Design of Nuclear Security Regime to Combat Nuclear Terrorism

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Abstract— Uses of nuclear and radioactive materials in peaceful applications in energy production, medicine, research and industry, to improve the daily lives of individuals internationally makes these materials on the move and in demand. On the other hand, the possible risk of using in terrorist purposes, by it falling into the wrong hands is a real and growing concern of the international community and one that stresses enhanced nuclear security. In this paper, the author will focus on efforts done by new nuclear energy users in the Middle East to sustain nuclear security and reduce this risk. These efforts include accounting of radioactive material and their related facilities, and helping to prevent illegal uses or transporting these materials, construction of a solid legislative, regulatory and enforcement bases, enhanced national capacity, and increasing international cooperation in nuclear security.

Keywords— Include Nuclear materials; radioactive materials; Terrorism; Illegal Use; Nuclear Security; Nuclear safety

I. INTRODUCTION

Nuclear terrorism is to use of nuclear or radioactive materials by terrorist groups, to cause fear to achieve political aims. This could include the use of stolen nuclear weapons, or fissile materials such as highly enriched uranium (HEU) and plutonium obtained from military or civilian sources to construct an improvised nuclear explosive device (IND). Nuclear terrorism may also include radioactive materials used in medical, industrial, scientific research applications and nuclear waste, by dispersal of these materials perhaps in conjunction with regular explosives as a “dirty” bomb to cause radiological contamination. Sabotage of a reactor or other nuclear facility is yet another form of nuclear terrorism [1, 2, 3].

Nuclear terrorism could be represented in several types as [4, 5, 6, 7]:

1. Using of a nuclear weapon.
2. Uses of radiological materials or radiation producing devices/materials, i.e. radiological terrorism
3. Sabotage of a nuclear facility, or a facility that uses nuclear materials targeting these materials, i.e. nuclear sabotage
4. sabotage of a facility that uses radioactive materials or radiation producing devices targeting these materials and devices, i.e. radiological sabotage

Nuclear terrorist incidents include the acquisition of nuclear materials, use or threatened use of these materials, or attack on nuclear materials or facilities, as well as the choice to fabricated threats that, to the extent they are convincing, would have the same effect. These incidents may include the following features:

- An attack using nuclear weapon,
- An attack on a nuclear reactor or a waste storage or disposal site,
- An attack on a nuclear facility or on nuclear materials, with a threat of a radioactive dispersion,
- An attack on nuclear materials during transportation to cause a release of radioactive materials,
- A trick threatening of using nuclear explosion or the release of radioactivity in a populated area,
- A limited discharge of radioactive materials as a warning of forthcoming higher level damage,
- An attack on symbolic targets like a national monument or a major public building using radioactive materials,
- An attack on industrial targets, e.g., factories, ports, etc. using radioactive materials,
- An attack on government centers and military targets using radioactive materials, and
- An attack on urban concentrations using radioactive materials.

The actual physical damage may range from null to terrible, but the main consequence will be creation terror in the minds of the public, which is the terrorist anticipated result.

There are several types of nuclear terrorism devices [8, 9, 10]:

1. Conventional nuclear weapon
2. Improvised Nuclear Device (IND) or crude nuclear bomb: a device intended to cause a yield-producing nuclear explosion by utilizing one of the two types of fissile material that could be used for this purpose, highly enriched uranium (HEU) or plutonium. IND may not be deliverable, safe, or secure.
3. Radiological Dispersal Device (RDD): a device that distributing or disperses radioactive material into the environment, resulting in radioactive contamination that would present a significant health hazard to the public.

4. Radiation Emitting Device (RED): a device that produces radiation that is used to expose potential victims to radiation produced by the device to cause harm via the radiation without distributing or dispersing the material. The source is placed or concealed in a location where it can deliver a radiation dose to a target, and may go undetected for a long period of time

While the use of either an RDD or an RED is considered the most plausible terrorist act, the general consensus is that such actions would result in a small number of immediate deaths [11].

1.1. Health hazards due to Radiation exposures

As a human is exposed to ionizing radiation, some of the radiation will be absorbed by his body. The absorbed radiation will form many charged particles cause, in turn, a number of chemical reactions to occur, at a cellular level, which have a power to attack the biological material of body cells. Some of these interactions will result in the death or permanent modification of individual cells or their main components. In case of higher doses of radiation more cells are likely to die leading to reduced organ function. Such effects are observed above some dose threshold, called deterministic effects, result in acute radiation syndrome, and known as radiation sickness. The first indications of acute radiation syndrome are nausea, vomiting, and diarrhea [12, 13, 14].

