DISASTER MANAGEMENT AT NUCLEAR POWER PLANT: COMPARATIVE ANALYSIS OF FUKUSHIMA AND PAKISTAN

Maimuna Ashraf*

Abstract

The dangers of nuclear tragedy are in debate since the first nuclear reactor was built in 1942. Any disaster can be hard to handle but a nuclear disaster requires even more complex management apparatus. In history there have been many nuclear tragedies at NPPs including the severe nuclear disasters of Three Miles Island (1979) and Chernobyl (1986). However Fukushima Daiichi disaster (2011) which was ignited by earthquake accompanied tsunami hoisted multiple apprehensions about safety of NPPs. Japan being an exceedingly well-organized nation towards managing natural disasters and upholding nuclear safety, found it difficult to manage the nuclear catastrophe. Pakistan has so far avoided any nuclear debacle and has a Nuclear Emergency Response Plan (NERP) prepared by Pakistan Nuclear Regulatory Authority (PNRA), Strategic Plans Division (SPD) and Pakistan Atomic Energy Commission (PAEC). However in case of any tragedy, Nuclear Emergency Management System (NEMS), National Disaster Management Agency (NDMA) and other organizations will launch an integrated response. A clear account does not necessarily certify that a nuclear tragedy cannot take place in future. In spite of these facts, serious concerns have been expressed after Fukushima nuclear disaster on Pakistan's capability to handle any plausible nuclear disaster; therefore the critical examination of Pakistan's nuclear disaster management is imperative for both authenticating the official stance of Pakistan as well as judging the validity of criticism levelled against the Pakistani nuclear industry's disaster mismanagement apparatus. The research thus aims to investigate the Pakistani nuclear establishment

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readiness to handle a Fukushima level disaster. In order to reach a conclusion about the country's capability to handle such a serious tragedy at NPP, the researcher selected few significant variables from Fukushima Daiiche case-study and investigated them in Pakistan's existing nuclear management apparatus.

Key Words: *Fukushima Disaster, Chernobyl, NEMS, NERP, NDMA, PNRA, SPD, PAEC.*

Introduction

The recorded human history has indefinite episodes of deluge, pandemics, plagues, epidemics, earthquakes, famines and volcanic outbursts. In early times when scientific awareness was vague, these adverse incidents were anticipated wrongly and were believed as 'God's wrath' to humans' evil acts.[1] Human beings were weak and defenseless to natural catastrophes and the furthermost imperative objective of their lives was to stand for the ferocity of nature. By the time as the world developed, the force and figures of natural and human-made disasters also increased. These devastating disasters coerced humans to take measures for handling these disasters. Hence, the account of disasters and its management is as old as the human history itself. [2] The preeminent historic instance of disaster and its management can be witnessed seventy-five hundred years back. The religious example is about the 'Noah's Ark'.[3] The narrative of Noah's ark conveys imperative teachings about the management of disasters. God directed his Prophet to make the Ark in order to guarantee protection from the imminent tragedy and to assure safety in cyclone and overflow. The story of Prophet Noah consequently enlightens that security and safety can be achieved by preparedness, even the Prophet adopted measures to handle the forthcoming disaster and planned for the life after it.

In early eras, the societies were just threatened by natural disaster because the world was not urbanized. However as the world has been developing and becoming more industrialized and urbanized, it is getting

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1 Anne-Caroline Rendu, Didier Grandjean, Klaus R. Scherer and Terence MacNamee, "The wrath of the gods: appraising the meaning of disaster," *SAGE Publications*, no. 2 (2008):192, doi: 10.1177/0539018408089078.

2 Frederick S. Tipson, "Natural Disasters as Threats to Peace," *United States Institute of Peace*, Special Report 324 (2013). http://www.usip.org/sites/default/files/SR324-Natural%20Disasters%20as%20Threats%20to%20Peace.pdf (accessed on September, 19, 2013).

3 Bennett-Smith, Meredith, "Evidence suggests Noah's Ark Flood Existed, Says Robert Ballard, Archaeologist Who Found Titanic," *The Huffington Post,* Dec, 12, 2012.http://www.huffingtonpost.com/2012/12/10/evidence-noahs-flood-ark-real-robert-ballard-archeologist-titanic_n_2273143.html (accessed on November, 16, 2013).

more exposed to severe natural and man-made disasters.[4] A disaster of any kind can cause serious damage to people, infrastructure or environment but a nuclear disaster can be the most complicated and perilous tragedy to handle. The International Atomic Energy Agency (IAEA) defines a nuclear radiation accident/disaster as "an event in which the radioactive release causes for serious dangerous consequences to society, environment and infrastructure. Examples include lethal effects to individuals, large radioactivity release to the environment, or reactor core melt."[5]

The potential nuclear risks are in debate since 1942, when the first nuclear reactor was built. Many constructive measures were taken with time for nuclear safety, however regardless of such measures there have been several nuclear debacles in history. The foremost serious nuclear disasters in history are Three Mile Island (USA-1979), Chernobyl (USSR-1986) and Fukushima Daiichi (Japan-2011). All of these three nuclear accidents took place at NPPs thus the danger of a nuclear event at NPP is quite real.[6]

The nature and severity of any nuclear event is categorized by International Nuclear/Radiological Event Scale (INES) of International Atomic Energy Agency (IAEA). The INES classifies the nuclear events at 1-7 levels. The nuclear events of less severity and safety significance are categorized at Level 1-3, and are named 'incidents'. Whereas the nuclear events of greater severity and safety significance are placed at Level 4-7, and are called 'accidents'. The severity of an event is about 10 times greater for each increase in level on the scale.[7] The nuclear accidents with major release of radioactive material with widespread health effects have been placed at Level 7 and are declared as 'Major Accidents'. The accidents with significant release of radioactive material are placed at Level 6 and are called 'Serious Accidents'. The accidents that cause limited release of radioactive material and results in at least several deaths from radiation are placed at Level 5 and are named as 'Accident with Wider Consequences'. The accidents with minor release of radioactive material with at least one death from radiation are put at Level 4 and are called

4 United Nations Human Settlements Programme, "Enhancing Urban Safety and Security: Global Report on Human Settlements 2007," *EARTHSCAN,* London (2007): 169-174.

