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NUCLEAR DISASTER MANAGEMENT

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Abstract

Arguably a nuclear emergency triggered by an act of war, sabotage or a natural disaster can be the most complex crisis to handle. The crippling of the Fukushima Daiichi nuclear power plant in Japan by a combination of an earthquake and a tsunami is a case in point. A highly disciplined nation, geared towards managing earthquakes and tsunamis and maintaining a high level of nuclear safety found itself struggling to handle this epic tragedy. Pakistan has a very small nuclear industry, which so far, has escaped any significant, glitches in its operations. A clean track record is not reason enough to conclude that nuclear emergencies may not take place. Officials at the National Disaster Management Agency (NDMA) point out that a Nuclear Emergency Response Plan (NERP) is being prepared in consultation with the experts of the Pakistan Nuclear Regulatory Authority (PNRA), Pakistan Atomic Energy Commission (PAEC) and the Strategic Plans Division (SPD). It is expected that this Plan will cover all kinds of contingencies to handle nuclear disasters. One hopes that it will include guidelines not only for the rescue and relief organisations but also for the general public to follow in a nuclear emergency. This paper aims at underscoring the importance of integrating the common man in the nuclear disaster management plan.

Key Words: Nuclear, Disaster Management, Chernobyl, Fukushima.

Introduction

The primary objective of this paper is to highlight various aspects of a nuclear disaster involving a nuclear power plant (NPP) and the need to involve the common man in preparing for it. In building up this case the author has examined the subjects of natural and manmade disasters and explained various aspects of the science and art of disaster management (DM). Although civilian nuclear disasters have been covered substantially, the effects of a nuclear weapon strike have also perfunctorily been touched upon. Although nuclear crises caused by the use of nuclear weapons and a malfunctioning NPP overlap in a number of places, and both need different treatment, the author has deliberately left out the former for the latter.

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DM and Mismanagement

The Theory of DM

Recorded human history is replete with incidences of floods, plagues, pestilence, epidemics, droughts, fires, earthquakes and wars. Disasters of biblical proportions like the flood that engulfed the people of Prophet Noah, about 7,500 years ago, find mention in religious texts. For centuries the venerable Noah tried in vain to bring his incorrigible nation to the right path. When he reached the end of his tether, the Lord decided to drown the unrepentant from among his flock. Noah was told to construct the Ark and board it with a pair of each living species to escape the ravages of the great flood.[1] This page from history informs us that not only did the Prophet prepare for the forthcoming disaster; he planned for the life after it. Nature still provides significant warnings, which if taken seriously can substantially reduce the quantum of disaster.

Disaster is defined as "A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources."[2] The experiences of domestic and international crisis management agencies have led to the recognition of DM as a new genre in management sciences.[3] This subject covers aspects like understanding disasters, the risks involved and the likely preparations to reduce expected losses. DM involves capacity building to mitigate the effects of a disaster. This includes preventive means to stop manmade disasters like terrorist attacks and preparatory measures in areas prone to natural calamities like earthquakes and hurricanes. The effectiveness of DM depends on the ability of the authorities to analyse potential threats and prepare contingency plans. These actions encompass the standard DM theory.[4] Risk analysis, assumes fundamental importance in reducing losses by instituting preventive and emergency measures. Risk is a combination of hazards and vulnerabilities. A hazard signifies the threat and the vulnerability and the weaknesses in the system. The degree of risk increases if anyone or both these factors are higher in proportion to the acceptable norm. The *International Strategy for Disaster Reduction* (ISDR) explains risk in the following manner:

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[1] "Chapter: Hood, Verses 31-49," *The Holy Quran*.

[2] "Disaster, Terminology: Basic terms of Disaster Risk Reduction," *International Strategy for Disaster Reduction* (ISDR), http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm (accessed March 27, 2011).

[3] Mansoor Raza, "Accountability in Disaster," *Dawn*, April 13, 2011.

[4] "Disaster Management Theories," *Kobenhavnas Universitet*, www.ku.dk/disaster_management (accessed March 30, 2011).

The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. Conventionally **risk** is expressed by the notation **Risk** = Hazards x Vulnerability. Some disciplines also include the concept of exposure to refer particularly to the physical aspects of vulnerability. Beyond expressing a possibility of physical harm, it is crucial to recognize that risks are inherent or can be created or exist within social systems. It is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of **risk** and their underlying causes.[5]

The quality of disaster response can be improved if DM plans and procedures are prepared on the basis of the available meteorological data and empirical evidence. An effective DM response depends on adequate preparations. This includes a slew of actions like deploying reliable warning systems, building the capacity of the rescue and relief organizations and enhancing the level of preparedness at the official and public level to handle different kinds of catastrophes. A nuclear DM response would include additional items like short term and long term decontamination measures.

The Problems of a Standard DM Response

Each upheaval has its own peculiar dynamics and there is no one-size-fits-all solution. A number of institutionalized responses at the national and international levels have been developed to handle disasters. None of these have so far proved to be comprehensive. In spite of a number of studies and efforts to fine tune this discipline, disaster management has invariably been held hostage to personal and institutional follies and foibles. The political and bureaucratic leadership have often been found wanting in handling and managing emergencies and their personal reputations have been washed away with the flotsam and jetsam of the receding disaster. It has been rare that a head of state or his team of crisis managers has come out of a disaster unscathed. One notable exception has been that of the Chilean President Sebastian Pinera. Last year Pinera personally spearheaded the campaign to rescue the trapped coalminers and personally received each one of the 33 men, as they were hoisted to safety from the collapsed mine after 68 days.[6] In

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[5] "Risk, Terminology: Basic terms of Disaster Risk Reduction," *International Strategy for Disaster Reduction* (ISDR), http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm (accessed March 27, 2011).