For people with acute radiation syndrome, the chance of survival decreases with increasing radiation doses. The cause of death in the most severe cases is due to severe damage in gastrointestinal tract and bone marrow, which results in internal bleeding and infections [13, 14, 15].

When a human is exposed to low doses of radiation, latent health effects, which are stochastic or non-deterministic effects in nature, such as cancers may result from permanent variation to cells [13, 14, 15].

To be observable effects, high doses will cause a sufficient number of cells to die essentially. Thus, a very high dose to the human whole body can cause death within days or weeks. For example, a dose of 5 Sv or more received instantaneously would probably be lethal, at least, without proper and on time, treatment. This dose might not prove fatal if received by a limited part of the body, but other early effects could occur, like an instantaneous absorbed dose of 5 Sv to the skin would probably cause, skin burns, while the damage may well be more severe than that caused by a conventional burn because it may well go deeper due to the penetration of the radiation. At any dose value, mutation of a cell is assumed possible to occur, although the probability of the mutation risk leading to health consequences will depend on the magnitude of the dose received. Thus, if the dose is lower than that which will lead to acute health effects or is delivered over a longer period of time, there is the possibility of cancer induction later in life. There is also the possibility of health consequences for the offspring of the person who received the dose, although such genetic health consequences have never actually been observed in human populations. The principal concern then with low doses of radiation is with the induction of cancer. Information on the effects of exposure to ionizing radiation is collected and assessed periodically through reports issued periodically by the United Nations Scientific Committee on the Effects of Atomic Radiation [13, 14, 15, 16].

1.2. Nuclear Explosions

Nuclear weapons are extremely efficient killing, devastation, and incendiary devices. The deaths in Hiroshima and Nagasaki resulted in 20-30% of the cases from primary burns, 50-60% from mechanical injuries, secondary burns, and approximately 15% from the radiation injuries. 120,000 persons were killed outright in both cities. In Hiroshima and Nagasaki, 13 and 7 km^2 areas were destroyed respectively. The blast pressure wave caused severe damage to structures at distance of 2-3km. Individuals who were close enough to ground zero, to receive a lethal dose of prompt nuclear radiation, were more likely to have been killed outright by the blast or thermal flash [17, 18, 19, 20, 21].

The two small detonations of nuclear weapons in Hiroshima (15kT)•, and Nagasaki (21kT), and the subsequent atmospheric nuclear tests preceding the atmospheric test ban treaty of 1963 have provided some information on the direct effects of nuclear explosions. Upon the detonation, a nuclear fission weapon disassembles and vaporizes within one millionth of a second. About 70 to 80% of the energy is converted into soft X-rays with an effective radiation temperature of $\sim 10^8$ K, most of the remaining energy comprises kinetic energy of the bomb debris. The primary thermal X-rays are absorbed by air within several meters of the device, heating the air and forming an embryonic fireball [17, 18, 19, 20].

The enormously hot sphere continues to expand rapidly by radiative transfer to the surrounding ambient atmospheric gases. As fireball grows and cools to about 3×10^5 K, the thermal irradiation becomes less penetrating, and the radiative fireball growth slows. At this point a shock wave forms and propagates at the fireball head. The shock wave continues to expand, the temperature of the shock–heated air decreases [17, 18, 19, 20, 21].

At about 30000 K, the thermal radiation of the fireball again becomes visible through the shock front. From a distance, the apparent radiation temperature then increases rapidly to the fireball, which is about 7500°K (approximately the temperature of the sun's surface), before decreasing again , as the fire ball continues to cool by radiation, expansion, and entrainment of ambient air [17, 18, 19, 20, 21].

Corresponding to the formation and growth of the fireball, two pulses of thermal irradiation are emitted, carrying away about 35% of the total energy of the explosion, mainly as visible, and near infrared radiation (spectrally, the average emission is very similar to sunlight). The first pulse of light originates from the shock wave carries ~1% of the total

• Kiloton=4.2×10^{12} J

thermal energy, and originates from the shock wave front. With its millisecond duration emission, it can damage the eye retina. The second burst of light, commences as the shock wave becomes transparent and in the incandescent is revealed with many seconds duration. Nuclear air bursts create a ground shock when the blast wave impacts the surface and induces ground motion [17, 18, 19, 20, 21].

In nuclear detonations, a large number of highly radioactive fission products appear as a result of the fission process of the fissile material, prompt neutrons and gammas. The latter will have their effect locally, while the fission products will be carried with the fireball for high distance of more than 15 km for 100 kT devices, and are transferred by atmospheric disturbances for very long distance.

