Nuclear Terrorism: Health and Environmental Hazards and Threats From Ionizing and Nuclear Radiation

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Foreword

After the atrocities of September 11, 2001, Jordan, which has an established reputation for moderation and stability and has itself been a target for terrorism, immediately condemned the attacks against innocent people and confirmed its support for the international coalition against terrorism. His Majesty King Abdullah II has been vocal in denouncing terrorism on the international scene and moved swiftly to join the fight against this phenomenon.

King Abdullah II was the first Arab and Muslim leader to foresee that the world’s realities had changed after September 11. He launched a campaign to highlight the true face of Islam in the wake of the terrorist attacks and was adamant in conveying the genuine religious principles of Islam, pointing out that this monotheistic religion of peace, tolerance, and equality had been “hijacked” by the perpetrators of the September 11th events.

In its international humanitarian efforts of peacekeeping around the world, Jordan was the first and only Arab and Islamic country to deploy a medical mission to Mazzar Al Sharif in Afghanistan. Over a period of 6 months, the Jordanian Armed Forces Medical Services team, composed of 400 army personnel of physicians, nurses, and medical technicians, treated almost 48,000 patients. A state-of-the-art field hospital containing 70 beds, equipped with two operating rooms, and having intensive-care units was established. It also contains sections for men, women, pediatrics, maternity, and various specialties, including dermatology, with a capacity of 10 surgeries and 500 outpatient visits daily. At the same time the hospital runs a training program for doctors, nursing staff, and technicians. This mission is indicative of Jordan’s commitment to help and assist all people who suffered from and were victims to the scourge of terrorism. Jordan has been and will continue to be a moderating and trusted force in the search for global peace.

Introduction

The skin plays a vital role as a barrier between the homeostatically maintained and permanent internal environment and the potentially toxic and hostile external environment. The damaging effects of human activities and pollution of the atmosphere are on the increase. The problem of ozone-layer depletion in the stratosphere by chemicals is a major crisis facing our environment. Scientists and physicians need to pay more attention to environmental factors, as well as the added problems of ionizing and nuclear radiation. The potential hazards to health and their effect on nature and life needless to say will affect the health of future generations.

Historical Background of Nuclear Weapons and Current International Strategic Issues

With the atomic bombing of Hiroshima and Nagasaki in 1945, a new era of warfare became a reality. Almost two decades later, President John F. Kennedy would forecast that by the 1990s, >20 countries worldwide would possess nuclear weapons. Within a few years of that prediction, the international community had taken decisive steps toward altering that nuclear nightmare through endorsement of the “Treaty on the Non-Proliferation of Nuclear Weapons” and other similar regional treaties. The International Atomic Energy Agency (IAEA) has been the instrument of government safeguards. Despite the IAEA, the arms race among the big powers has continued, often leading to the building of arsenals of conventional arms and other weapons of mass destruction: chemical, biologic, and nuclear.

The shaping of super-power nuclear arsenals has now changed. Assuming that the Start-2 treaty clears the Russian Duma and that Start-3 follows, by the year 2007 Russia and the United States will have decreased their nuclear weapons to 2,000–2,500 each (down from
45,000 and 30,000, respectively, at their peak). It would then make sense for the smaller Chinese, French, and British arsenals to be reduced.6

Fear about the spread of weapons of mass destruction and the missiles to deliver them have, if anything, intensified. The collapse of the Soviet Union brought with it the danger that ex-Soviet weapons scientists might use their skills abroad in conflicts such as has occurred between India and Pakistan. Other potential “hot spots” include the Korean peninsula, the Middle East, and the borderless terrorist organizations such as Taliban, al Qaeda, and Osama bin Laden, that might have the ability to obtain missiles that carry chemical, biologic, or nuclear weapons.7–9

Nuclear Terrorism

The terrorist assault on September 11, 2001, has awakened the world and in particular America to the absolute reality of mega-terrorism that might kill millions of people at a single stroke.10 Graham Allison, director of the Belfore Centre for Science and International Affairs at Harvard University’s Kennedy School and author of Avoiding Nuclear Anarchy (MIT Press, 1991), believes that even in the midst of the current crisis, responsible leaders must acknowledge the possibility that much more catastrophic terrorist acts may yet come. It is easy to put one’s hand on and steal radioactive material, but it is not as easy to make a nuclear weapon without the help of scientists and a country or an organization.