[6] Alexei Barrionuevo and Simon Romero, "Trapped 68 Days, First Chilean Miners Taste Freedom," *New York Times*, October 12, 2010,

comparison the official response was muted, when more than 40 Pakistani miners lost their lives on March 20, 2011 in the Sorrange (also spelled Sorenj) coalmines near Quetta.[7] Official apathy is not unique to developing countries. It happens in the most technologically advanced nations as well. Bush administration's response to Hurricane Katrina, which struck the predominantly Black area of New Orleans in 2005, was slow and haphazard. A US congressional report declared failure at all levels i.e. "individual, corporate, philanthropic and governmental" to meet the Katrina challenge.[8] The first responders sent by the City and State administration failed to bring the situation under control and the Federal Emergency Management Agency (FEMA) did not measure up to the task given to it. In his autobiography President Bush admitted his failure in not physically visiting the disaster hit areas.[9]

DM in less developed countries is doubly difficult. The government machinery is not only hobbled by inertia at all administrative tiers, it is also hamstrung by resource scarcity. Patchy and ragged responses to human tragedies have often caused deep rooted grievances and resulted in fatal political fallouts. One natural disaster that actually hastened the dismemberment of Pakistan was cyclone Bhola that struck East Pakistan on 12 November 1970. An estimated 500,000 people lost their lives, 2000 square kilometres of land was devastated, islands disappeared and losses worth billions of dollars were reported. A country already wracked and weakened by an insurgency funded and sponsored by neighbouring India desperately needed a healing touch. This godsend opportunity was callously wasted, when President Yahya Khan on his return journey from Beijing failed to touch down in Dhaka. He merely overflew the devastated area to make a detached assessment of the losses.[10] Bhola proved to be the last nail in the coffin of a united Pakistan. The inept handling of the crisis added to the public anger against the federal government located in West Pakistan. Nearly a year and a bloody civil war later East Pakistan chose to go its own way. More recently, an independent media did not leave any stone unturned to highlight the deficiencies in the official response to the 2010 floods, which ravaged almost all parts of Pakistan. The government survived because the common man

www.nytimes.com/2010/10/13/world/americas/13chile .html (accessed March 23, 2010).

[7] "19 Die in Sorenj Mine Blast, 42 Miners Trapped Inside," *News*, March 21, 2011.

[8] "Homeland Security Report: Katrina Response a Failure of Leadership," *CNN Politics*, February 14, 2006, http://articles.cnn.com/2006-02-13/politics/katrina. congress_1_katrina-response-national-emergency-management-association-homeland-security?_s=PM:POLITICS (accessed March 23, 2011).

[9] George W. Bush, *Decision Points* (US: Random House Group, 2010), 310-331.

[10] Kamal Matinuddin, *Tragedy of Errors: East Pakistan crisis, 1968-1971* (Lahore: Wajidalis Pvt. Ltd., 1994), 147-48.

never got an opportunity to build up on his grievances, as the country reeled from one disaster to another.

Nuclear DM

As compared to a natural disaster, a nuclear emergency caused by war or an industry related incident is far more complex to handle. A nuclear disaster has far graver implications since it involves long term radiation effects. A nuclear and radiation accident is defined by the IAEA as "an event that has led to significant consequences to people, the environment or the facility. Examples include lethal effects to individuals, large radioactivity release to the environment, or reactor core melt."[11] The likelihood and potential impact of the release of nuclear radiation in the environment has been the subject of discussion ever since the first nuclear weapon was used and the first nuclear reactor was installed. Nuclear disasters are a matter of acute public concern owing to the long term environmental and biological damages that they can cause. Nuclear DM involves a number of technical measures and special equipment to reduce the risk of radioactivity. The response involves a host of agencies like the ministries of defence, energy, interior, foreign affairs, health, food, environment etc and requires intricate coordination.

Whereas, in case of a nuclear strike on a city can cause widespread damage to the civilians and is difficult to control, the damage from an industrial accident can be localised and restricted, with proper planning. An accident at a nuclear power plant requires an onsite as well as offsite response. The first responders from law enforcement agencies, rescue and relief services and medical facilities are trained to react to within the precincts of the nuclear establishment as well as in the contiguous areas. In case the meltdown does take place and the adjoining areas are threatened, an evacuation plan has to be organised. In case the nuclear fallout spreads, neighbouring countries have to be informed. A huge decontamination exercise has to be launched to sanitise men, material and foodstuff. Areas irretrievably damaged have to be closed to human and animal entry until, in years to come, the effects of radiation wear off. For instance the crippled reactor at Chernobyl was entombed with cement dropped by helicopters and later by a steel mesh.[12] This place is off limits; it is estimated it will take nearly 20 million years to heal. At times such drastic measures are not possible, particularly in case the radiation seeps to

[11] "Ines – The International Nuclear and Radiological Event Scale User's Manual, 2008 Edition," *IAEA*, Vienna, www-pub.iaea.org/MTCD/publications/PDF/INES-2009_web.pdf (accessed June 14, 2011).

[12] K. Samwell, Chernobyl Re-entombed in Steel, *Techgage,* September 20, 2007, techgage.com/news/chernobyl_re-entombed_in_steel (accessed June 14, 2011).

inaccessible places like the ocean bed. In short, nuclear DM requires technical expertise beyond the scope of a standard DM response.

A History of Nuclear Disasters

Hiroshima and Nagasaki

Mankind was first exposed to the horrors of mass destruction caused by nuclear strikes on the Japanese cities of Hiroshima and Nagasaki in August 1945. People and property located at Ground Zero (GZ) instantly vaporised. The casualty estimates during the first two to four months of the bombings were between 90,000–166,000 people in Hiroshima and 60,000–80,000 in Nagasaki. Roughly half of these deaths had occurred on the first day. Out of the people who died on the day of the explosion, 60 per cent died from flash or flame burns, 30 per cent from falling debris and 10 per cent from other causes. During the following months, large numbers died from the effect of burns, radiation sickness and other injuries, compounded by illness. Out of the total immediate and short term causes of death, 15–20 per cent died from radiation sickness, 20–30 per cent from flash burns, and 50–60 per cent from other injuries, compounded by illness. In both cities, most of the dead were civilians.[13]

Since 1945, there has been no further employment of atomic weapons but accidents have taken place in the military and civilian applications of nuclear technology, severely endangering and in certain cases destroying life and property, and causing immense environmental damage. Emergencies at nuclear power plants (NPPs) have attracted wide media attention. NPPs are vulnerable because they hold huge amounts of explosive inventory on their premises, comprising nuclear cores and spent fuel e.g. the six reactor cores at the Fukushima Daiichi held 487 tonnes of uranium. Of this 95 tonnes included 230 kg of plutonium, from MOX (mixed oxide fuel contains plutonium blended with natural, reprocessed or depleted uranium) assemblies, with a further 1,838 tonnes of spent fuel, including 1,838 tonnes stored in the central pool store.[14] An accident at an NPP can cause extensive leaks of radioactivity. The extent of a nuclear and radiological disaster is measured on the scale of International Nuclear and Radiological Events or INES ranging from 0 to 7. The worst disasters at INES 7 or near about have taken place in Three Mile Island (TMI), USA (1979), Chernobyl, former USSR (1986) and

[13] "Special Report 6: August 1947 Atomic Bombing of Hiroshima and Nagasaki," *Geo436*, http://www.geo436.com/special-report-6-august-1947-atomic-bombings-of-hiroshima-and-nagasaki/ (accessed March 22, 2011).

[14] Paul Dorfman, "Who to Trust on Nuclear," *Dawn*, April 16, 2011.