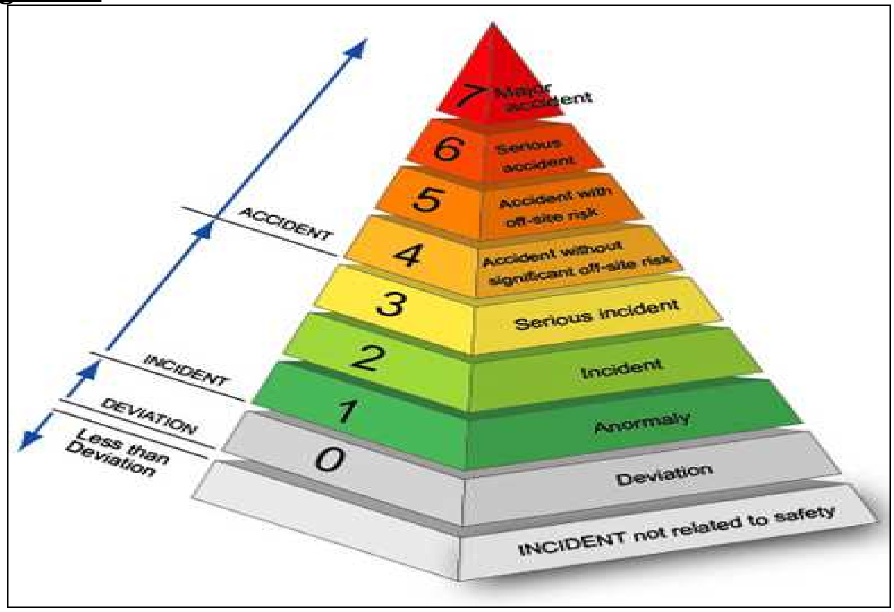
5 IAEA Safety Glossary, "Terminology Used In Nuclear Safety and Radiation Protection," *International Atomic Energy Agency,* Vienna (2007). http://www-pub.iaea.org/MTCD/publications/PDF/Pub1290_web.pdf (accessed on Sep., 18, 2014)

6 *The Fukushima Nuclear Accident and Crisis Management* (The Sasakawa Peace Foundation: 2012), 6-8. http://www.spf.org/jpus/img/investigation/book_fukushima.pdf. (accessed on Sep., 12, 2014)

7 "INES- The International Nuclear and Radiological Event Scale," *International Atomic Energy Agency.*http://gnssn.iaea.org/regnet/Pages/INES.aspx (accessed on Sep., 17, 2014)

'Accidents with Local Consequences'. These are the four Levels of nuclear 'Accidents' and after it the nuclear tragedies are called 'Incidents'.[8]

Diagram 1:



In 2011, "The Guardian" published a list of 33 serious nuclear incidents and accidents at NPPs, ranked by INES. The Chernobyl (1986) and Fukushima Daiichi (2011) were placed at Level 7 by INES due to the significant release of radioactivity in these nuclear accidents.[9] The global developmental practices are nevertheless constructive but the Fukushima tragedy, which was instigated due to earthquake/tsunami, forced states to reconsider their safety standards at NPPs. Pakistan has a small nuclear industry and till writing of these lines has successfully escaped any nuclear tragedy. Yet it does not refute the possibility that a nuclear tragedy can happen in future.

Importantly, nuclear disaster management is possible, provided the nuclear industry and government adopt appropriate procedures to address the nuclear related problems. For instance, the Nuclear Disaster management (NDM) requires several technical measures and special equipments to reduce the dangers of radioactivity. The response engages a number of organizations and ministries (i.e. defense, energy, interior,

8 "INES- The International Nuclear and Radiological Event Scale," *International Atomic Energy Agency*.http://gnssn.iaea.org/regnet/Pages/INES.aspx (accessed on November, 12, 2013)

9 Nuclear Accidents- And How They Are Ranked. https://docs.google.com/spreadsheet/ccc?key=0AonYZs4MzlZbdFc0cVRMVDR5c1ZmeC1lR2hac0xjMXc&hl=en#gid=1 (accessed on 11 September, 2013)

foreign affairs, health, food, environment etc), in addition involves a comprehensive synchronization and coordination. Whereas any accident at a nuclear power plant (NPP) involves an onsite as well as offsite response and in case of meltdown when the neighbouring areas are in danger then an evacuation plan has also to be instigated. Moreover if the nuclear fallout spreads then neighbouring countries have to be informed. The nuclear disaster management includes a huge decontamination process to sanitize things, food and people. A persuasive management and supervision is mandatory for the effective implementation of disaster reduction procedures. This requires inclusive management, altogether by the country establishment and primarily by the people.[10]

Pakistani officials affirm that an appropriate nuclear disaster management apparatus has been established by Pakistan's nuclear establishment and the absence of any recorded accident in the Pakistan nuclear industry also confirms it. In spite of these facts, serious concerns have been expressed after Fukushima nuclear disaster on Pakistan's capability to handle any plausible nuclear disaster; therefore the critical examination of Pakistan's nuclear disaster management is imperative for both authenticating the official stance of Pakistan as well as judging the validity of criticism levelled against the Pakistani nuclear industry's disaster mismanagement apparatus. The research thus aims to investigate the Pakistani nuclear establishment readiness to handle a Fukushima level disaster. In order to reach a conclusion about the country's capability to handle such a serious tragedy at NPP, the researcher selected few significant variables from Fukushima Daiiche case-study and investigated them in Pakistan's existing nuclear management apparatus.

Theory of Disaster Management

In order to elucidate the concerns that how disasters takes place, what can be the possible reactions before, during and after a disaster, the scholars and professionals pursued to construct a theory about disaster. Disaster has been originated from the French word 'Desastre' which means 'Bad Star'. 'Des' refers to bad and 'aster' refers to star.[11] The shortest definition of disaster is given by Quarentelly "Disaster is a catastrophic incident that goes beyond the capacity".[12] If such a serious