The overall energy distribution of the nuclear explosion is approximately given as follows [17, 18, 19, 20, 21]:

- 35% thermal radiation, 50% blast and shock, 5% prompt radiation, 10% radiation from fission products.
- The prompt gamma radiation from the burst is absorbed in the earth atmosphere, producing high energy Compton electrons, which causes currents interacting with the earth magnetic field, generating electromagnetic pulse (EMP) which can disturb radiowave propagation from tens of Hertz to tens of giga Hertz. It also induces quasi direct currents in conducting structures. Metallic objects like antennas and buried power and telecommunication networks, even short radio antennas and other electrical lines can collect considerable amount of energy could upset, break down, and burn out susceptible electrical and electronic components.

1.3. Paper Objective

The objective of this paper is to provide a model of a nuclear security regime to protect nuclear material while in use or storage against theft, sabotage or other malicious acts that could, if successful, have unacceptable radiological consequences, which represents guidance in implementing, maintaining or enhancing nuclear security, and is intended to facilitate a uniform and consistent approach to security.

II. MATERIAL AND METHODS

The use of nuclear weapons on Hiroshima and Nagasaki, and the reactor accidents at Three Mile Island (TMI) in USA and Chernobyl in former USSR, has strongly influenced the public opinion of any nuclear accident or disaster to be most often connected, inaccurately, to only these events. Even though such situations may not easily be repeated, one must be prepared to face any nuclear/radiological accident of lower magnitudes and ensure that the impact of such an accident is always kept under control considering the higher population densities together with an enhanced urban infrastructure due to economic prosperity.

2.1 Approach to nuclear and radiological security regime

Nuclear security is the prevention and detection of, and response to any illegal act involving nuclear material, radioactive material or their associated facilities such as theft, sabotage, unauthorized access, illegal transfer or any other malicious act [9, 10, 11].

The model of nuclear security regime for the radioactive material defined in this paper addresses the radiological concerns and hazards associated with the unauthorized removal, sabotage and other malicious acts involving nuclear material.

The basic strategy to be adopted for a complete management of this nuclear security regime is springs from the following:

- To support the nuclear security regime by the prominent backbone of strengths that constitute the security regime continuum such as prevention, justification, compliance of regulatory requirements, preparedness, capacity development, response, etc.
- To strengthen the existing legal framework of the nuclear security regime through various legal and regulatory means.
- To institutionalize the framework of nuclear security regime by identifying the participants at various administrative levels with their respective responsibilities.
- To implement the framework of nuclear security regime through the strengthening of existing action plans or by preparing new action plans at the national and subnational levels.

2.2. Design of nuclear security regime

2.2.1. General approach

- States must establish a legislative and regulatory framework covering the security of nuclear materials that effectively interfaces with the nuclear security regime security in each state, which bears the responsibility for establishing, implementing and maintaining this regime within a state entirely.
- Security measures taken to protect nuclear materials against malicious acts during use, storage or transport of these materials should be based on threat assessment to combat any unacceptable consequences generated.
- Development of a graded and consistent system for specifying adequate levels of protection to combat malicious acts depending on logical and transparent basis which leads to developing a radiological model to evaluate the potential radiological consequences resulting from these acts.

2.2.2. Basic security considerations

The security considerations regarding the nuclear material available in this model are focused on the following main concerns: State responsibility, legislative and regulatory frameworks, the need to competent authority, responsibilities of all partners involved in transport, importance of security culture, threat assessment, defense in depth, Using of a graded approach Administration systems, emergency plans and confidentiality.

2.2.3. Security considerations for use, storage or transport of nuclear material

Transport of nuclear material is a short-term stage, between each of successive stages: production, use, storage and disposal of the material. In principle, the potential radiological consequences of the loss of control due to theft of nuclear material during these stages are similar, while the potential consequences of an act of sabotage might differ to a great extent depending on the location of the nuclear material. This required an adequate nuclear security system design that combines the concepts of defence in depth and the graded approach to attain preventing the material from becoming susceptible to malicious acts.

The nuclear security system should be planned to consider: quantity and the physical and chemical form of the nuclear material. As well as the following required measures to protect nuclear material:

- Identification of the actual possible malicious acts involving any nuclear material, to enable an appropriate response and recovery efforts to start as soon as possible,
- Providing rapid response to any attempts directed towards, or actual, unauthorized access to the nuclear material, or to other malicious acts involving nuclear material, and
- Combating any malicious acts by prevention, detection and delay of any unauthorized access.