Fukushima, Japan, (2011).[15] The first two of these accidents occurred because of design flaws, human error and poor safety regulations. None was caused by a natural disaster before Fukushima. DM techniques played a role in aggravating or lessening the consequences of the disaster. Major nuclear crises are summed up as follows:

Three Mile Island (TMI)

A "serious accident" took place at TMI-2 in Middleton Pennsylvania on March 28, 1979.[16] It began with a fairly common steam power plant failure – the loss of feed water to the generator. A "combination of design, training, regulatory policies, mechanical failures and human error," took it to a point, where "it eventually produced the worst known core damage in large scale nuclear power reactors" till that time.[17] As the steam generators stopped removing heat, the turbine and then the reactor automatically shut down and the pressure in the nuclear portion of the plant began to increase. The pilot-operated relief valve, located at the top of the pressurizer, was opened to let off excess pressure but became stuck and did not close down. As a result, cooling water poured out of the stuck-open valve, causing the core of the reactor to overheat. As the coolant flowed from the core through the pressurizer, the instruments failed to give the level of coolant in the core. Since the level of water in the pressurizer was high, it was assumed that the core was covered with coolant. When the alarms sounded and warning lights flashed, it was not related to the loss-of-coolant accident. Instead a series of actions were taken that made matters worse like reducing the flow of coolant through the core. Since adequate cooling was no longer available, the nuclear fuel overheated leading to a meltdown. About half the core melted during the early stages of the accident. Fortunately, the walls of the containment building were not breached and radiation was not released into the environment. Although caught off guard, the plant managers took immediate steps to regain control of the reactor and ensure adequate cooling to the core. Inspectors were dispatched to the site and response teams were mobilized. Helicopters collected radioactive traces from the atmosphere and a ground team assisted in radiation monitoring. The White House was notified and all non-essential staff was ordered off the plant's premises. By the evening of March 28, the core appeared to have cooled and the reactor seemed stable. On the morning of March 30, there was a significant release of radiation from the plant's auxiliary

[15] David Teeghman, "Top 5 Worst Nuclear Disasters," *Discovery News*, news.discovery.com (accessed March 23, 2011).

[16] John G. Kemeny, *Report of the President's Commission on the Accident at Three Mile Island –The Need for Change: The Legacy of TMI* (Washington DC: Permagon Press, 1979), 2.

[17] L. M. Toth, A. P. Malinauskas, G. R. Eidam, & H. M. Burton (eds.), *The Three Mile Island: Diagnosis and Prognosis* (Washington: American Chemical Society, 1986), 2.

building, as pressure was relieved from the primary system to avoid curtailing the flow of coolant to the core. In an atmosphere of growing uncertainty, expectant mothers and infants within a 5 mile radius of the plant were evacuated. The presence of a large hydrogen bubble in the dome of the pressure vessel that holds the reactor core, stirred worries that it might burn or even explode, breaching the containment building. The crisis ended on April 1, when it was determined that the bubble could not burn or explode because of the absence of oxygen in the pressure vessel. There was no reported loss to life but it did shake public confidence in nuclear reactors and led to the closure of the TMI Plant. The reactor industry was dealt a deathblow, as no more nuclear reactors were manufactured in the US after 1979.

Post incident inquiries revealed a combination of personnel error, design deficiencies, and component failures.[18] The Presidential Commission blamed everyone but primarily blamed the operators.[19] In Charles Perrow's opinion normal or system's accident in an industry take place because of multiple failures in six areas collectively identified as Design, Equipment, Procedures, Operators, Supplies and Materials and Environment (DEPOSE). These areas are either dependent or *tightly coupled* or independent or *loosely coupled* but each has a bearing on each other.[20] This theory indicates that precautions have to be taken in all areas to prevent a domino effect overwhelming all response options.

Chernobyl

One of the worst nuclear incidents took place at Chernobyl in Ukraine (former USSR) in April 1986. Massive release of heat and radiation caused death and high degree of exposure among the operators and the rescue and clean-up staff. It also left major environmental scars. One of the survivors blamed it primarily on human error and to a lesser extent on technology.[21] Others held the flawed reactor design accountable for the accident. The Chernobyl NPP had four RBMK-1000 design reactors – two units had been constructed between 1970 and 1977, while two more were completed in 1983. Another set of two RBMK reactors was under construction at the time of the accident. An artificial lake was constructed to provide cooling water for the reactors. The RBMK-1000 is a "boiling light water reactor," in which, the reactor core

[18] "Backgrounder on the Three Mile Island Accident," *US NRC*, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html (accessed March 17, 2011).

[19] Charles Perrow, *Normal Accidents: Living with High-Risk Technologies* (New Jersey: Princeton University Press, 1999), 7.

[20] Ibid., 8.

[21] Bernice Han, "Chernobyl Survivor Still Backs Nuclear Energy," *Dawn*, April 18, 2011.

creates heat, producing a steam-water mixture. When very pure water (reactor coolant) moves upward through the core absorbing heat, the steam-water mixture leaves the top of the core and enters the two stages of moisture separation, where water droplets are removed before the steam is allowed to enter the steam line. The steam line directs the steam to the main turbine causing it to turn the turbine generator, which produces electricity. The unused steam is exhausted to the condenser, where it is condensed into water. The resulting water is pumped out of the condenser with a series of pumps, reheated, and pumped back to the reactor vessel. The reactor's core contains fuel assemblies which are cooled by water, which is force-circulated by electrically powered pumps. Emergency cooling water is supplied by other pumps, which can be powered by onsite diesel generators. Other safety systems, such as the containment cooling system, also need electric power.[22] One of the most important characteristics of an RBMK reactor is that it can possess a "positive void coefficient," where an increase in steam bubbles or "voids" is accompanied by an increase in core reactivity. As steam production in the fuel channels increases, the neutrons that would have been absorbed by the denser water now produce increased fission in the fuel. There are other components that contribute to the overall power coefficient of reactivity, but the void coefficient is the dominant one in RBMK reactors. The void coefficient depends on the composition of the core. A new RBMK core will have a negative void coefficient. At the time of the accident at Chernobyl 4, the reactor's fuel burn-up, control rod configuration and power level led to a positive void coefficient large enough to overwhelm all other influences on the power coefficient. On 25 April, prior to a routine shutdown, the reactor crew at Chernobyl 4 began preparing for a test to determine how long turbines would spin and supply power to the main circulating pumps following a loss of main electrical power supply. This test had been carried out the previous year, but the power from the turbine ran down too rapidly, so new voltage regulator designs were to be tested. A series of operator actions, including the disabling of automatic shutdown mechanisms, preceded the attempted test. By the time that the operator moved to shut down the reactor, the reactor was in an extremely unstable condition. A peculiarity of the control rods' design caused a dramatic power surge as they were inserted into the reactor. The interaction of very hot fuel with the cooling water led to fuel fragmentation along with rapid steam production and an increase in pressure resulting in the destruction of the reactor. The overpressure caused the cover plate of the reactor to partially detach, rupturing the fuel channels and jamming all the control rods, which were only halfway down at that time. Intense steam