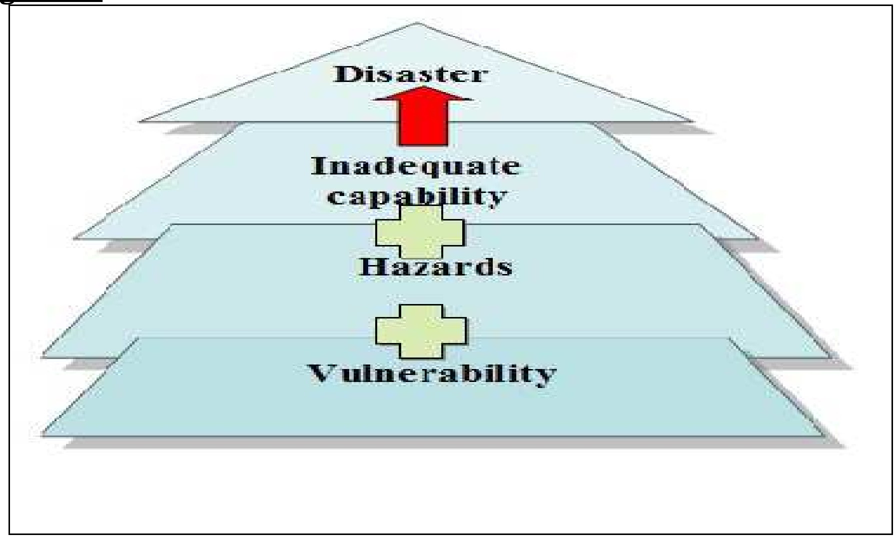
10 "IAEA Safety Standards for Protecting People and the Environment: Severe Accident Management Programmes for Nuclear Power Plants," *International Atomic Energy Agency,* 1376. (2009). http://www-pub.iaea.org/MTCD/publications/PDF/Pub1376_web.pdf (accessed on September, 16, 2012).

11 Himayatullah Khan, Asmatullah Khan, Laura Giurca and Vasilescu, "Disaster Management Cycle: A Theoretical Approach," *Management and Marketing Journal*6, 1. (2008): 1. http://www.mnmk.ro/documents/2008/2008-6.pdf (accessed on November, 17, 2013)

12 "Definition of Disaster". *CYEN.* <http://www.cyen.org/innovaeditor/assets/Disaster_Management_Notes_and_Questions.pdf>, (accessed on November. 17, 2013)

disorder to human life is caused by natural hazard then it is called as "*natural disaster*", where as a serious human disorder caused by industrial or technological hazards is called "*human-induced disaster*". Disaster that can be foreseen with higher accuracy and gives respond time is called *slow-onset*, contrarily, disaster that is unable to foreseen, occur abruptly and gives no respond time is called *quick-onset*.[13] A disaster either natural or man-made is a phase of risk processes that makes the adjustment complicated and paralyzes the regular life. Disasters are a combination of hazard, human vulnerability and inadequate capability or actions to reduce the possible negative cost of threat, which is shown in above diagram.

Diagram 2:



Vulnerability + Hazards + Vulnerability = Disaster [14]

Risk (R) is the outcome of vulnerability (V) and hazard (H). It is usually conveyed by the equation ***R (Risk) = H (Hazard) x V (Vulnerability)***. Risk can be defined as the likelihood of dangerous outcomes or probable losses in the form of casualties, damages, injuries, property or environmental damages and economic disruption, due to interactions between made-made or natural vulnerable situations and hazards.[15]

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13 Don Schramm and Richard Hansen, Disaster Management Center, *Aim & Scope of Disaster Management: Study Guide and Course Text*, 1991, University of Wisconsin-Madison. <http://epdfiles.engr.wisc.edu/dmcweb/ AA02AimandScopeofDisasterManagement.pdf>, (accessed on Nov. 18, 2013)

14 "Introduction to Disaster Management," *VUSSC.*http://www.col.org/SiteCollection Documents/Disaster_Management_version_1.0.pdf(accessed on August, 13, 2013)

15 Training Manual, *Conceptual and Institutional Framework of Disaster Management,* 2012, An Initiative of National Disaster Management Authority and Indira Gandhi

The term "disaster management" includes the entire subject of disaster associated activities. In history, the term disaster management was merely associated to the post-disaster activities which were supposed to be handled by relief organizations, however in modern times it is more associated to the pre-disaster measures. The "disaster management" thus involves combination of necessary measures, procedures, plans, approaches and actions that can be taken before, during and after a disaster with an objective to prevent a disaster, reduce the damages and recover from its devastation.[16]The history of disaster and its management is very old but the 'disaster management approach' is relatively new in theory and practice. The rising number of serious disasters with an increasing number of human losses faced by national and international crisis management organizations, led to introduce 'disaster management' as an advanced subject in management sciences. The success of disaster management depends on the capability of disaster associated organizations to investigate the potential risks and formulate the emergency plans which society can understand and execute. All these procedures and actions are encompassed in the standard disaster management theory.[17]

The approaches that are adopted before a potential disaster takes place are termed as pre-disaster activities. The approaches carried out in pre-disaster phase are disaster risk reduction, mitigation and preparedness. The measures taken to ensure preparedness are devised after assessing the nature of hazards, risks and vulnerabilities. Pre-disaster measures facilitate the reduction of severity of disaster.[18] In case the potential disaster materializes, certain measures are to be adopted to reduce the lethality of event. The measures if taken properly, timely and efficiently can mitigate the impacts of disaster. The approaches executed during disaster phase are termed as response and relief actions. This phase demands comprehensive coordination of first responders, civil-defense institutions, medical centers and relief organizations.[19]

National Open University, Delhi. <http://www.ignou.ac.in/upload/Conceptual%20and%20Institutional%20Framework%20of%20Disaster%20Management.pdf>, (accessed on November. 20, 2013)

16 Corina Warfield, The Disaster Management Cycle, <http://www.gdrc.org/uem/disasters/1-dm_cycle.html>, (accessed on September, 19, 2014)

17 Ibid.

18 "Predisaster activities," *World Health Organization.*http://www.searo.who.int/entity/emergencies/documents/WHO_Predisaster_Activities.pdf. (accessed on September, 13, 2014).

19 Ibid.

Diagram 3:

The post-disaster measures are very crucial because the delay in disaster relief actions can hoist the damages. The success of post-disaster approaches is directly proportional to the coordination of society and organizations involve in response, recovery and rehabilitation activities.

