of germ cells:

The stem-cell spermatogonia in males. The oocytes, primarily the immature ones, in females. Spermatogonia continue to multiply throughout the reproductive life span of an individual. However, oocytes are not replaced during adult life. The genetic effects that could be caused by radiation are too numerous to be considered here individually. For radiation risk assessment, genetic complaints can be grouped as:

Dominant and X-linked, single-gene disorders: i) Chromosome disorders ii) Multifactorial disorders

Dominant and X-Linked Single-Gene Disorders: Most cells from humans contain two sets of chromosomes with coordinated pairs of genes, one gene from each parent. The matched gene partners can differ, with one gene being dominant over its recessive partner gene.

Achondroplastic dwarfism is an example of a dominant gene disorder that could be caused by ionizing radiation.

A recessive gene can only show its consequence if both partner genes show the result. If a bad gene is present on the X-chromosome, it will always produce an effect in males. This is because males only have one X-chromosome.

Females have two X-chromosomes. If a female has one bad gene on an X-chromosome, but the other X-chromosome has a good gene partner, then the bad gene can behave as recessive (i.e., not having an influence). Single-gene disorders associated with the X-chromosome are called X-linked effects. Muscular dystrophy is an example of an X-linked effect that could be caused by ionizing radiation.

There is no direct sign that the above-indicated diseases have been induced by radiation in humans. However, based on results of animal studies, the diseases are considered possible consequences of radiation exposure.

Chromosome Disorders: Chromosome damage in germ cells of parents can influence heredity. Most somatic cells of humans have 23 pairs of chromosomes, with one member of each pair donated by the father and the other by the mother.

Radiation exposure of the parents could lead to an abnormal number of chromosomes (aneuploidy) in their offspring, which could harshly affect the unborn or newborn child.In most cases, aneuploidy will result in spontaneous loss of pregnancy. In the remaining cases, a severely pretentious child would be expected.

Down's syndrome is an example of a consequence of aneuploidy. People with aneuploidy have a significant reduction in their life expectancy, have abnormal body features and have no children.

Multifactorial Disorders: Multifactorial disorders (diseases) involve complex patterns of inheritance. These disorders signify a very large class of genetic diseases.A specific combination of distorted genes must be present for multifactorial diseases to occur. Environmental factors can also be important.

Examples of Multifactorial Diseases Include:

- Congenital malformations (e.g., spina bifida and cleft palate)
- Constitutional diseases
- Degenerative diseases

Late Somatic Effects: Late somatic effects of irradiation are those effects that occur in somatic cells years after brief exposure. Cancer is the somatic effect of most concern in radiation risk assessment. For chronic exposure to radiation over many years, the late somatic effects may occur during the irradiation period [22].

Cancer does not appear immediately after brief radiation exposure. It appears only after a delay (latent period). For humans, the latent period may be many years for some cancers (e.g., lung cancer). Other factors such as cigarette smoking can also influence the cancer risk from radiation exposure. Mechanisms presently considered to be involved in the induction of cancer by radiation include:

The induction of mutations
The activation of oncogenes (cancer-causing genes)
The inactivation of tumor suppressor genes (genes that protect from cancer)
The induction of cancer-causing viruses

More than one mechanism could be involved for a given type of cancer. However, the relative importance of the indicated mechanisms is not clear.

Harm from Large Radiation Doses

Harm from Short-Term Exposure: Large radiation doses can destroy millions or more cells in tissues of the body. Because tissues of the body have important functions, abolishing large numbers of cells in tissue can main to impairment of organ function, morbidity and death from organ failure.

Deterministic (nonstochastic) effects of irradiation are those health effects that arise only when huge numbers of cells are demolished by radiation. For such effects, there is a threshold dose below which the health effect does not occur.For deterministic effects, the harshness of the health effect can increase as the radiation dose increases above the threshold.

Deterministic health effects include: i) Morbidity ii) Lethality

Associated Signs and Symptoms or Radiation Injury: Deterministic effects usually appear within a few months after brief (short-term) exposure to large radiation doses (e.g., from a nuclear weapon or nuclear accident). The initial effects seen are associated with what has been called the prodromal phase (acute radiation sickness phase).