[22] "Boiling Water Reactors," *Independent Statistics and Analysis*, www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/bwr.html (accessed on March 23, 2011).

generation then spread throughout the whole core causing a steam explosion and releasing fission products to the atmosphere. About two to three seconds later, a second explosion threw out fragments from the fuel channels and hot graphite.[23]

Chernobyl was a terrible blow to the nuclear industry and is considered among the worst incident involving nuclear reactors. It directly or indirectly affected a number of European countries. Angela Liberatore in her book *In the Management of Uncertainty: Learning from Chernobyl*, undertook a study of how different countries interpreted the incident in the light of their national interests, and why they adopted nuclear risk management procedures to suit their own convenience. This comparative analysis included short-term responses and long-term consequences of Chernobyl in the neighbouring countries of France, Italy and Germany and the European Union's regional approach in managing transnational risks. The policy communication model developed by Liberatore illustrated the interaction among scientists, who choose what was "relevant" knowledge; politicians, who decided how much they want to know (and what they let the public know); social movements and interest groups, which push to utilise and disseminate knowledge; and the mass media, which accesses and selects information to be broadcast as "news." Liberatore's comparative focus upon "uncertainty management" provides a practical framework for the practical management of trans-boundary environmental risks.[24] Keeping Liberatore's thesis in mind, it is interesting to note, how countries and organisations reacted in the aftermath of the Fukushima incident (discussed later in this paper). For instance, while the commercial nuclear lobby downplayed its negative fallouts, the German government decided to say goodbye to this form of energy by 2022.[25]

Tokaimura

In Asia, Japan is one country, which is inherently prone to natural disasters like earthquakes and tsunamis. Its position is further complicated because it fulfils one third of its energy needs through NPPs. It has a total of 18 power plants, housing 55 nuclear reactors. Thirteen of these reactors are located on the coastline. Some of these power plants are located in seismically active zones. The Japanese have experienced incidents at their NPPs and have devised elaborate strategies to handle such emergencies. In September 1999, an

[23] Zhores A. Medvedev, *The Legacy of Chernobyl* (Oxford: Basil Blackwell Ltd, 1990), 26-36.

[24] Angela Liberatore, *The Management of Uncertainty: Learning from Chernobyl* (The Netherlands; Gordon & Breach Publishers, 1999).

[25] Annika Breidthart, "German Government Wants Nuclear Exit by 2022 at Latest," *Reuters*, May 31, 2011, http://www.reuters.com/article/2011/05/31/us-germany-nuclear-idUSTRE74Q2P120110531 (accessed June 14, 2011).

accident took place at a nuclear fuel processing service firm at Tokaimura, 125 km northeast of Tokyo in Ibaraki Prefecture, when workers handling uranium provoked the release of high levels of radiation from the plant. It was level 4 on the INES scale, but many rated it at level 5. An earlier nuclear disaster in Japan, rated at level 3, had taken place in 1997 at a nuclear fuel reprocessing plant, also in Tokaimura. The Tokaimura disaster raised questions about the flaws in the nuclear DM system. In June 2000, Japan's Special Measures Law for Nuclear Accidents took effect, which required the government to conduct a comprehensive drill every year. After this incident Japan considered additional measures to reform its nuclear safety policy.[26] Japanese regulators are certainly aware of the danger of earthquakes and they take safety extremely seriously. Like other buildings in Japan, nuclear reactors are also able to withstand earthquakes. The problem arises when the earthquake is bigger than the design capacity. This problem was highlighted by the earthquake that centred near the Kashiwazaki-Kariwa NPP in 2007. The earth movements generated by that quake were larger than the plant's design limit. Fortunately, the safety systems worked as designed in spite of the quake's physical impact. Before the plant reopened, new safety features were added to ensure that it was capable of withstanding bigger earthquakes.

Fukushima

Fukushima superseded Chernobyl as the worst nuclear accident in recent times. On Friday, March 11, 2011, a force 8.9 earthquake triggered a giant tsunami on the north eastern coast of Japan. This double disaster crippled the Fukushima-Daiichi power plant. It resulted in "hydrogen explosions, fires, partial melting of irradiated or 'spent' fuel in the reactors, the uncovering and possible burning of irradiated fuel in spent fuel ponds at reactor 4 and perhaps other reactors."[27] As a safety measure, seven out of ten operating reactors shut down automatically after the shocks but the radioactive fission products in the reactor's uranium fuel continued to generate heat. The cooling systems malfunctioned because the external power supply had been disrupted due to the quake and the backup generators located in the basement were inundated by the tsunami waters. There was no way to remove decay heat from the reactors' radioactive fuel, resulting in a meltdown. As an emergency measure

[26] "Tokaimura Nuclear Disaster," *Book Rags*, http://www.bookrags.com/research/tokaimura-nuclear-disaster-ema-05/(accessed March 17, 2011).

[27] David Albright, Paul Brannan, and Christina Walrond, "Fukushima Crisis: A Chronology: Preliminary Assessment of Accident Sequences and Potential Atmospheric Radiation Releases," *Institute for Science & International Security (ISIS*), March 31, 2011, isis-online.org/isis-reports/detail/fukushima-crisis-a-chronology/ (accessed April 1, 2011).

seawater was pumped in to cool the reactors. Helicopters and fire tenders were also pressed into service to douse the inferno. Immense quantities of contaminated water eventually flooded the tunnels. Weeks later, 11,500 tons of water contaminated with low levels of radiation flowed into the sea.[28] As the crisis developed a number of hydrogen explosions took place. The explosion in the Unit 2 reactor and the fire in the spent fuel pond in the reactor building for Unit 4 raised the level of the INES scale to its maximum limit of 7, signifying large scale release of radioactive material, with widespread health and environmental effects. Although officials of the Japanese Nuclear Safety Commission stressed that it was only one-tenth of the Chernobyl accident,[29] an official of the Tokyo Electric Power Company (Tepco) admitted that "radiation leak could eventually top that of the Ukranian disaster." The effects of radioactivity could have been greater had the westerly winds blown the radioactive plume out to sea, making a landfall on the US west coast.[30] Nonetheless there were reports of high radioactivity in foodstuff and tap water in the local area.[31] Five villages around the Plant have become un-liveable and the residents have left the area for good.[32] It will take a long time before the exact damage from Fukushima could be determined but for now critics blame vested interests in giving the 40 year old plant a ten year extension prior to the disaster.[33] It has also been pointed out that low paid contract employees comprising 88 per cent of the total nuclear work force and 89 per cent of the 10,303 workers employed at the Fukushima were ill trained and poorly equipped to handle radioactive material.[34]

The Fukushima incident has triggered global panic. The Obama administration has asked for $1.9 billion in fiscal year 2012 for nuclear security

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[28] Hiroko Tabuchi and Ken Belson, "Japan Releases Low-Level Radio-Active Water into Ocean," *New York Times*, April 4, 2011, www.nytimes.com/2011/04/05/world/asia/05japan.html (accessed April 5, 2011).