The organizational factors thus have a fundamental function in understanding, preventing and handling any type of nuclear accident. The two prominent theories; 'Normal Accident Theory' and High Reliability Organizations' have appropriately addressed the organizational aspects of safety. The Normal Accident Theory was introduced after Three Mile Island nuclear accident (1979), the theory supports the idea that accidents are 'normal' and the existing complex technological systems makes the hazardous accidents highly unavoidable. Conversely, High Reliability Theory argues that appropriate organization design and its management procedures can assure the safety from extremely hazardous accidents.[20]

Consequently, the nuclear disaster management approaches are devised by related organizations to deal with the long term potential radiation affects that may cause harm to the workers, people and environment. The nuclear disaster management approach works according to the disaster management theory, framework (discussed above) and country's nuclear disaster plan.[21]

Fukushima Daiichi Disaster: Case-Study

On March 11, 2011, earthquake accompanied by tsunami hit the Pacific Coast of Tohoku, Japan. The earthquake was of magnitude 9.0 on

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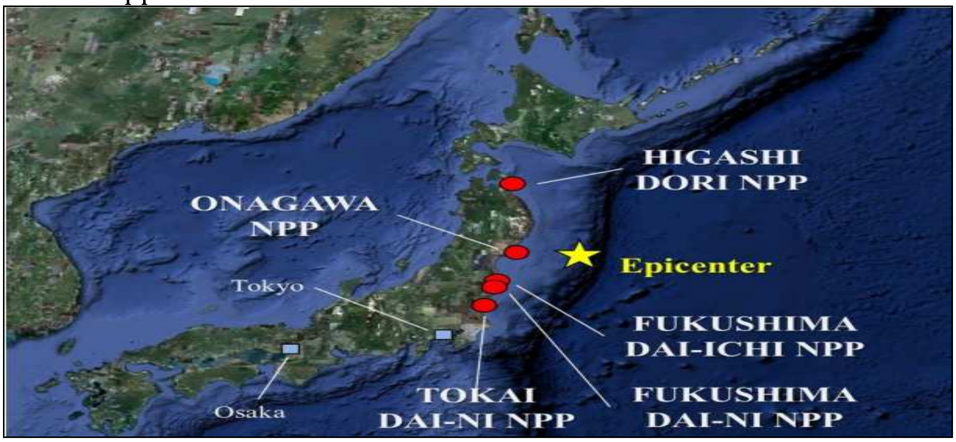
20 Scott, Sagan. *The Limitation of Safety- Organizations, Accidents and Nuclear Weapons.* Princeton University Press. (1993).

21 "Nuclear Emergency response Plan."*California Department of Public Health,*http://www.cdph.ca.gov/healthinfo/environhealth/documents/nerp/nerp.pdf (accessed on June, 10, 2013 and also accessed on September, 10, 2014)

Richter scale and is called as *Great East Japan Earthquake* due to severe seismic tremors. The earthquake and high tsunami waves widely affected the Japan's biggest island, Honshu, where five nuclear power plants were located; Higashi NPP, Fukushima Daiichi NPP, Fukushima Daini NPP, Tokai Daini NPP and Onagawa NPP.[22] The damage was caused on four NPPs but the most serious tragedy was triggered at Fukushima Daiichi NPP, which was placed at Level 7 on INES. The Fukushima Daini was put at level 3, Onagawa at level 1 while the Tokai Daini was placed at level 0.[23] The research is thus focused on Fukushima Daiichi NPP due to the severity of accident happened there.



NPP Sites of "Pacific Coast of Tohoku"[24]

What went wrong at Fukushima Daiichi?

The tsunami hit the six nuclear reactors located at Fukushima Daiichi NPP, operated by the Tokyo Electric Power Company (TEPCO). The Units 1, 2 and 3 were operating normal whereas the Unit 4, 5 and 6 were shutdown for scheduled inspections. Due to seismic movement, the off-site power from main grid was totally cut off at all Fukushima Daiichi NPP and emergency shut-down feature commenced at Units 1 to 3. After the offsite power lost, the onsite Emergency Diesel Generators (EDGs) were kicked in to provide power for the emergency core cooling systems.[25]The 14m high

22 "IAEA International Fact Finding Expert Mission Of The Fukushima Daiichi NPP Accident Following The Great East Japan Earthquake and Tsunami", IAEA Mission Report.(2011). http://www-pub.iaea.org/mtcd/meetings/pdfplus/2011/cn200/documentation/cn200_final-fukushima-mission_report.pdf.P-11-12.(accessed on September 15, 2014)

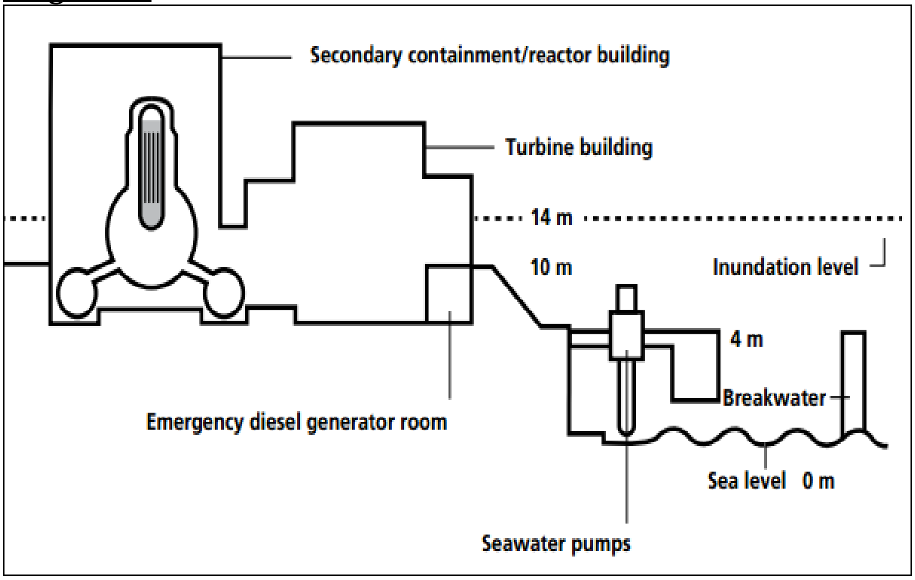
23 Phillip Lipsy, Kenji Kushida and Trevor Incetri."The Fukushima Disaster and Japan's Nuclear Plant Vulnerability in Comparative Perspective", *Environmental Science & Technology.*(2013). P-6082.http://web.stanford.edu/~plipscy/LipscyKushidaIncertiEST2013.pdf. (accessed on September, 16, 2014).

24 Ibid. p-23.

25 "The Official Report of The Fukushima Nuclear Accident Independent Investigation Commission", *The National Diet of Japan,* (2012). p-12. https://www.nirs.org/fukushima/naiic_report.pdf . (accessed September, 14, 2014).

tsunami waves flooded the 10m elevated plant and completely destroyed the 12 out of 13 EDGs.