The prodromal phase is made up of the symptoms and signs appearing in the first 2 days after brief exposure to radiation. After super-lethal doses of several tens of Gy, all individuals begin to show all symptoms associated with the prodromal phase within about 15 minutes. Reactions during the prodromal phase are mediated via the autonomic nervous system. They are expressed as gastrointestinal and neuromuscular symptoms.

The gastrointestinal symptoms are:

- Appetite loss ii) Nausea iii) Vomiting iv) Diarrhea v) Intestinal cramps vi) Salivation vii) Dehydration

The neuromuscular symptoms are:

- Fatigue ii)Apathy iii) Listlessness iv) Sweating v) Fever vi) Headache vii) Low blood pressure (hypotension), followed by hypotensive shock

Other deterministic effects of radioactivity include bleeding, infection, hair loss, temporary suppressed sperm counts and permanently suppressed ovulation. Morbidity can arise from damage to the skin, eye, thyroid, liver, lung, bone marrow and other sites.Death can arise from severe damage to key organs (e.g., skin, intestines, bone marrow, lung and liver).

Radiation-induced deterministic effects can unfavorably impact the performance of humans (i.e., performance degradation). Members of population exposed to a nuclear weapon could be severely impaired by deterministic effects of brief exposure to neutrons and gamma rays.

The US military uses a computer program called HPAC to evaluate performance degradation based on combinations (complexes) of radiation-induced symptoms and signs over time. The time patterns of the symptom complexes depend on the type of exposure (e.g., brief, chronic, etc.).

Prodromal effects of irradiation can also arise from radiation exposure resulting from a nuclear accident or radiological incident. This happened to Russians involved in the Chernobyl accident that occurred in April 1986. Three hundred Chernobyl accident victims suspected of suffering from the acute radiation sickness were sent to the specialized treatment center in Moscow and to hospitals in Kiev within the first 3 days following the start of the Chernobyl accident. Over the subsequent days, some 200 additional people were admitted for examinations.

Acute radiation sickness was confirmed in 99 of the 128 people (firemen, Unit 4 reactor operators, turbine-room duty officer and auxiliary personnel) admitted to the specialized treatment center in Moscow during the first 2 days of the Chernobyl accident and in 6 of the 74 victims hospitalized during the following 3 days.

Harm from Long-Term Exposure: Deterministic effects also include radiation effects (other than cancer and genetic effects) that continue to occur after an extended period (e.g., years) of chronic (long-term) exposure. Such chronic exposure can arise from long-lived radionuclides ingested via contaminated food or inhaled via contaminated air.Russian nuclear workers at the Mayak plutonium production facility in the Chelyabinsk region (near the Urals Mountains) were exposed over years to neutrons plus gamma rays and to alpha radiation plus gamma rays. Various deterministic effects were caused by these radiation exposures. Other effects (e.g., cancer) were also induced.

In addition to cancer, genetic effects (in their children) and prodromal effects, two effects were seen in Mayak workers that were not previously reported in western literature:Pneumosclerosis (severe damage to the lung mainly from inhaled plutonium) is one of the new effects reported in Mayak nuclear workers. Chronic radiation disease (mainly from exposure over years to gamma rays). Pneunosclerosis appears to be related to radiation pneumonitis and pulmonary fibrosis in the lung.

Chronic radiation disease (or chronic radiation sickness) was originally reported by the Russian physicians, A. K. Gus'kova and G. D. Baysogolov. They described chronic radiation disease as being characterized by varying degrees of cardiovascular, gastrointestinal and neural system disorders.Chronic radiation disease occurred mostly in workers with total gamma-ray doses in excess of 1 Gy. Both pneumosclerosis and chronic radiation disease can occur years after the start of chronic exposure to radiation.

Harm from Exposure to Radiation and Other Hazards (Chemical, Biological): The number of different types of chemical/biological (CB) agents that potentially could be involved in combined nuclear/biological/chemical (NBC) exposure of humans in association with a terrorist incident is staggering.

Potential CB agents contain the following biologicals:

- Anthrax ii) Botulinum toxin iii) Staphylococcus enterotoxin B iv) Tularemia v) Brucellosis vi) Smallpox virus

Among the chemicals are: i) Sarin ii) Distilled mustard iii) VX nerve iv) Tabun v) Soman vi) Phosgene vii) Chlorine viii) Hydrogen cyanide ix) Cyanogen chloride

Genetically engineered organisms also represent a possible future hazard.