[29] "Japan N-emergency at Maximum Level," *Dawn*, April 13, 2011.

[30] Ian Sample, "Radiation from Fukushima Spreads, But the Threat to the Rest of the World is Low," *Guardian*, April 12, 2011, www.guardian.co.uk/profile/iansample (accessed April 14, 2011).

[31] "Fukushima Nuclear Accident Update Log," *International Atomic Energy Agency*, www.iaea.org/newscenter/news /tsunamiupdate01.html (accessed March 22, 2011).

[32] Ian Sample, "Radiation from Fukushima Spreads."

[33] Hiroko Tabuchi, Norimitsu Onishi and Ken Belson, "Japan Extended Reactor's Life, Despite Warning," *New York Times*, March 21, 2011, www.nytimes.com/2011/03/22/world/asia /22nuclear.html (accessed March 23, 2011).

[34] Hiroko Tabuchi, "Japanese Workers Braved Radiations for a Temp Job," *New York Times*, April 9, 2011, www.nytimes.com/2011/04/10/world/asia/10**work**ers.html (accessed April 11, 2011).

programmes,[35] and many countries involved in producing electricity from NPPs ordered safety reviews. It also renewed demands by anti-nuclear lobbyists for a closure of the nuclear industry.[36]

India's Nuclear DM Capability

India has an ambitious plan to produce electricity through nuclear energy. Currently it is operating 20 NPPs and two boiling water reactors similar to the crippled Japanese reactors. Six units at two of these plants are at tsunami risk. A month after the Fukushima incident, the chairman of the state run Nuclear Power Corporation Sheryans K. Jain, declared that inspectors had found the structures of the Indian NPPs adequate to handle severe natural events like earthquakes and tsunamis.[37] Although India had suffered a monumental industrial disaster, when poisonous chemicals leaked from the Union Carbide plant in Bhopal killing thousands of people in 1984, serious observers are of the opinion that Indian NDMA is ill prepared to handle nuclear and radiological incidents. The organisation is said to lack resources and trained manpower, to save people living close to NPPs in case of an explosion or meltdown. Maj. Gen. (retd) J.K. Bansal, head of the nuclear disaster management group of the Indian NDMA, has countered such criticism by contending that his organisation was fully prepared to handle any situation and that there was no cause for worry. He elaborated that well trained and well equipped disaster response teams, located at 12 points in the country, could quickly reach any plant and control the situation as per nuclear disaster guidelines – prepared by core group of atomic energy, defence research, security and health personnel, assembled at a nuclear disaster management workshop in May 2006. The guidelines cover scenarios ranging from accidents at nuclear power plants to "dirty bomb" attacks in cities. Critics were, however, quick to point out that NDMA workers checking travellers returning from Japan were not donning hazmat suits and were operating in their usual khaki uniforms with last-minute addition of gloves and face masks.[38] Indian nuclear security managers were also found wanting in an earlier incident, when highly radioactive cobalt 60 disappeared from Delhi University's chemistry department in 2010 and found its way into a scrap shop in Delhi's Mayapuri area. Before officials from the NDMA and the Bhabha Atomic Research

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[35] Toby Dalton, "Nuclear Security after Fukushima," *Carnegie Endowment for Peace*, April 13, 2011, carnegieendowment.org/publications/index.cfm?fa=view&id=43591 (accessed April 15, 2011).

[36] "Thousands March Against Nuclear Power in Japan," *Dawn*, April 25, 2011.

[37] "India Increases Safety Measures at N-plants," *Dawn*, April 15, 2011.

[38] Shobhan Saxena, "How not to Prepare for a Nuclear Crisis," *Economic Times*, March 20, 2011, m.economictimes.com/PDAET/articleshow/7746907.cms (accessed March 21, 2011).

Centre (BARC) could unravel the mystery and remove the toxic material from the junk market, 10 people had been contaminated and one had died.[39] It has been surmised that if monitors could not prevent cobalt 60 to reach scrap dealers, they could hardly address larger issues like managing food and water supply in a radioactive environment. It has also been pointed out that during a recent drill at the Kalpakkam NPP, walkie-talkies were not in working order and the transport system was in a mess.[40] India's first brush with nuclear disaster took place in March 1993, when a fire caused a blackout at the Narora NPP.[41] Researchers at the American University have calculated at least 124 "hazardous incidents" at Indian NPPs between 1993 and 1995.[42] In September 1986, operators had discovered the presence of radioactive iodine at more than 700 times normal levels at the Tarapur Atomic Power Station (TAPS). An estimated 3000 workers were exposed to "very high" and "hazardous" radiation levels before the leak was discovered and TAPS was shut down for year-long repairs.[43] In 2004, tidal waves of the Asian tsunami had entered the Kalpakkum power plant located off the coast of Chennai. Official press releases downplayed the incident by claiming that no damage had been done.[44] India has eight nuclear reactors in the southern state of Tamil Nadu and plans to set up another 3 plants by 2015. This puts 20 million Sri Lankans located right next door at extreme nuclear risk. After the Fukushima incident the Sri Lankan government decided to sign a memorandum of understanding (MOU) with the Indian government as a cautionary step against possible nuclear accidents. The Sri Lankan worries are exacerbated by the fact that it was also hit by tsunami on 26 December 2004, when a massive tidal wave hit the coastal belt of the island nation killing thousands of people.[45] India's poor

39 J. M. C. Keati, "Greenpeace Finds Radioactive Hotspots at India's Mayapuri Scrap Yard," *Green Peace Blog*, May 14, 2010, http://www.greenpeace.org/international/en/news/Blogs/nuclear-reaction/greenpeace-finds-radioactive-hotspots-at-indi/blog/11781 (accessed March 25, 2011).

40 Shobhan Saxena, "How Not to Prepare for a Nuclear Crisis."

41 Ravindra K. Dhir & M. Roderick Jones, *Concrete in the Service of mankind: Concrete Repair, Rehabilitation and protection* (London: Chapman & Hall, 1996), 45.