Diagram 4:



Reactors at Fukushima Daiichi damaged by tsunami[26]

The sea water was injected through seawater pump but after sometime the tsunami also annihilated the seawater cooling pumps and the electric wiring system. Due to the absence of electricity and physical damage to pathways; the excess to control room, instrumentation of control systems, lightning, communication and monitoring of equipments became extremely complicated. It became difficult to cool down the reactors hence the steam generated and the reactors started heating up. To relieve pressure, superheated steam was released which caused hydrogen explosions at units 1 to 4. The hydrogen explosion destroyed the outer shell of reactors, thus consequently reactors 1 to 3 suffered meltdown. The radioactive material released and later the low contaminated water was released into the sea in order to treat the highly contaminated water.[27]

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26 James M. Acton and Mark Hibbs, "Why Fukushima Was Preventable", *Carnegie Endowment.* (2012). http://carnegieendowment.org/files/fukushima.pdf. (accessed on September, 17, 2014).

27 "The Official Report of The Fukushima Nuclear Accident Independent Investigation Commission", *The National Diet of Japan,* (2012). P-13-14.https://www.nirs.org/fukushima/naiic_report.pdf . (accessed September, 14, 2014).

What could have mitigated the disaster?

The Fukushima disaster was instigated due to natural hazards but some human-induced errors augmented the tragedy. There were serious problems which placed the disaster at INES 7, i.e. the elevation of NPP, the location of EDGs, height of seawater pumps, errors in preparedness measures, delay in onsite response and absence of some significant safety procedures. The Onagawa was more closed to epicentre but survived tsunami because the plant's seawall was 14m high, enough for high tsunami waves. On the contrary the seawall at Fukushima Daiichi was 10m high; the physical structure of plant was designed to survive 5.7m high tsunami waves while the tsunami waves were 14m high. The EDGs at Fukushima Daiichi were damaged because they were placed at the plant's elevation level.[28] The tsunami waves would not wipe out the EDGs if the seawall was higher or if the EDGs were located at elevated place. The damages could have been mitigated if the electric circuits and backup power cooling systems were waterproof. The EDGs at other four NPPs survived tsunami consequently the damages were not as severe as at Fukushima NPP.

After the loss of offsite power, a backup 66kV transmission line was tried to feed reactor 1 but failed due to mismatched sockets.[29]There was absence of some valid tools while the staff at site was not well trained to response effectively and timely in such a serious accident. This shows that effective preparedness measures were not in placed for potential risks. To make excess easy to control room in severe nuclear tragedy, the control room must have been located at an elevated place at plant or at distance from the plant. In result of total breakdown of communication, the onsite establishment and central government was oblivious to each other's situation and actions. Thus, some serious gaps in preparedness and response declare the Fukushima tragedy a purely man-made disaster.

The possible danger of tsunami was estimated after 2002 and a research for potential 10-15m high tsunami was also conducted in 2008 but TEPCO underestimated the tsunami risks. Though TEPCO was aware of risks and essential safety procedures were recommended.[30] Hence the negligence within TEPCO's safety culture was another reason behind this serious accident.

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28 Phillip Lipsy, Kenji Kushida and Trevor Incetri." The Fukushima Disaster and Japan's Nuclear Plant Vulnerability in Comparative Perspective", *Environmental Science & Technology.*(2013). P-6083.http://web.stanford.edu/~plipscy/ LipscyKushidaIncertiEST2013.pdf. (accessed on September, 16, 2014).

29 "The Official Report of The Fukushima Nuclear Accident Independent Investigation Commission", *The National Diet of Japan,* (2012). p-13-14. <https://www.nirs.org/ fukushima/naiic_report.pdf>. (accessed September, 14, 2014).

30 Ibid.,p-44.

Pakistan's Nuclear Disaster Management: Case-Study

Pakistan has a small nuclear industry and all its NPPs are under IAEA safeguards but the risks of natural hazards and man-made errors after Fukushima disaster have ignited worries. Pakistan has currently three operational commercial NPPs. The first NPP known as Karachi Nuclear Power Plant (KANUPP-1) is sited on Arabian Sea Coast and become operational in 1972. The KANUPP-II (K-2), KANUPP-III (K-3) and KANUPP-IV (K-4) will be established with Chinese help to produce 2400 megawatts. The other two operational commercial NPPs, Chashma Nuclear Power Plant-1 (CHASNUPP-I) and Chashma Nuclear Power Plant-II(CHASNUPP-II) are sited nearby Mianwali, Punjab. Both NPPs were installed by PAEC with Chinese support in 2000 and 2011 respectively. CHASNUPP-III and CHASNUPP-IV are underway projects of 340 megawatts and will be inaugurated soon.[31] Pakistan has lately announced to build 32 NPPs to generate 40,000 megawatts as part of "Nuclear Energy Vision 2050". These developments and Fukushima nuclear event ignited fears that any tragedy can put 20 million people of Karachi at risk.[32]

Nuclear Security Action Plan (NSAP)

Any state possessing nuclear technology cannot rule out the possibility of a nuclear tragedy. Pakistan has therefore installed a nuclear disaster management apparatus to protect workers, public and environment from the lethal effects of radiation. The Pakistan Nuclear Regulatory Authority (PNRA) is responsible for nuclear safety in country and works with IAEA and Convention on Nuclear Safety (CNS) to corroborate safety standards on all its NPPs.

To assess the potential risks to nuclear safety, a mechanism based on gap analysis and IAEA nuclear safety standards was developed, and a Nuclear Security Action Plan (NSAP) was devised by PNRA with collaboration of Strategic Plans Division (SPD) and Pakistan Atomic Energy Commission (PAEC) in 2006. The plan was prepared to establish an effective response in nuclear related event. The salient features of NSAP includes the appropriate determination of emergency planning zones, availability of necessary resources for implementing necessary protective measures, management/administrative arrangements among various organizations involved in the response and protection actions, interface arrangements, information transmission and exchange, protective

31 "Pakistan Nuclear Regulatory Authority".http://www.pnra.org/c1.asp. (accessed on September, 13, 2014).