Out of concern about likely terrorist acts, smallpox vaccinations were initiated on January 24, 2003 among some key medical personnel in the U.S. Little is known about dose-response relationships in humans for many of the individual agents of interest. Even less is known about possible harm from joint exposures. It is possible to adequately envisage the consequences of combined exposure when the modes of action of individual agents are known. However, key knowledge is lacking at the present time about dosimetry and modes of action.

Reasons Behind the Need for Koodankulam Nuclear Power Project: The peoples of Kudankulam have been opposing the Koodankulam Nuclear Power Project (KNPP) ever since it was conceived in the mid-1980s. The people of Koodankulam village themselves were misled by false promises such as 10,000 jobs, water from Pechiparai dam in Kanyakumari district and fantastic development of the region. They tried in vain to tell them that they were being deceived. Without any local support, they could not sustain the anti-Kudankulam movement for too long. Now the people of Kudankulam know and understand that this is not just a fisher folk problem, they may be displaced and they have to deal with radioactive poison. Their joining the movement in 2007 has invigorated the campaign now. And almost all of us here in the southernmost tip of India oppose the Kudankulam NPP for a few specific reasons:

- The KKNPP reactors are being set up without sharing the Environmental Impact Assessment (EIA), Site Evaluation Study and Safety Analysis Report with the people, or the people's representatives or the press. No public hearing has been conducted for the first two reactors either. There is absolutely no democratic decision-making in or public approval for this project.
- The Tamil Nadu Government G.O. 828 (29.4.1991 – Public Works Department) establishes clearly that "area between 2 to 5 km radius around the plant site, [would be] called the sterilization zone." This means that people in this area could be displaced. But the KNPP authorities promise orally and on a purely adhoc basis that nobody from the neighboring villages would be displaced. This kind of adhocism and doublespeak causes suspicion and fears of displacement.
- More than 1 million people live within the 30 km radius of the KNPP which far exceeds the AERB (Atomic Energy Regulatory Board) stipulations. It is quite impossible to evacuate this many people quickly and efficiently in case of a nuclear disaster at Kudankulam.
- The coolant water and low-grade waste from the KNPP are going to be dumped in to the sea which will have a severe impact on fish production and catch. This will undermine the fishing industry, push the fisher folks into deeper poverty and misery and affect the food security of the entire southern Tamil Nadu and southern Kerala.
- Even when the KNPP projects function normally without any incidents and accidents, they would be emitting Iodine 131, 132, 133, Cesium 134, 136, 137 isotopes, strontium, tritium, tellurium and other such radioactive particles into our air, land, crops, cattle, sea, seafood and ground water. Already the southern coastal belt is sinking with very high incidence of cancer, mental retardation, down syndrome, defective births due to private and government sea-sand mining for rare minerals including thorium. The KNPP will add many more woes to our already suffering people.
- The quality of construction and the pipe work and the overall integrity of the KNPP structures have been called into question by the very workers and contractors who work there in Kudankulam. There have been international concerns about the design, structure and workings of the untested Russian-made VVER-1000 reactors.
- The then Minister of State in the Ministry of Environment and Forest Mr.Jairam Ramesh announced a few months ago that the central government had decided not to give permission to KNPP 3-6 as they were violating the Coastal Regulation Zone stipulations. It is pertinent to ask if KNPP 1 and 2 are not violating the CRZ terms.
- Many political leaders and bureaucrats try to reassure us that there would be no natural disasters in the Kudankulam area. How can they know? How can anyone ever know? The 2004 December tsunami did flood the KKNPP installations. There was a mild tremor in the surrounding villages of Kudankulam on March 19, 2006. On August 12, 2011, there were tremors in 7 districts of Tamil Nadu.
- Indian Prime Minster himself has spoken about terrorist threats to India's nuclear power plants. Most recently, on August 17, 2001, Minister of State for Home, Mr. MullappallyRamachandran said: "the atomic establishments continue to remain prime targets of the terrorist groups and outfits."