A crude nuclear device could create an explosive force of 10,000–20,000 tons of TNT, which might kill millions. The fear of having weapons of mass destruction in Russia that could be stolen and then sold to terrorist groups or states is possible. It is believed that 40,000–80,000 nuclear weapons and weapons–usable material created in the Soviet Union were poorly controlled and stored; these could be stolen and available for sale. After the fall of the Soviet Union, there were incidents in which individuals and groups succeeded in stealing weapons material from Russia. In 1999, ~1,000 pounds of highly enriched uranium material, sufficient to build 20 nuclear weapons, were found in Kazakhstan. Terrorists groups have unsuccessfully attempted to break into Russian nuclear-storage sites. The dual challenge is that plutonium, an accumulation originating from nuclear programs, is an available energy source and could be used for the production of nuclear weapons (1 g of plutonium is equivalent to about 1 ton of oil).11

The Baker-Cutler Task Force to make secure all nuclear weapons and material as fast as possible has recommended the following safeguards12: (1) make nuclear weapons and nuclear materials safe; (2) dispose of all extract highly enriched uranium not needed for weapons; (3) control stores of excess Russian plutonium; (4) reduce the Russian nuclear complex.

In the aftermath of the terrorist attacks of September 11, 2001, on New York City and Washington, many started to think that a more horrible possibility could happen if terrorists were to obtain weapons of mass destruction, whether chemical, biologic, or even nuclear. A report released in December 2000 by the Central Intelligence Agency’s National Intelligence Council concluded that some terrorists or insurgents will attempt to use weapons of mass destruction against US interests, the United States itself, its forces and facilities overseas, or its allies.13 It is also expected that some countries that harbor terrorists might help them obtain access to weapons of mass destruction, in addition to support given to some terrorist groups in the form of finance and training. Recent terrorism has been shown to include suicide bombing and suicide attacks by airplanes on civilian targets. In the future, this kind of terrorism might include the use of nuclear material in addition to both chemical and biologic agents.

Nuclear Science and Technology

Nuclear science and technology have developed through contributions of scientists from ~100 countries and 17 cooperating international organizations. The International Nuclear Information System database is compiled, checked, and maintained by the IAEA based in Vienna, Austria, which is an autonomous intergovernmental organization within the United Nations system. The IAEA emphasizes through international coverage the peaceful uses of nuclear science and technology. It is also concerned with nuclear power, physics, chemistry, fusion, life sciences, environmental waste, ionizing radiation, radioisotopes, radiation protection, and safety. The organization covers the legal aspects, sociology, nuclear law, and documentation as well. The first radiation source in history was the x-ray tube, which Karl Wilhelm Röntgen, a German physicist at Würzburg, invented in 1895. In 1934, the first artificial radioactive materials were produced. X-ray epilation of facial hirsutism was frequently used during the first two decades of the 20th century and continued to be so widely used that Cipollaro and Einhorn entitled their article “The use of x-ray for the treatment of hypertrichosis is dangerous.”14 In 1904, use of the x-ray for treatment of tinea capitis was introduced in Paris. As many as 320,000 afflicted children were treated with x-rays between 1904 and 1959, until the discovery of griseofulvin made oral medication preferable. Radiodermatitis, encompassing telangiectasia, cicatricial alopecia, baldness, and malignancies, often occurred.15–17
From Hiroshima and Nagasaki to Chernobyl

The bombing of Hiroshima on August 6, 1945, destroyed 1.8 square miles, killed 40,000 people outright, and injured another 40,000. Many of the injured died a few days, months, and even years after the bombing due to radiation exposure and burns. The energy effects of both bombs were immediate: blast 35%, thermal radiation 60%, and ionizing radiation 5% (80% gamma and 20% neutrons). All of these caused significant destruction within seconds or minutes. The delayed effects were principally radioactive fallout and other possible environmental effects occurring over an extended period ranging from hours to centuries. The bombing of Nagasaki followed on August 9, 1945.