32 Beenish Altaf, "Safety and Security of Pakistan's Nuclear Power Plants-Analysis," *Eurasia review,* March 7, 2014. http://www.eurasiareview.com/07032014-safety-security-pakistan-nuclear-power-plants-analysis/. (accessed September, 14, 2014).

measures (potassium iodine administration, access control, sheltering, evacuation etc).[33]

Mitigation and Preparedness

Pakistan has clear distinction of its onsite (on NPPs) and offsite (organizations) nuclear emergency force. Many nuclear safety regulations are envisaged to ensure preparedness and mitigation. PNRA regulations PAK/909 demands emergency plan from licensee and approval of plan is mandatory before fuel is brought in nuclear installation. The regulation PAK/914 on the "Management of Nuclear Accident or Radiological Emergency" deals with establishment of onsite and offsite emergency response plans. In 2013, PNRA assessed on-site emergency exercises at K-1. The regulations for Safety of Nuclear Installations and Site-Evaluation are dealt under PAK/910 of PNRA. The Safety of NPP Design is verified and review periodically under regulations PAK/911.[34]PNRA also regularly conduct drill exercises of all organizations involved in emergency plan, to improve and ensure the effective implementation of the nuclear emergency response plan.

IAEA has issued an implementing guide about Design Basis Threat (DBT) which assists to draft a safety plan by assessing hazards and vulnerabilities. Pakistan has adequate measures to functionalize DBT. The country has an evacuation and decontamination plan to handle the radioactive exposure in a nuclear unfortunate incident. For this matter, the Nuclear Security Emergency Coordination Center (NuSECC) works round the clock and has network of 6 emergency mobile labs in different cities of country. Moreover, the Nuclear Security Training Center (NSTC) provides training for officials from NPPs, operators of radiation facilities, first responders (onsite) and personnel from various organizations.[35]

Response

If a nuclear event goes beyond the capacity of onsite responders, it becomes the responsibility of National Disaster Management Authority (NDMA). The National Disaster Response Plan (NDRP) of NDMA covers the nuclear and radiological events. The Nuclear Emergency Management System (NEMS) is an extensive body of SPD and functions in collaboration with NDMA. In case of a tragedy, both NEMS and NDMA would ensure the implementation of required measures for a timely and effective

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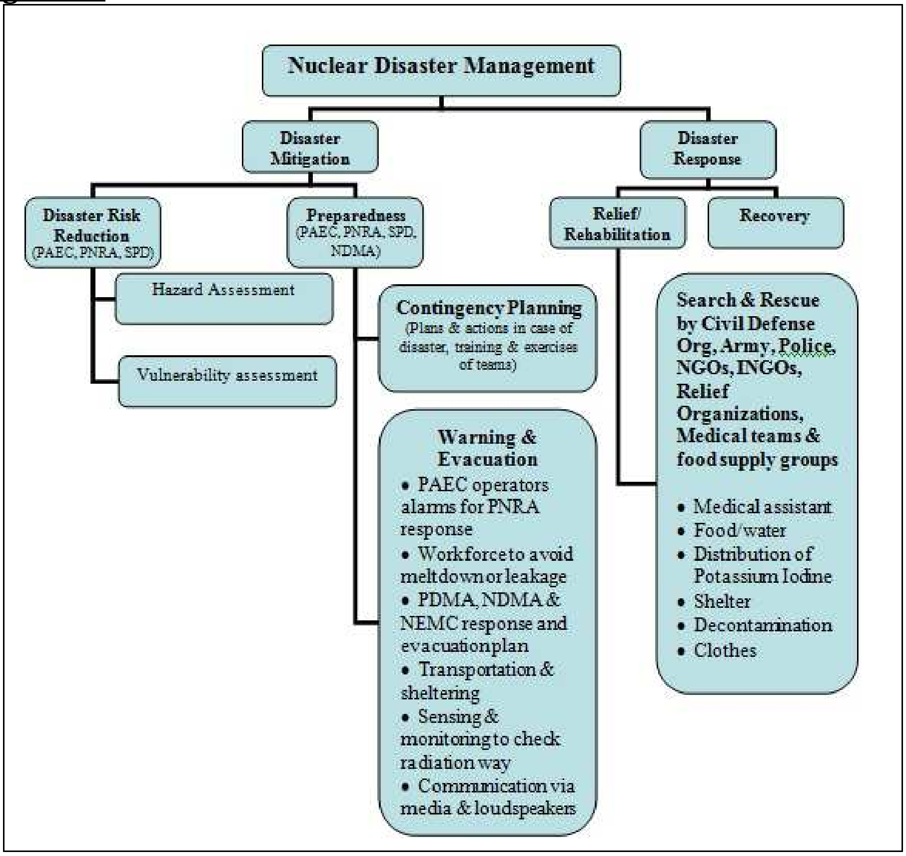
33 "Nuclear Security Action Plan," *Pakistan Nuclear Regulatory Authority.* http://www.pnra.org/nsap.asp. (accessed September, 12, 2014).

34 Convention on Nuclear Safety, Special National Report by the Government of the Islamic Republic of Pakistan, for Second Extraordinary Meeting, August, 2012, p.44-45.

35 "Nuclear Security Action Plan," *Pakistan Nuclear Regulatory Authority.* <http://www.pnra.org/nsap.asp>. (accessed September, 12, 2014).

response.[36] The evacuation and decontamination plan will be carried out by these organizations and by other trained workforce. To review the preparedness and response measures, ten training courses were organized by PNRA in the year 2013 for police, civil-military organizations, Rescue teams, Frontier Constabulary (FC), SPD), Bomb Disposal Squads, intelligence teams, health institutes and PAEC.[37]

Diagram 5:



An overview that how Pakistan's Nuclear Disaster Management Apparatus likely to work in a nuclear tragedy[38]

In a nutshell (as shown in diagram above), the country's nuclear disaster management apparatus would likely to work as accordingly. The

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36 "Convention On Nuclear Safety," Special National Report by the Government of the Islamic Republic of Pakistan for Second Extraordinary Meeting. (2012): 43-44. http://www.pnra.org/reports/Special%20National%20Report%202012-Pakistan.pdf. (accessed on September, 15, 2014).

37 "PNRA Annual Report 2013," *Pakistan Nuclear Regulatory Authority.*http://www.pnra.org/pnrarpt/PNRA%20Annual%20Report%202013.pdf. (accessed September, 12, 2014)

38 Researcher's own effort and understanding.

PAEC operators would alarm PNRA to activate emergency response. The onsite trained workers would take measures to avoid any possible radioactive exposure. If radiation spreads, the NDMA and NEMS would trigger a national level response. All ministries, civil-defense institutions and relief organizations etc will be informed to conduct a response. The evacuation plan and the plan to distribute potassium iodide would be launched. To communicate and guide general public about further instructions, the local cables and mosque loudspeakers will be used.