42 "Nuclear Power Plant Accidents in India," May 30, 2011, http://www.scribd.com/doc/39458960/Nuclear-Power-Plant-Accidents-in-India (accessed June 14, 2011).

43 Benjamin K. Sovacool, "A Critical Evaluation of Nuclear Power and Renewable Electricity in Asia," *Journal of Contemporary Asia* vol. 40, no. 3 (August 2010): 380.

44 Press releases of the Indian Nuclear Power Corporation (NPC) on the impact of the tsunami that struck Kalpakkam on December, 26, 2004, www.dae.gov.in/press/tsunpcil.htm (accessed March 15, 2011).

45 J.A. Fernando, "Sri Lanka to be Cautious on Indian Nuclear Incidents, Plans to Sign MoU with India," *Asian Tribune*, April 13, 2011, http://asiantribune.com/news/2011/04/12/sri-lanka-be-cautious-indian-nuclear-accidents-plans-sign-mou-india (accessed April 15, 2011).

nuclear safety record is indeed worrisome for its neighbours. A well known atomic scientist, P. Balram, actually advised the Indian government to temporarily shut down all NPPs for a thorough safety review. He warned that a nuclear disaster could affect neighbouring countries. His advice has obviously fallen on deaf ears.[46] There have also been public protests against NPPs. Plans to construct the world's biggest NPP – the Jaitpur Nuclear Power Project – on the western coast in the Konkan region, 400 km from Mumbai, by the French company Areva, has been opposed by local fishermen and farmers. Local residents worry that nuclear effluence would contaminate fish, prawns and squid and damage the famous Alphonso mango crop. Violent protests and police retaliation left at least one person dead from among the mainly Muslim fishing community.[47] Nuclear problems in the neighbouring country should also be cause of concern for Pakistan.

Pakistan's Nuclear DM Capacity

There has been limited debate in the local media on nuclear safety in Pakistan after the Fukushima incident. One opinion piece co-authored by disarmament advocates within the Indian and Pakistani scientific communities cautioned the South Asian nuclear establishments in generic terms about the susceptibility of their atomic reactors to natural disasters, human errors, design failures and poor safety standards.[48] Another op-ed article by a local nuclear physicist, well known for his anti-nuclear sentiments decried the country's capacity to handle a Fukushima type of disaster. It highlighted the Karachi Nuclear Power Plant (KANNUP)'s vulnerability to "sabotage, terrorist attack, equipment failure, earthquake, or a tsunami" and warned that the direction of the sea breeze could put the population of Karachi at risk of widespread radioactive fallout.[49] One reader disagreed with this assessment and called it scaremongering. He reasoned that KANUPP was safely located on a rock 12 metres above the sea surrounding it, and was, therefore, well above the three-metre-high tsunami waves that hit Karachi coast in 1945. He also argued that Pakistani reactors were "designed to withstand earthquakes of a very high magnitude, as much as

[46] "Indian Atomic Programme Should be Closed," *BBC Urdu Service*, April 1, 2011, http://www.bbc.co.uk/urdu/india/2011/04/110401_nuclear_projects_sz.shtml (accessed April 2, 2011).

[47] Phil Hazelwood, "Protests Mount Against Nuclear Power Plant in India," *Dawn*, April 25, 2011.

[48] A.H. Nayyar, M.V. Rammana & Zia Mian, "Fukushima Lessons," *Dawn*, January 27, 2011.

[49] Pevez Hoodbhoy, "Pakistan Can't Handle Fukushima," *Express Tribune*, March 22, 2011, http://tribune.com.pk/story/136020/pakistan-cant-handle-fukushima/ (accessed March 23, 2011).

9 on the Richter scale."[50] Another article by a well known economist suggested that Pakistan should go for safer reactor designs.[51] One letter to the editor warned against importing radioactivity contaminated Japanese cars and car kits, and exposing the domestic airline crews to resident radioactivity in Japan.[52] A radio report highlighted the apprehensions of the local labour and fishermen from hazards posed by the NPPs. The Karachi based Pakistan Institute of Labour Education and Research (PILER) and the Pakistan Fisher Folks Forum in a joint letter addressed to the PAEC demanded that all NPPs in Pakistan be shut down and the nuclear fuel located at these sites shifted from the vicinity of human habitation and water sources. They also lamented the fact that the PAEC website has not provided any safety instructions, after the Japanese nuclear disaster.[53]

To be fair Pakistan's small nuclear industry, operating under state controls and IAEA safeguards, has done reasonably well and its safety record for 38 years of nuclear operations has been quite satisfactory. Although former Chairman PAEC, Dr I.H. Usmani, had unveiled plans to establish at least three NPPs in 1961, at Karachi, Lyallpur (now Faisalabad) and in East Pakistan in 1961,[54] Pakistan could only establish two NPPs. These produce only 462 MW, which accounts for merely 2.15 per cent of the country's total electricity production. KANUPP's small (137 MW) Canadian pressurized heavy water reactor (PHWR) became operational in 1972 but faced immediate problems like non-availability of fuel and spare parts as a consequence of the Indian nuclear explosion in 1974. Resultantly it was forced to operate below its capacity. After the first thirty years of operation, the plant life was assessed to be actually 11 years and it was given an extension of another 30 years in 2002.[55] Two questions have been raised about the safety of KANUPP: One is its susceptibility to a tsunami generated by an earthquake in the Arabian Sea and two, its location near a major city. Although KANUPP was located away from the populated areas, due to rampant urbanisation, more than 8 million

[50] Zahir Kazmi, "Fact and Fiction, Letter to the Editor;" *Express Tribune*, March 23, 2011, http://tribune.com.pk/story/136738/fact-and-fiction/ (accessed March 25, 2011).

[51] Shahid Javed Burki, "Will Japan's Tsunami Wave Hit Pakistani Shores?" *Dawn Economic & Business Review*, April 4-10, 2011.

[52] Dr Khuram Shaukat Yusofzai, "Radioactivity Hazard in Pakistan," Letter to the Editor, *Dawn*, April 19, 2011.

[53] "Shutdown Atomic Power Plant: Demand," *BBC Urdu Service*, April 1, 2011, http://www.bbc.co.uk/urdu/pakistan/2011/04/110401_labour_nuclear_a.shtml (accessed April 2, 2011).

[54] "Plans for Nuclear Power Stations," *Dawn*, April 26, 2011.