- The important issue of liability for the Russian plants has not been settled yet. Defying the Indian nuclear liability law, Russia insists that the Inter-Governmental Agreement (IGA), secretly signed in 2008 by the Indian and Russian governments, precedes the liability law and that Article 13 of the IGA clearly establishes that NPCIL is solely responsible for all claims of damages.
- In 1988 the authorities said that the cost estimate of the Kudakulam 1 and 2 projects was Rs. 6,000 crores. In November 1998, they said the project cost would be Rs. 15,500. In 2001, the ministerial group for economic affairs announced that the project cost would be Rs. 13,171 crores and the Indian government wouldinvest Rs. 6,775 crores with the remainder amountcoming in as Russian loan with 4 percent interest. The fuel cost was estimated to be Rs. 2,129 crores which would be entirely Russian loan. No one knows the 2011 figures of any of these expenses. No one cares to tell the Indian public either.
- The March 11, 2011 disaster in Fukushima has made it all too clear to the whole world that nuclear power plants are prone to natural disasters and no one can really predict their occurrence. When we cannot effectively deal with a nuclear disaster, it is only prudent to prevent it from occurring. Even the most industrialized and highly advanced country such as Germany has decided to phase out their nuclear power plants by the year 2022.Switzerland has decided to shun nuclear power technology. In a recent referendum, some 90 percent of Italians have voted against nuclear power in their country. Many Japanese prefectures and their governors are closing nuclear power plants in their regions. Both the United States and Russiahave not built a new reactor in their countries for 2-3 decades ever since major accidents occurred at Three Mile Island and Chernobyl.

In our own country, Mamta Banerjee government in West Bengal has stopped the Russian nuclear power park project at Haripur in PurbaMedhinipur district and taken a position that they do want any nuclear power project in their state. Similarly, the people of Kerala have decided not to host any nuclear power project in their state.

[13] And finally, the Indian government's mindless insistence on nuclear power, utmost secrecy in all of its nuclear agreements and activities and its sheer unwillingness to listen to the people's concerns and fears make us very doubtful about the real benefactors of all this nuclear hoopla. Is it all for us, the people of India? Or for the corporate profits of the Russian, American and French companies? Or for the Indian military? Are the lives and futures of the Indian citizens inferior to all these?

Safety Feature in Kudankulam NPP: The Kudankulam is located on the coast of the Gulf of Mannar, at 24Kilo Meters to the north-east from Kanyakumari,in Tamil Nadu State. The Kudankulam Nuclear Power Projects are world's most advanced VVER-1000 reactors designed by Russian Engineers & Scientists. The design has been evolved from serial design of VVER 1000 reactors, of which 15 units are under operation for last 25 years. The VVER design adopted at Kudankulam has in additional many additional unique safety features.

The VVER 1000 reactor chosen for Kudankulam is inherent safe having features the following:

- Negative power coefficient: Wherein any increase in reactor power is self-terminating.
- Negative Void Coefficient: reactor will shut down, if there is loss of water.
- Four independent safety Trains even though one alone is sufficient for the 100% safety of the reactor.
- Emergency reactor shutdown.
- Emergency boron injection.
- Containment spray.
- High pressure safety injection.
- Primary system emergency and planed cool down and fuel pool cooling.
- Primary circuit shut down cooling.
- Provisions for withstanding external effects involving earthquake, tsunami/storm, tidal waves, cyclones, shock waves, fire and aircraft impact on main buildings
- Kudankulam site is located far off (about 1500 km) from the tsunami genic fault (where tsunamis originate). Thus, if there is a tsunami, it would take time and lose its energy by the time it strikes Kudankulam site. Whereas against this, the tsunami genic fault was only about 130 km away at Fukushima.
- The supplementary control room and the four diesel generator - safety train rooms are on condition that with water tight doors to keep them against flooding. We should *normally* ensure that the doors remain shut down when the reactors are operating by using interlocks or severe administrative procedures.
- For cooling of the core in a shutdown condition, to remove the decay heat, four independent cooling trains, each with its own diesel generator set, are provided.There is a back up to this through *hydro* accumulators (in two stages).

Investigation Method

Selection of Respondents for the Survey: A sample of 206 residents of neighbor villages of Kudankulam in Tamilnadu that were older than 20 years old was selected. The number of respondents from Kudankulam was first determined based on the population ratio was classified according to gender and age. 206 subjects were then selected from (114 men and 92 women) as potential respondents for the survey.