Comparative Analysis of Fukushima and Pakistan

Pakistan has a robust nuclear emergency plan to handle a nuclear event which has been discussed above, yet a comparative analysis of Fukushima Daiichi and Pakistan is imperative to check the validity of concerns levelled against Pakistan's nuclear management apparatus. The researcher has picked few crucial variables related to NPPs, critically evaluated its existence, checked its effectiveness and ultimately compared Pakistan's capability to handle a Fukushima level disaster. The variables discussed below are seismic design of NPP, seismic risks, elevation of plant, status of EDGs, height of seawater pumps, evacuation plan and distribution of potassium iodide. The comparison of each variable is as follows:

1. The seismic design of a nuclear power facility ensures the reactor's capacity to survive earthquake and tsunami. The Fukushima Daiichi nuclear power facilities were capable to withstand an earthquake of magnitude 6.7 at Richter scale while the earthquake that hit reactors on March 11, 2011 was of 9.0 at Richter scale.[39] The ground acceleration at Fukushima varied from 0.30g to 0.55g[40] which causes severe seismic tremors but the design value of KANUPP-1 is 0.1g[41] and is said to withstand the ground acceleration of 0.2, which is far less than Tohoku earthquake.
2. The Pacific Coast of Tohoku has four tectonic plates; Eurasian plate, North American plate, Philippines sea microplate and Pacific plate. The Tohoku earthquake occurred on the boundary of the North American plate and the Pacific plate.[42] In Pakistan, three active

[39] "Nuclear Power Plants and Earthquakes", *World Nuclear Organization.*(2014). http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Nuclear-Power-Plants-and-Earthquakes/. (accessed on September, 12, 2014).

[40] William Parker, "Damager from Earthquakes 'Not a Significant Risk' for San Onofre". (2014). http://www.songscommunity.com/docs/cep_seismic.pdf. (accessed on Sep. 17, 2014).

[41] "Convention On Nuclear Safety," Special National Report by the Government of the Islamic Republic of Pakistan for Second Extraordinary Meeting. (2012). P-14.http://www.pnra.org/reports/Special%20National%20Report%202012-Pakistan.pdf.

[42] "IAEA International Fact Finding Expert Mission Of The Fukushima Daiichi NPP Accident Following The Great East Japan Earthquake and Tsunami", IAEA Mission

tectonic plates (Arabian plate, Eurasian plate and Indian plate) at Makran and Gwadar coast can affect K-1 of Arabian Sea coast.

3. The distance of Fukushima Daiichi NPP from earthquake was 178km.[43] Whereas Karachi is located approximately at distance of 150-200km from the triple junction of tectonic plates at Makran and Gwadar coast[44]. Hence in case of severe collision of these tectonic plates, serious risks like Fukushima tragedy can be posed to K-1.
4. After the Tohoku earthquake, the 14m high tsunami waves reached the Fukushima Daiichi NPP within about 46 minutes.[45]On other hand, Pakistan's chief meteorologist stated that an earthquake of 9 at Richter scale in Makran trench would create 23feet high tsunami waves that would reach within 90 minutes at Arabia sea coast.[46] However in 1945, the waves that hit Karachi coast were 4m high.
5. The Fukushima Daiichi nuclear power reactor facilities were located at 10m high above the sea-level while KANUPP-1 is 11.9m (39feet) above the sea-level.[47] The EDGs at Fukushima were placed at 10m whereas in Pakistan the emergency cooling systems are placed at 11.89m.[48] Pakistan's NPPs are located at higher elevation than Fukushima nonetheless the NPP height must be corresponding to the maximum wave height recorded within 300km as recommended by IAEA 2010. It is argued in a recent study that K-1 has plant elevation lower than the recorded wave run-up.[49]
6. At Fukushima NPPs, the sea water pumps were 4m high from sea-level and were badly destroyed due to tsunami. At KANUPP-1, the

Report.(2011). <http://www-pub.iaea.org/mtcd/meetings/pdfplus/2011/cn200/documentation/cn200_final-fukushima-mission_report.pdf.>P-19. (accessed on Sep. 15, 2014)

43 "Fukushima Nuclear Accident Analysis Report", *Tokyo Electric Power Company*. (2012). P-7.http://www.tepco.co.jp/en/press/corp-com/release/betu12_e/images/120620e0104.pdf. (accessed on Sep. 16, 2014).

44 Roger Bilham, Sarosh Lodi, Susan Hough, Saria Bukhary, Abid Murtaza Khan and S, Rafeeqi. "Seismic Hazard in Karachi, Pakistan: Uncertain Past, Uncertain Future", Seismological Research Letters, 78 (6). (2007). P-601.http://pasadena.wr.usgs.gov/office/hough/bilham_et_al_2007SRL.pdf. (accessed on Sep. 13, 2014).

45 "IAEA International Fact Finding Expert Mission Of The Fukushima Daiichi NPP Accident Following The Great East Japan Earthquake and Tsunami", IAEA Mission Report. (2011).

46 "1945: The Tsunami That Devastated Makran", *Dawn.com.* <http://www.dawn.com/news/1131310>. (accessed on Sep. 17, 2014).

47 "Convention On Nuclear Safety," Special National Report by the Government of the Islamic Republic of Pakistan for Second Extraordinary Meeting. (2012). P-10.http://www.pnra.org/reports/Special%20National%20Report%202012-Pakistan.pdf.