[55] Rifat Ali, "Ageing Management of Principal Component for K-1 Life Extension," (paper presented at International Seminar on Nuclear Safety and Security Challenges of the 21st Century on 21-23 April 2011, at National Centre of Physics, Islamabad, Pakistan).

people now live in its vicinity.[56] The Geological Survey of Pakistan (GSP) places Karachi in Zone 3 on its hazard map. The sub-surface geology indicates the junction of three tectonic plates i.e. the Indian, Arabian and Eurasian, about 40 km away from Karachi.[57] The real threat of tsunami to the Pakistani coastal cities is an earthquake in the Makran Subduction Zone (MSZ).[58] Out of the 50 earthquakes of magnitude 8 and above that struck the Pakistani coastline during the past 75 years, only four (1919, 1943, 1945, and 1956) were accompanied by tsunamis. The 1945 tsunami did damage the Manora lighthouse and killed more than 4,000 people but its main area of impact was Ormara. According to a meteorologist an earthquake of the magnitude of 8.5 on the Richter scale in the MSZ can unleash tsunami waves of 5 metres height in Ormara, 3.5 metres in Gwadar, 4.3 metres in Pasni and only 0.75 metres in Karachi within 21 to 33 minutes.[59] In such an eventuality those who will bear the brunt of the tsunami would be the coastline communities.[60] Environmentalists contend that growing mangroves in the coastal regions can lessen the effects of a tsunami.[61] The possibility of an earthquake or a combination of an earthquake and tsunami hitting Karachi and damaging KANUPP is not as strong as Fukushima, which was located between two fault lines. However, one lesson that can be learnt from the disaster is to move the population centres away from the close vicinity of NPPs. The Japanese authorities are seriously considering plans to change the trend of concentrating the administrative and business functions in heavily populated areas like Tokyo.[62]

CHASNUPP Unit 1 and 2 are located near Mianwali, far away from high density urban centres. CHASNUPP-1, which started up in May 2000 under international safeguards, operates a 325 MWe (300 MWe net) Chinese pressurised water reactor (PWR). Construction of Chashma-2 started in December 2005 and grid connection is expected this year. Pakistan faces an

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56 "Tens of Millions Living in Nuclear 'Danger Zone': Study," *Dawn*, April 23, 2011.

57 Dr Syed Iqbal Mohsin, "Preparing for Earthquakes," *Dawn*, March 17, 2011.

58 Subduction is the process in which one plate is pushed downward beneath another plate into the underlying mantle when plates move towards each other. The denser plate slides under the less dense plate. Faulting occurs in the process, in which rocks break and move along the fractures. The subducted plate usually moves in jerks, resulting in earthquakes. The area where the subduction occurs is the subduction zone. A long, narrow, deep depression forms in this area. It is called an oceanic trench, (accessed April 5, 2011), library.thinkquest.org/17457/platetectonics/5.php

59 Humera Hafeez, 'The Potential of Tsunami Generation along Karachi and the Makran Coast of Pakistan," *Pakistan Journal of Meteorology* vol. 4, issue 7 (July 2007): 25-40.

60 Bhagwandas, "Coastal Communities Exposed to Tsunamis," *Dawn*, March 21, 2011.

61 Naseer Memon, "Dealing with Disaster," *Dawn*, April 19, 2011.

62 "In the wake of Disaster," *Japan Times*, April 12, 2011, reproduced in "Other Voices: Far Eastern Press," *Dawn*, April 14, 2011.

acute energy shortfall to the tune of 5000 MW. Under its Energy Security Plan, the Government of Pakistan plans to increase electricity production to 8,800 MW by 2030 from all sources including nuclear energy. For this reason site evaluation for new NPP projects is under progress.[63] In order to ensure that Pakistan is not found wanting in its nuclear safety processes, after the Fukushima incident, Pakistan Atomic Energy Commission (PAEC), the utility company running the state owned NPPs, conducted a safety review.[64] After the review, the PAEC declared its NPPs safe against the impact of natural disasters. The Commission stressed that safety had been reviewed by experts from the International Atomic Energy Agency (IAEA) and the World Association of Nuclear Operators (WANO),[65] and there were no operational problems at any of its nuclear plants.

There is a clear division of labour regarding onsite and offsite management of nuclear emergencies.[66] As per the Pakistan Nuclear Regulatory Authority (PNRA) ordinance, the safety and security of all civil nuclear installations including the NPPs falls under its purview.[67] In order to prevent an accident and the pilferage of radioactive materials it regularly audits the country's medical, agricultural and power generation facilities. It has undertaken various initiatives to improve nuclear safety. It works closely with the IAEA and implements the latest techniques in its operations. Pakistan is a signatory to the Convention on Nuclear Safety (CNS) since 1994. The Convention was ratified in 1997. This obligates Pakistan to maintain appropriate safety standards at all its NPPs. The "Regulations on Management of Nuclear Accident or Radiological Emergency," (PAK/914) was promulgated in 2008. This was followed by KANUPP's offsite nuclear emergency response plan (KOFREP). In 2008 and 2009, C-1 and K-1 carried out exercises to test their onsite emergency responses, which were evaluated by PNRA. The KOFREP was practised in June 2010, involving the Provincial Disaster Management Agency (PDMA), city government, district health authorities, local police etc. The National Radiation Emergency Coordination

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[63] "Convention on Nuclear Safety: Report by the Government of Pakistan for the Fifth Review Meeting 2011," (Islamabad: PNRA, 2010), 2.

[64] PAEC official website, www.paec.gov.pk/ (accessed March 21, 2011).

[65] "Nuclear Power Plants Safe, Says Pakistan," *Dawn*, March 15, 2011, http://www.dawn.com/2011/03/15/nuclear-power-plants-safe-says-pakistan.html (accessed March 17, 2011).

[66] Discussion with the spokesperson of the PNRA Bushra Nasim, on the sidelines of the International Seminar on Nuclear Safety and Security Challenges of the 21st Century, 21-23 April 2011, National Centre of Physics, Islamabad, Pakistan.

[67] The mission of the PNRA is: "To ensure safe operation of nuclear facilities and to protect radiation workers, general public and the environment from the harmful effects of radiation by formulating and implementing effective regulations and building a relationship of trust with the licensees and maintain transparency in its actions and decisions," www.pnra.org/ (accessed March 17, 2011).