Which method of power generation do you think emits less carbon dioxide (CO2) when generating electricity?.

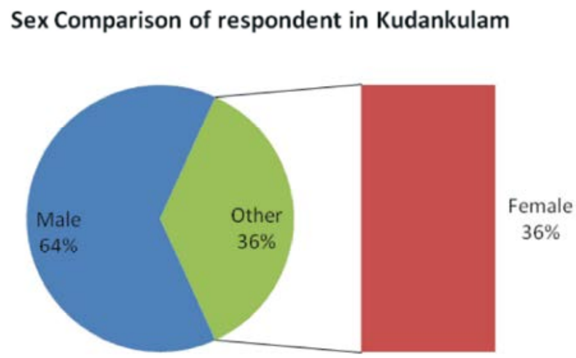

Fig. 5: Sex Comparison of respondent in Kudankulam

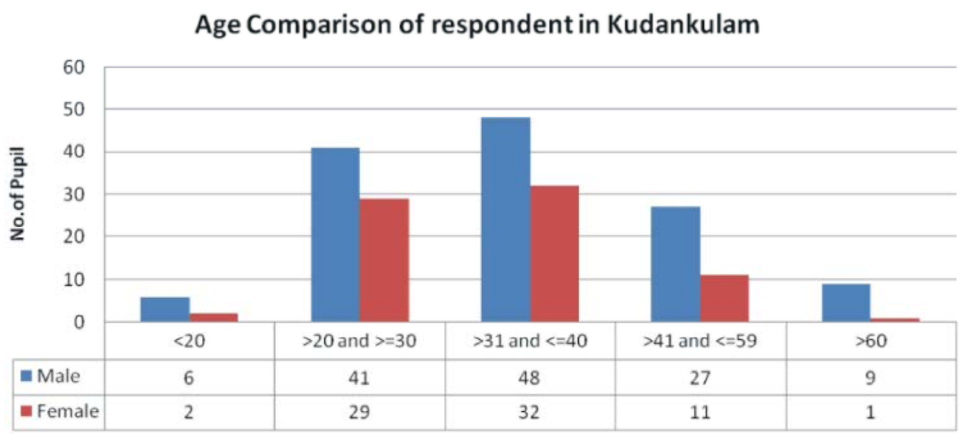

Fig. 6: Age Comparison of respondent in Kudankulam

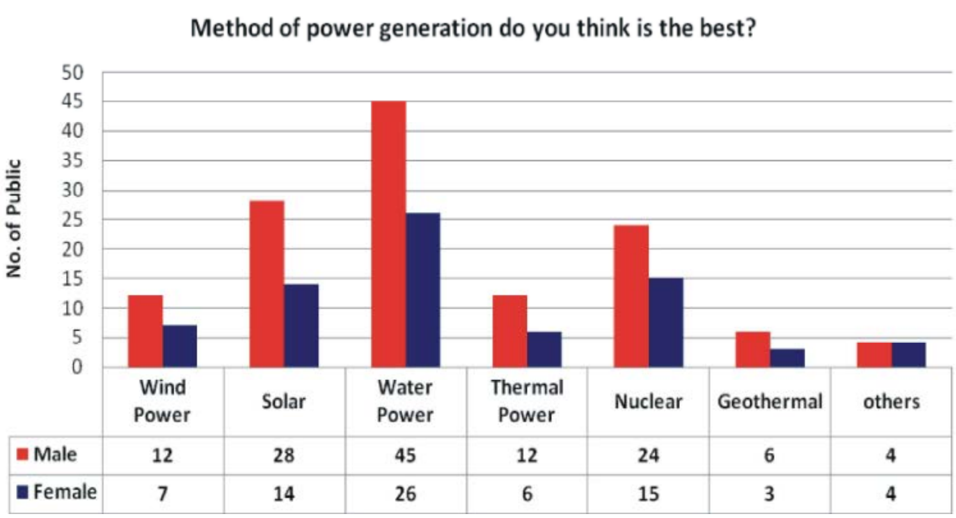

Fig. 7: Method of power generation do you think is the best?