The damage exhibited to manmade structures and other objects by both bombs was the result of the following effects of the explosions: (1) blast, or pressure wave, similar to that of normal explosions (2) primary fires, that is, those fires started instantaneously by the heat radiated from the atomic explosion; and (3) secondary fires, that is, those fires resulting from the collapse of buildings and damage to electrical systems.

The casualties sustained by the inhabitants of both cities were due to (1) flash burns caused directly by the almost-instantaneous radiation of heat and light at the moment of explosion; (2) burns resulting from the fires caused by the explosion; (3) mechanical injuries caused by the collapse of buildings and flying debris and the forcible hurling of persons struck by the blast pressure wave; (4) radiation injuries caused by the instantaneous penetrating radiation (in many respects, similar to excessive x-ray exposure). The skin was the organ most vulnerable to radiation. The first stage of skin reaction was erythema, followed by acute exudative radiodermatitis that often became chronic radiodermatitis. This condition preceded ulceration, necrosis, atrophy, and scarring. Keloid formation was a common late development among the Japanese victims.

There has been great difficulty in estimating the total casualties in the two Japanese cities due to the atomic bombing. The explosive destruction of civil installations (hospitals, fire and police departments, and government agencies), the state of utter confusion immediately afterward, and the uncertainty regarding the actual population before the bombing all contribute to the difficulty of making accurate estimates of casualties. The total numbers, however, were 255,000 in Hiroshima and 195,000 in Nagasaki between the dead and injured.

Chernobyl Accident

The world’s worst nuclear-plant accident happened in 1986 in Chernobyl, Ukraine, and released radiation 200 times the level of the combined radiation released by the atomic bombs dropped on Hiroshima and Nagasaki in 1945. The accident had a profound effect on communities worldwide and continues to have great psychological, health, and social repercussions in the world until today.18

The accident happened because of overheating of the nuclear fuel, which then set fire to the graphite mass in the reactor. The fire destroyed much of the fuel, and radioactive fission products were carried in the flue gases to a height >1,000 m from the site, from where it was dispersed and fell to the ground as dry or wet fallout within a 30-km radius. Because of two chemical explosions, radioactive substances were also ejected onto the roofs of the plant buildings and into the environment.

Of the 400,000 people once living within the 30-km zone, 135,000 relocated because of the explosion.19 Workers who tried to extinguish the graphite fire at the reactor died immediately from radiation poisoning. Twenty-eight firefighters died of radiation sickness in the first 3 months, in addition to the few who died immediately of heart attacks. Another 31 people were killed in the acute phase of the accident, receiving radiation doses in the range of 4,000–16,000 mSv. Hundreds of people were heavily exposed to radiation or injured, in addition to the 237 people who suffered from acute radiation poisoning and were hospitalized.

Some 800,000 people were hired or ordered to collect the radioactive material, which had been spread across the whole area, and were subsequently exposed to radiation. The Chernobyl accident led to many psychosomatic complaints, dermatologic problems, headaches, nausea, diarrhea, and insomnia. The substantial radioactive emissions of the accident persisted for 10 days. Most of the nuclear contamination occurred in the surrounding area of Belarus, but changing wind direction badly affected parts of the Ukraine as well, including Kiev, and the Bryansk area of Russia.20 Radioactive iodine, mainly iodine-131 with half-life of 8 days, was the most important source of exposure during the first few weeks after the accident. One thousand cases of thyroid cancer in children 3–5 years old were detected compared with an expected 0.5 cases per 1 million per year. Ninety percent of the thyroid cancers were of the papillary type, and in most, they were highly invasive and metastasized.21 After the accident, there were 4,000 abortions in western Europe, due to fears of deformities in the offspring caused by nuclear contamination. Children born into families affected by the radioactive fallout from Chernobyl have been found to have germline mutations, although studies carried out on the effects of radiation after the bombs at Hiroshima and Nagasaki have never shown germline mutations.

Radiation Sources

The health risks from radiation include the following sources22:
1. Natural radiation, which is cosmic and is due to radon, a gaseous substance that forms as the metal radium decays. Solar terrestrial radiation is natural and present everywhere. These come from the ground, stones, buildings, and even from friends. Radiation-meter devices and other equipment have demonstrated the presence and intensity of radiation in nature. There is even some exposure for those remaining inside a building.