Centre (NRECC) also regularly participates in international emergency exercises such as Convex conducted by the IAEA[68]

Once the nuclear disaster extends beyond the limits of the NPPs, it technically becomes the responsibility of the NDMA. Paragraph 1 of the NDMA's National Disaster Response Plan (NDRP) circa March 2010 covers nuclear and radiological incidents. It also includes wars as the cause of a disaster. One can infer that it includes nuclear wars as well.[69] Another document, the National Disaster Risk Management categorises Chemical, Nuclear & Radiological (CNR) accidents as "human induced." This gives an impression that a natural catastrophe triggering a nuclear disaster has not been included in the risk calculus.[70] Typically the response to an accident at a power plant could unfold as follows: Soon after the incidence of a nuclear emergency, the operators from PAEC would raise the alarm triggering a response from the PNRA. Trained staff would activate well rehearsed emergency measures to prevent a meltdown and radiological leaks. Reports from government agencies, media and the PDMA would prompt the NDMA to activate a national response in areas likely to be affected by radiological contamination. Distress calls would be made to all principal decision makers and stakeholders. This would include the political and administrative machinery, including the secretariats of the PM, the President, and the strategic ministries. Requests would be made for requisitioning the services of the defence forces, civil defence, police, rescue and relief organisations, foreign governments, international organisations, NGOs, medical teams, food supply managers etc to launch an elaborate rescue and relief operation. First responders including fire fighting units and rescue teams would be rushed to recover the victims from under the rubble and put out the fires. The district administration would be alerted to begin evacuation of the local populace from radioactive hotspots. Transport would be commandeered and police deployed to manage the exodus, from around GZ. Radiation levels would be determined and necessary advisories issued regarding taking appropriate protective measures. The services of the state and private media and loudspeakers of mosques would be used to inform the public about relocation plans. Decontamination measures to disinfect the people and material would be executed.

The response trajectory would obviously depend upon the preparedness levels of the government, the federal and provincial DM agencies, the first responders and the public at large. If the common man has not been trained

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[68] "Convention on Nuclear Safety: Report by the Government of Pakistan for the Fifth Review Meeting 2011," (Islamabad: PNRA, 2010), 7.

[69] "National Disaster Response Plan (NDRP)," March 2010, www.ndma.gov.pk /Documents/NDRP/NDRP.pdf (accessed March 21, 2011).

[70] "Disaster Risks in Pakistan - NDMA Pakistan," www.ndma.gov.pk/Documents /NDRP/NDRP.pdf (accessed March 21, 2011).

for an emergency, the overall response would be marred by panic and chaos. At the moment the citizenry is not trained to respond to disasters in general and nuclear disasters in particular. The individual reaction to a disaster is instinctive. In case of an earthquake, people rush outdoors. In case of floods, there is a tendency to move to higher ground but there is absolutely no awareness of what to do in case of a nuclear accident or attack. Radioactivity adds a whole new dimension to a disaster. In a nuclear emergency, the shelters or safe zones must be free of radioactive contamination before people occupy these. Food and water will not be issued before it has been declared safe for human consumption. To avoid disorder and to minimise fear and uncertainty, public must be trained to react in an organised manner. The common man should be made part of the disaster management and not merely remain a bewildered spectator, to events as they unfold. There is growing realisation that no public awareness programme has materialised so far.[71] This can be done, systematically by preparing those at high risk i.e. those located near nuclear installations or likely nuclear targets. The public should be encouraged to know the following aspects of the nuclear disaster plan:

- Individual and collective safety measures for nuclear emergencies caused by wars, sabotage or natural calamities like earthquakes or tsunamis.
- Alarm systems and alarm levels.
- Announcement of radioactivity levels.
- Rescue & Evacuation plans.
- Location of Nuclear shelters.
- Availability of hazmat suits.
- Food and water supply in radioactive zones.
- Decontamination plans.

Important information from this list should be placed on the NDMA website and other public service domains. Officials at the NDMA point out that the NBC Policy and Nuclear Emergency Response Plan (NERP) is under formulation in coordination with the PNRA, PAEC and SPD and would be shared when complete.[72] While the agencies concerned fashion out a holistic plan, it is suggested that public awareness should be enhanced by:

- Running a public awareness campaign about nuclear safety precautions on the media.

[71] Faizan Mansoor, "Public Awareness and Involvement in the Licensing Process for Safe and Secure Use of Nuclear Energy," (paper presented at International Seminar on Nuclear Safety and Security Challenges of the 21st Century on 21-23 April 2011, at National Centre of Physics, Islamabad, Pakistan).

[72] Email from Brigadier Sajid Naeem, from NDMA, to the author on March 22, 2011.

- Organising nuclear safety days at schools and work places.
- Organising seminars in public and private organisations.
- Holding periodic tabletop exercises and physical drills involving the public as well as all the rescue and relief agencies.
- Running short courses for public representatives and local leaders for handling nuclear emergencies within their own constituencies.

Conclusion

DM is not a knee jerk reaction to a problem. It requires serious thinking and planning and is a deliberate process. Nuclear DM requires technical knowhow, equipment and preparation. The first step in DM planning of any kind involves identifying the exact nature of hazard, which can cause injury, damage or loss of life and property, disrupt social and economic activity and environmental degradation.[73] The next step is making a detailed disaster risk assessment of the vulnerability of the life, property and livelihood of people located in potentially hazardous zones. This involves "a review of both the technical features of hazards such as their location, intensity, frequency and probability; and also the analysis of the physical, social, economic and environmental dimensions of vulnerability and exposure, while taking particular account of the coping capabilities pertinent to the risk scenarios."[74] The risk scenarios are akin to what are known in the military as the enemy hypotheses. Based on these scenarios, a number of response contingencies are developed. These plans are then disseminated to the rescue and relief agencies and shared with the people likely to be at the centre of this storm.

Public awareness and public information can play an important role in actually reducing the effects of a disaster. The former involves "the processes of informing the general population, increasing levels of consciousness about risks and how people can act to reduce their exposure to hazards. This is particularly important for public officials in fulfilling their responsibilities to save lives and property in the event of a disaster." Public awareness activities can create a culture of risk reduction. This can be engendered through public information, dissemination, education, radio or television broadcasts, use of printed media, as well as, the establishment of information centres and

[73] "Hazard, Terminology: Basic Terms of Disaster Risk Reduction," *International Strategy for Disaster Reduction* (ISDR), http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm (accessed March 27, 2011).

[74] "Disaster Risk Assessment, Terminology: Basic Terms of Disaster Risk Reduction," *International Strategy for Disaster Reduction* (ISDR), http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm (accessed March 27, 2011).

networks and community and participatory actions.[75] The latter involves public dissemination of available "information, facts and knowledge provided or learned as a result of research or study."[76] Nuclear disaster is perhaps the most difficult crisis to handle. It must be based on the available best practices. It needs not only to enhance safety at the NPPs but also prepare the people for the worst case scenarios. The involvement of the common man in the nuclear DM response can prove critical to its success■

[75] "Public Awareness, Terminology: Basic Terms of Disaster Risk Reduction," *International Strategy for Disaster Reduction* (ISDR), http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm (accessed March 27, 2011).

[76] "Public Information, Terminology: Basic Terms of Disaster Risk Reduction," *International Strategy for Disaster Reduction* (ISDR), http://www.unisdr.org/eng/library/lib-terminology-eng %20home.htm (accessed March 27, 2011).