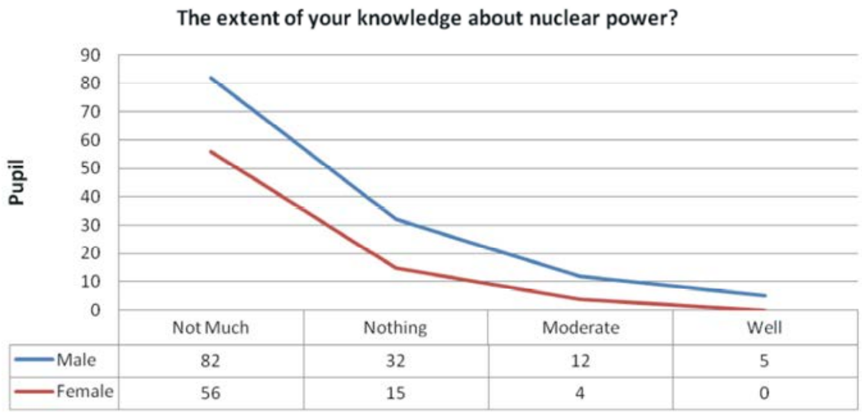

Fig. 8: The extent of your knowledge about nuclear power?

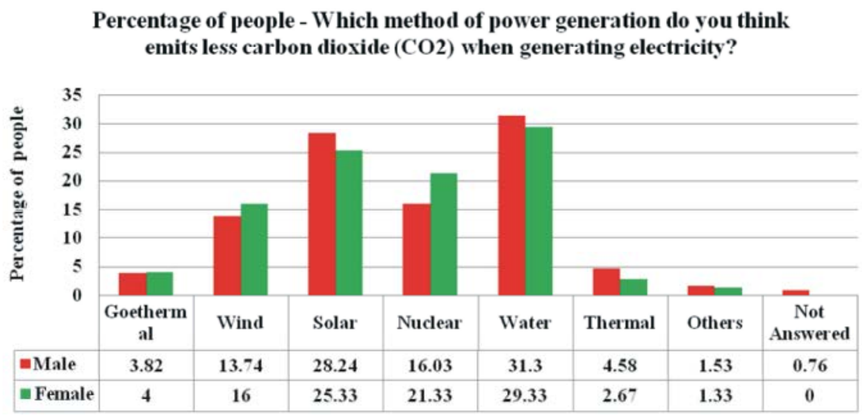

Fig. 9: Percentage of people - Which method of power generation do you think emits less carbon dioxide (CO_2) when generating electricity?

CONCLUSION

This study observed the relationship among risk assessment, risk perception model and risk perception model of local residents near KNPP in Kudankulam - Idinthakarai region. The summary of the results is as follows.

- The extent of the severity of risk is significantly affected by the perceived extent of damage due to a given hazard. In particular, radiation-related hazards are perceived as more severe than other hazards.
- The extent of acceptance on the risks by NPPs is significantly related to the factors of social benefits by NPP and trust to NPP Company by the local residents. The benefits to the local region are not found to be statistically significant on risk acceptance model.
- Respondents' amount of knowledge is not significantly correlated with any of the items. The results suggest that only technical explanation to the resident is not sufficient to establish mutual reliable relationship between NPPs engineers and local residents.
- Value similarity between NPPs with local residents is not statistically significant. Nuclear power plants company is perceived as making efforts to gain public trust in the region.
- NPP engineers are expected to possess expert knowledge in nuclear power, communication skills and expertise in safety in order to conduct more smooth risk communication.

The result demonstrates that risk acceptance model of local residents to NPPs can be arranged by traditional trust model. The result by this study is beneficial for risk communicators to manage communication framework with local residents.

Remarks and Recommendations: The following is the remarks and Recommendations of Kudankulam people's survey;

- More of the People of Kudankulam, surveyed think that Water Power/ Nuclear Power generation is the best method of power generation.
- Lack of knowledge on safety of nuclear power causes people's anxiety. Hence, public information on nuclear energy and its safety aspects should be emphasized.
- A bigger number of the peoples of Kudankulam, surveyed use "Internet" as source of information on nuclear power. Compared with "TV", internet cost is significantly less. Hence, institutions on nuclear science and technology should utilize this medium more actively in providing information on nuclear power.