In addition to have capabilities for:

- bringing the nuclear material under secure regulatory control by suitable correction action, and
- Minimizing and moderating the radiological consequences of any malicious act.

III. RESULTS

Since theft of nuclear material can lead to nuclear proliferation and the possible construction of improvised nuclear devices or radiological dispersal and exposure devices, measures to detect and respond to such acts are essential components of a comprehensive nuclear security program. However, it is recognized that an important factor of an effective nuclear security system is the effective measures for controlling the transfer of aiding components like equipment, non-nuclear material, technology or information that may assist in the development of nuclear explosive devices, improvised nuclear devices or other radiological dispersal devices.

It is necessary for States to review continuously the threats associated with nuclear material, and to evaluate the effects of any changes in those threats for the conditions of security procedures. States should share this information with all partners in transport process, as appropriate. The basic steps required for identifying security procedures are:

- Assessing the potential consequences of malicious acts,
- Performing a threat assessment by the aid of intelligence based information,
- Creating security planes to be applied to nuclear material packages or conveyances
- Describing security objectives for each security level,
- Identifying administrative and technical requirements or particular security measures essential to meet the security objectives.
- During transportation of nuclear materials: describing suitable security procedures to meet regulatory Classifying radionuclides and activities in each package and their transport options, and assigning the required security levels to the packages, and requirements and to protect against the design basis threat.

Radioactive materials, but not the fissile nuclear materials, are not capable to be used to produce a nuclear explosion. However, these materials do have the potential to be used as terror weapons either in the form of a radiological dispersal device (RDD) or a radiation emission device (RED). The use of an RDD or an RED is considered by many to be the most likely terrorist scenario because many radioisotopes are used widely in daily life applications in medicine, industry and research, and therefore available to the terrorists, but at the same time, their effect will be so limited and will never be compared to nuclear explosives.

Development of a radiological model to evaluate the potential radiological consequences resulting from malicious acts provides a logical and transparent basis for developing a graded and consistent system for specifying adequate levels of protection.

IV. DISCUSSIONS

Nuclear terrorism involves the use of nuclear materials to generate fear to attain political objectives. This study focuses on the use of terrorist groups through their attainment of some level of nuclear capability to cause fear. The potential political, psychological, economic, health and social effects of a nuclear terrorist acts are always inflated.

Reducing the probability of theft or sabotage of nuclear material during transport is accomplished by a combination of measures of prevention, detection, delay and response to such acts. These measures are complemented by other measures to recover stolen material and moderate possible consequences as well as to control and handle the nuclear material appropriately, to further reduce the radiological and other consequences.

In the case improvised nuclear device, At least three measures should be undertaken as significance measures to reduce IND threats: secure and eliminate HEU in all countries, track HEU globally, and encourage implementation of strict national and international security standards. Implementation of these measures will not remove entirely the risk that terrorists will manufacture and detonate a crude but effective nuclear device, but will reduce that risk which will persist at some level as long as stocks of fissile material exist. The timely recreation of these recommendations will reduce, significantly, the probability of occurrence of the second most high consequence form of nuclear terrorism.
Since State entirely bears the responsibility for establishing, implementing and maintaining a security regime within its territories. States need to establish a legislative and regulatory framework covering effectively the security of nuclear material to protect it against malicious acts based on evaluating the threat to the material and its potential to generate destructive consequences.
The radiological consequences arising from radiological attacks are extremely variable depending on the type and nature of the event and the type and amount of nuclear material involved.
The RDD scenario is considered a more likely one since it is very attractive for terrorists to cause harm and can be undertaken with simple capabilities. It is also considered suitable due to the potential radiological consequences of a malicious act involving different types of nuclear materials. At the same time we must admit that the potential psychological, social, political, and economic effects of a nuclear terrorist acts are overstated.
In addition to what has been mentioned, national measures to counter the threat may include the following:

- Develop measures to control the movement of goods and people across international borders.
- Obtain modern technology and tools to upgrade the physical security of nuclear weapons components, nuclear materials, and installations.
- Minimize insider threats.
- Obtain the latest technologies for the packaging, sealing, and monitoring of nuclear materials during transportation.
- Create an independent and highly trained guarding force devoted exclusively for nuclear facilities and materials.

V. CONCLUSION

This study is an effort to assess the character and extent of the threat of nuclear terrorism using nuclear, or radioactive materials. It reviews numerous forms of nuclear terrorism, ranging from the detonation of a nuclear weapon to the use of a nuclear trick threatening to governmental and public life aspects. Measures to combat the nuclear threat during use, storage, or transport of nuclear materials are discussed in the proposed nuclear security regime.

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