48 Ibid.,P-12.

49 Phillip Lipsy, Kenji Kushida and Trevor Incetri."The Fukushima Disaster and Japan's Nuclear Plant Vulnerability in Comparative Perspective", *Environmental Science & Technology.*(2013). P-6084.

pump house floor is 2.74m high and in most awful scenario can be demolished by severe gushing of water and wreckage.[50]

7. The EDGs and cooling power systems worked for about 30 hours at reactors of Fukushima Daiichi. Whereas K-1 has mobile EDGs, passive emergency cooling systems and fire water tanks to cool-down reactors for about 72 hours.[51]
8. In case of serious nuclear disaster, the evacuation of people away from the contaminated area is an essential step for public safety. Almost 185,000 residents were evacuated from vicinity of 20km and around 200,000 people evacuated from ten towns of surrounding areas of Fukushima NPP.[52] As a protective measure from radiation exposure, Japan distributed 230,000 units of potassium iodide to evacuated centers around NPP. Pakistani nuclear establishment says that in case of serious nuclear tragedy, an area about 5km will be evacuated and evacuation plans are in place for it. Pakistan is working to extend evacuation plans in circumference of 15km which covers people up to 100,000. Moreover, country has enough stock of potassium iodide for people in vicinity of K-1.[53]

Recommendations

A number of views, opinions, suggestions and recommendations can be derived from the above mentioned facts and analysis. As it is known fact that countries having NPPs keep on reassessing/re-evaluating the seismic hazards, potential risks, vulnerabilities, technological features and emergency zones with time and events, therefore suggestions focusing on these are deliberately ignored. The international safety standards about NPPs have been revised after Fukushima accident and many states including Pakistan has taken improved safety measures. Pakistani nuclear establishment has increased the quantity of EDGs nonetheless an improved protective measure would be the water proofing of electric circuits and EDGs. The emergency power system should be placed at much elevated place, behind flood-proof doors or in watertight bunkers. To avoid any possible risk, an emergency control room must be build at a

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50 "Convention On Nuclear Safety," Special National Report by the Government of the Islamic Republic of Pakistan for Second Extraordinary Meeting. (2012). P-12.

51 "Nuclear Power: 'K-2, K-3 Nuclear Reactors More Safe Than Fukushima". *The Express Tribune.*http://tribune.com.pk/story/662959/nuclear-power-k-2-k-3-nuclear-reactors-more-safe-than-fukushima/. (accessed on September, 13, 2014).

52 ZbigniewJaworowski, "Japanese Nuclear Power and Wrath of Nature". <http://www.21stcenturysciencetech.com/Articles_2011/Japan_nuclear_Jaworowski.pdf.> (accessed on September, 18, 2014); Larry Greenemeier. "Does Potassium Iodide Protect People from Radiation Leaks/", *Scientific American.*(2011). <http://www.scientificamerican.com/article/japan-earthquake- tsunami-radiation/>. (accessed on September, 26, 2014).

53 "Nuclear Power: 'K-2, K-3 Nuclear Reactors More Safe Than Fukushima".

much elevated location away from K-1, which can be used in an extreme tragedy.

An evacuation plan about K-1 is in place but as the contamination zone extends up to 50miles[54] thus an option to gradually but persistently move away citizens from the vicinity of NPP should be examined. Such a strategy will help in handling less people and avoiding chaos in emergency situation because a populated and economically significant Karachi cannot afford heavy population or trademarks near NPPs. Pakistan has recently announced plan to construct 32 NPPs at 8 sites across country and reportedly 6 sites have been identified so the possibility to purchase extensive land in vicinity of these NPPs must be investigated. For instance Kaemari town is located 16km away from K-2, so is it affordable to purchase this land or what can be the alternative measures to keep the area less populated around 30km. The operational lifetimes of 32 new NPPs is supposed about 60 years hence in absence of imperative actions the area around NPPs will be heavily populated in six decades. Conversely, as the safety of these NPPs is concerned, these plants are based on ACP-1000 model which has been recognized to be fully compliant with all the safety standards set by IAEA.[55]

Pakistan seems to launch an allied response in case of a nuclear disaster thus it is argued that which would be principal responsible body to launch and lead the response if a nuclear mishap happens. Who will be questioned and who would be liable? There are apprehensions about NDMA (tasked for evacuation plans and other significant actions in nuclear emergency plan) due to its substandard performance to handle natural hazards in country. It would be accordingly more organized for Pakistan to have a principal and liable 'Federal Nuclear Emergency Management Agency' to deal with nuclear/radiological related accidents.

At last but not the least, the general public must be trained to respond nuclear tragedy in an organized manner. The people living in vicinity of NPPs must be informed about protective measures, possible risks, evacuation plan and sheltering sites etcetera in order to avoid chaos and ensure efficiency in a nuclear event. The electronic media, cable advertisements, pamphlets, drill exercises and seminars can be the ways to develop the desired awareness.

Conclusion

The Nuclear Disaster Management is a complex modus operandi that involves serious analysis, planning and premeditated course of action.

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[54] "Backgrounder on Emergency Preparedness at Nuclear Power Plants", United *States Nuclear Regulatory Commission.*http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/emerg-plan-prep-nuc-power-bg.html. (accessed on September, 29, 2014).

[55] "Chinese Reactor Design Passes Safety Review", *World Nuclear News*. http://www.world-nuclear-news.org/NN-Chinese-reactor-design-passes-safety-review-0812145.html. (accessed on April, 3, 2015)

It requires scientific information, technical equipment, comprehensive preparedness, systematic arrangement and timely response. The most imperative step of disaster management is to identify the hazards, which can result in casualties, injuries or any kind of damage to infrastructure, economy or environment. The subsequent important course of action is to devise a 'disaster risk review' of the potential 'hazard zones'. This includes the assessment of the severity and exposure of potential disaster, and the requisite capacity to handle the tragedy. On the basis of this assessment, the response is prepared and shared with concerned organizations and public.

The Fukushima disaster was instigated by earthquake accompanied by tsunami but worsened due to the absence of measures, timely response and human-made errors. The effects could be mitigated; some serious gaps were witnessed in preparedness and response approaches which declare the Fukushima tragedy a purely man-made disaster. Every state possessing nuclear technology is vulnerable to natural and human-induced disasters and is responsible to adopt imperative measures; Pakistan in this regard is not an exceptional case. Pakistan has an effective management apparatus at NPPs which has successfully avoided any tragedy till now. The Nuclear Emergency Response Plan (NERP) is in practice with the coordination of PNRA, SPD and PAEC. The plan includes all the ministries, law & enforcement agencies, relief organizations, disaster management authorities, medical institutes, first responders, operators, counter intelligence teams, workforce and the public in vicinity of NPPs. Generally speaking states make threat assessments and in according to assessed threat, it develops a Design Basis Threat (DBT) that helps to prepare a security plan. The IAEA has issued an implementing guide about DBT. In this regard, adequate measures are in place. The capacity to provide necessary technical support in implementing necessary protective and response measures are available within the country along with monitoring equipment as well as assessment capabilities.

Moreover after the Fukushima Daiichi disaster, the safety procedures have been reassessed and revised; yet some additional measures are required keeping in view the Fukushima level severe nuclear tragedy. To conclude, the handling of nuclear disaster like Fukushima is quite challenging but manageable.