REFERENCES

1. Kimura, H., K. Furuta and A. Suzuki, 2003. Psychological Factors Affecting Public Acceptance of Nuclear Energy:Comparative Analysis Focusing on Regional Characteristics and Degree of Knowledge Prasad. Transactions of theAtomic Energy Society of Japan, 2: 379-388.
2. Yagi, E., S. Takahashi and M. Kitamura, 2007. Clarification of Nuclear Risk Recognition Scheme through DialogueForum. Transactions of the Atomic Energy Society of Japan, 6: 126-140.
3. Huang, L., Y. Zhou, Y.T. Han, J.K. Hammitt, J. Bi and Y. Liu, 2013. Effect of the Fukushima Nuclear Accident onthe Risk Perception of Residents near a Nuclear Power Plant in China. Proceedings of the National Academy ofSciences of the United States of America, 110, 19742-19747. http://dx.doi.org/10.1073/pnas.1313825110
4. http://www.dianuke.org/thirteen-reasons-against-the-koodankulam-nuclear-power-project/.
5. Hayano, S., *et al*., 2014. Whole-body counter survey results 4 months after the Fukushima Dai-ichiNPP accident in Minamisoma City, Fukushima. J. Radiol. Prot., 34: 787-799.
6. Health & Safety Laboratory. Human Vulnerability To Thermal Radiation Offshore, Report Number Fs/04/04, 2004 http://www.hse.gov.uk/research/hsl_pdf/2004/hsl04-04.pdf
7. Huang, L., J. Bi, B. Zhang, F. Li and C. Qu, 2010. "Perception of people for the risk of Tianwan nuclear power plant," Frontiers of Environmental Science & Engineering in China, 4(1): 73-81.
8. Tateno, S. and H.M. Yokoyama, 2013. "Public anxiety, trust and the role of mediators in communicating risk of exposure to low dose radiation after the Fukushima Daiichi Nuclear Plant explosion," Journal of Science Communication, 12(2): 1-22.
9. Tsunoda, K., 2001. "Public response to the Tokai nuclear accident," Risk Analysis, 21(6): 1039-1046.
10. Ulleberg, P. and T. Rundmo, 2003. "Personality, attitudes and risk perception as predictors of risky driving behavior among young drivers," Safety Science, 41: 427-443.
11. Yim, P.A. and P.A. Vagenov, 2003. "Effects of education on nuclear risk perception and attitude," Progress in Nuclear Energy, 42(2): 221-235.
12. Allen, F.R., A.R. Garllick, M.R. Hayns and A.R. Taig, 1992. TheManagement of Risks to Society from Potential Accidents (ElsevierApplied Science).
13. Le Guen, J., 1995. Generic Terms and Concepts in the Assessment and Regulation of Industrial Risks, Health and Safety Executive Discussion Document.
14. India 2020: A Vision For The New Millenium by Dr. A. P. J. Abdul Kalam, formerPresident of India, also known as the Missile Man of India.
15. Powerful Science Communication and Transformation of Societies By Dr. A. P. J. AbdulKalam, Science Communicator Volume 02, Issue 01, January 2011.
16. Michanek, G. and P. Söderholm, 2009. "Licensing of nuclear power plants: The case of Sweden in an international comparison", Energy Policy, 37: 4086-4097.
17. Vivianne, H.M., V.H.M. Visschers, C. Keller and M. Siegrist, 2011, "Climate change benefits and energy supply benefits as determinants of acceptance of nuclear power stations: Investigating an explanatory model", Energy Policy, 39: 3621-3629.
18. www.mi.infn.it (Considerations related to specific concepts: Water cooled reactors, gas cooledreactors, metal cooled reactors, non-conventional reactors).
19. Fei, T., J.G. Richard, A.R. Kersting, S.M. Don, C. Oi, M.J. Driscoll and E. Shwageraus, 2012. "A survey of alternative once-through fast reactor core designs", International Congress on Advances in Nuclear Power Plants 2012, ICAPP 2012, 3: 1562-1571.
20. Michanek, G. and P. Söderholm, 2009. "Licensing of nuclear power plants: The case of Sweden in an international comparison", Energy Policy, 37: 4086-4097.
21. Jewell, J., 2011. "Ready for nuclear energy?: An assessment of capacities and motivations for launching new national nuclear power programs", Energy Policy, pp: 1041-1055.
22. http://www.indiainfoline.com/article/news/birds-started-nesting-in-area- surrounding-npp-of-kudankulam-5770977289_1.html.