2. Artificial radiation, which includes substances discharged into the atmosphere through nuclear tests and releases from nuclear-power plants. Some items also contain radioactive substances, such as home smoke detectors and the paints used in luminous watches and measuring instruments, which contain radioactive phosphorus substances in the paint.

3. X-rays used for airport searches, postal examinations, or building inspections.

4. Agricultural radiation used in developing hundreds of new strains of food crops and plants that resist heavy rain, frost, or pests. Foodstuff irradiation also eliminates parasites like *Trichina* and pathologic bacteria like *Salmonella*. Irradiated food does not become radioactive itself and presents no risk to the consumer.

5. Radiation used to sterilize equipment, such as surgical instruments and gloves, that cannot withstand heat. Certain drugs are also irradiated for better preservation and to eliminate bacteria.

6. Dumping and burying of nuclear waste into the sea or deep underground, which will eventually disintegrate and lead to nuclear pollution.

7. Diagnostic use, such as mammography, magnetic resonance imaging, and radiocontrast agents.

### Types of Radiation

The types of radiation include the following:

1. Alpha radiation is particulate, being the nuclei of helium. The atoms of heavy elements such as uranium, radium, and radon emit them. They have a high linear-energy transfer and poor penetration because they cannot travel more than a few centimeters and are blocked totally by the epidermis of the skin.

2. Beta radiation consists of smaller electrons and can be generated from radioactive isotopes, such as radioactive strontium, or produced in a linear accelerator. They are able to penetrate a little deeper than alpha radiation. The energy of electrons is almost totally absorbed at a depth proportional to the given voltage. Sheet metal, window glass, and ordinary clothing can stop beta radiation. It is possible to irradiate the whole skin area with an electron beam. The minimal depth-dose characteristics that may be achieved avoid the irradiation of subcutaneous structures, which would occur if x-ray therapy, which is absorbed exponentially, were used. This technique is used in the treatment of some skin diseases like mycosis fungoides. Electron beam therapy is used to irradiate skin cancers at sites where the malignant lesion to be treated is large or overlies cartilage or bone. The mode of absorption of high-energy x-rays produced from a linear accelerator or of gamma rays is relatively independent of the atomic number of the tissue irradiated. Low-voltage x-rays are absorbed disproportionately in high-atomic-number materials. During the Chernobyl nuclear-power-plant accident in 1986, very strong beta-radiation exposure burned the skin of firefighters.

3. Gamma radiation is produced by the decay of radioactive substances, either naturally occurring, such as radium, or from manmade isotopes, such as radioactive cobalt and iridium. Its range in air is long, and its penetration power is substantial. It causes interaction with internal body cells. Radioactive isotopes may be used for interstitial therapy by utilizing the rapid decrease in dose with distance from the source to achieve a restricted high-dose area in tissues. Lead and concrete are excellent barriers for gamma radiation.

4. X-ray radiation is similar to gamma and is emitted by nuclei, can be produced artificially in an x-ray tube that itself is not radioactive, and can be electrically operated and controlled.

5. Neutron radiation is more penetrating than gamma rays and can be stopped only by thick concrete, water, or paraffin barriers. Neutron radiation only exists close to nuclear reactors and nuclear fuel.

6. Grenz rays (“borderline” in German) are the most poorly penetrating ionizing rays, which are in the 6–15-kV range and are at the borderline with non-ionizing radiation. Ninety percent of the radiation is absorbed in the upper 1 mm of the skin.

### Utilization of Radiation

Any material, including living cells, absorbs radiation. Each kilogram of material absorbs energy (joules), and in terms of radiation protection, the unit is called the gray (Gy). One Gray of alpha radiation is ~20 times more intense than 1 Gy of gamma radiation, which is a biologic risk.

Occupational exposure to radiation should not be higher than a formula called mSu, which means “the radiation weighting factor.” The dose limits for the public are lower. For patients who are exposed to x-ray examinations, they receive higher doses, but in radiotherapy, doses are 100 times greater. Dosimeters based on photographic films in a lightproof casing are always needed to measure radiation doses. Electronic dosimeters are carried by persons at high radiation risk at nuclear-power stations and research institutions.
Reactions to Radiation

The reaction to radiation depends on the number of doses and the duration of exposure:

1. With small doses of radiation, erythema, burns, ulcerations, a delay in healing, temporary alopecia, nausea, vomiting, headache, fatigue, diarrhea, and fever occur, in addition to a temporary drop in the leukocyte count.

2. With higher doses of radiation, the lymphocyte and thrombocyte levels drop severely, and bleeding occurs. There will also be an increase in the risk of current infection.

3. Even higher doses may lead to death, secondary to intestinal mucosal membrane damage, dehydration, and central nervous system damage. High radiation also causes sterility and malignancies. The nuclear radiation in Hiroshima and Nagasaki caused 20,000 cancer cases per 100,000 population. In Chernobyl, it caused 1,000 cases of thyroid cancer.

Protection from Radiation

The review of global developments in nuclear and radiation safety is continuous, focusing on the many activities being undertaken jointly by regional and international organizations. The topics of review include efforts to enhance and raise the level of safety of power plant sites. The regulations in the Code of Practices regarding radiation safety are strict. The exposure of paramedical personnel to ionizing radiation with poor protection standards could be dangerous, especially the late radiation effects causing carcinogenesis.

Many people die every year of radiation sickness or reduced immunity directly related to too many unnecessary x-ray examinations. Some of the causes of high deaths in Russia, for example, are due to faulty equipment, outdated attitudes to health care, inadequate training in hospitals and x-ray departments, and inadequate shielding from radiation. In 1978, the US Food and Drug Administration sat a multidisciplinary committee on radiation therapy, with the following recommendations as described by Goldschmidt:

1. The potential risk of treatment with any form of radiation of a benign, non-life-threatening disease must be recognized. Ionizing radiation therapy may be considered if other, safer methods have not succeeded in alleviating the condition and if the consequences of no further treatment are unacceptable. This should not lead to an overreaction about the presumed risks of radiation, where the known risks of radiation may be traded off against the unknown risk of some other therapeutic modality.

2. The Committee strongly endorsed the concept that it must remain the prerogative of the physician to have available for use any form of therapy—radiation, drug, or others—in which the benefits accruing to the patient from its use are considered to outweigh the risks inherent in its use.

3. Infants and children should be treated with ionizing radiation only in very exceptional cases.

4. Direct irradiation of the skin areas overlying organs that are particularly prone to late effects, for example, thyroid, eyes, gonads, bone marrow and breast, should be avoided.

5. Medical practitioners who use ionizing radiation should be adequately trained in both the practical and theoretical aspects of radiation therapy and protection.

6. Meticulous radiation protection techniques should be used in all instances.

7. The depth of penetration of the x-ray beam should be chosen in accordance with the depth of the pathologic process.

8. Laboratory and epidemiologic studies should be initiated and/or continued to fill the gaps in our knowledge of the effects of ionizing radiation at the doses used in the past and present.

Conclusions

Radiation, whether ionizing or nuclear, is recognized to be hazardous to health, nature, and the environment. The IAEA guidelines and safeguards are important and intended to assist governments and to enjoin them on the obligations arising from safeguard agreements.

We should admit that changing our global perspectives on science and technology that serve our communities is becoming mandatory. This includes the technical and commercial development of radiation material significantly. At the same time, we have to face the rising demands for energy from different sources, including nuclear power. We are also facing major health and environmental challenges that can be dealt with by considering nonproliferation and safeguard aspects so as to produce a common international understanding and cooperation. Technology transfer in the prevention and management of ionizing and nuclear radiation and radioactive waste is essential. It is, in the end, the moral and ethical commitment of individuals, governments, and world leaders that will prevent the spread, abuse, or misuse of nuclear, chemical, and biological weapons. It means to abolish the threat to survival of the human race and avoid the destruction of life on our planet. As ex-Crown Prince of Jordan El-Hassan bin Talal has stated in the Report of the Independent Commission on International Humanitarian Issues, humanitarianism is the basic orientation toward the best interests and welfare of all people. It demands that whatever detracts from human well-being must be questioned, regardless of its effects on economic growth, political power, or the stability of a certain order.
References