ENHANCING "STREET-LEVEL" FIRST RESPONDER TRAINING AND COMMUNICATION WHEN ENCOUNTERING BIOLOGICAL, CHEMICAL AND RADIOLOGICAL AGENTS

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ABSTRACT

Following an emergency such as a fire, a vehicle rolling over and spilling its contents, or encountering chemical incompatibilities, first responders (FRs), usually employed by a local police or fire department, are trained to respond to the event and mitigate the hazards accordingly. However, after the events of September 11, 2001, FRs are now faced with the possibility of encountering a Weapon of Mass Destruction (WMD) that combines conventional explosives, such as dynamite, with radioactive materials.

Since radiation cannot be detected by the human senses, even experienced FRs may be hesitant to proceed because of encountering radioactive materials yielding a high dose rate. Although external and internal monitoring is performed, a combination of engineering, administrative (e.g., Protective Action Guides) and personal protective equipment (PPE) controls can reduce exposure to all three agents. In addition, decontamination is an important precaution to remove any contamination that may have accumulated on the outer layer of PPE or clothing. Radioactive material shipments must follow Department of Transportation regulations using institutions that are authorized to receive and possess radioactive material. This paper provides information to enhance "street-level" FR training and communication when encountering biological, chemical and radiological agents, specifically, the "dirty bomb" scenario which is most unique to FRs. In addition, protecting FRs and the general public against a "dirty bomb" scenario will provide equal, if not greater, protection against chemical and biological weapon scenarios. Therefore, threats from a WMD can be quantified and mitigated accordingly without putting the FR or the general public in any unnecessary danger.

INTRODUCTION

Following an emergency such as a fire, a vehicle rolling over and spilling its contents, or encountering chemical incompatibilities, first responders (FRs), usually employed by a local police or fire department, are trained to respond to the event and mitigate the hazards accordingly. Additional training often includes stabilizing or treating injured members of the general public at the scene prior to transporting them to a hospital or medical facility. Based on these types of scenarios, FRs are trained to use the appropriate personal protective equipment (PPE) to prevent injury and exposure to themselves (1). The source terms consist of a wide variety of chemicals, chemical compounds, mixture of compounds, pathogens displaying certain physical and/or health hazards, and characteristics such as:

- A flammable or combustible liquid,
- A compressed gas,
- An organic peroxide,

- An explosive,
- An oxidizer,
- A pyrophoric,
- An unstable reactive material,
- A carcinogen,
- A reproductive toxicant,
- Chemicals with a high degree of acute or chronic toxicity, or
- Bloodborne pathogens.

The Occupational Safety and Health Administration (OSHA) (2, 3) and Centers for Disease Control and Prevention (CDC) (4) have established lists of hazardous chemical agents and substances based on substantiated tests.

A WEAPON OF MASS DESTRUCTION (WMD)

After the events of September 11, 2001, FRs are now faced with the possibility of encountering situations involving a Weapon of Mass Destruction (WMD). This term and its associated acronym received its notoriety primarily from the media. Interestingly, U.S. law had already promulgated a definition in 1992, as follows:

> *The Weapons of Mass Destruction Control Act of 1992, Title XV of the Defense Authorization Act of 1993*, P.L. 102-484 (enacted October 23, 1992), relates "to the proliferation of nuclear, biological, and chemical weapons (weapons of mass destruction) and their related technology . . ." (5)

A FR's basic training already addresses chemical and biological weapon scenarios, i.e., chemical hazards, bloodborne pathogens, toxins and explosives. However, terrorist attacks involving radioactive materials, most likely through the use of a "dirty bomb," and the effects of radiation from such an event create a unique situation. Experienced FRs may be hesitant to proceed because of encountering radioactive materials yielding a high dose rate.

This paper provides information to enhance "street-level" FR training and communication when encountering a "dirty bomb" scenario, which is most unique to FRs. The required training and PPE associated with protecting oneself against this type of scenario will provide equal, if not greater, protection against chemical and biological weapon scenarios. In addition, this information will be useful for local fire and police departments and other community support organizations when encountering a "dirty bomb" and other types of scenarios.

WHAT IS A "DIRTY BOMB"?

A "dirty bomb," or radiological dispersion device (RDD), is a bomb that combines conventional explosives, such as dynamite, with radioactive materials in the form of powder or pellets. In most instances, the conventional explosive can cause far more damage and injury than the radioactive material. The radioactive material would be dispersed into the air and ground surface causing panic and frightening people making them believe buildings or land would be unusable for long periods of time. The low amounts of radioactivity and radiation levels created by most probable sources would not be enough to kill people or cause severe illness. According to a United Nations report, Iraq tested a "dirty bomb" device in 1987, but found that the radiation levels were too low to cause significant damage. Thus, Iraq abandoned any further use of the device. Nevertheless, the extent of contamination would depend on a number of factors including the size of the explosive, the amount and type of radioactive material used, and weather conditions. Prompt, accurate, non-emotional public information might prevent the panic sought by terrorists, and detecting the kind of radioactive material employed in the explosion would greatly assist local authorities in advising the community on protective measures, such as quickly leaving the immediate area or going inside a building until being further advised. Subsequent decontamination of the affected area could involve considerable time and expense.

Another scenario involves concealing a powerful radioactive source in a public place, such as a trash receptacle in a busy train or subway station, where people passing close to the source might receive a significant external radiation dose. In order to achieve this scenario, subversive organizations would have to confiscate a concentrated radioactive source from an irradiation, sterilization or medical therapy facility. Invasive activities such as removing several layers of shielding surrounding the source would be required to access the actual radioactive material (6, 7).

Although not for terrorist reasons, this scenario actually occurred on September 13, 1987 in the city of Goiania in Central Brazil. Approximately 250 people were exposed to a 50.9-tera-Becquerel (1,375.8-curie) Cs-137 source from an abandoned radiotherapy unit. At least 14 patients showed some degree of bone marrow depression and eight developed the classic signs and symptoms of significant radiation exposure. Twenty-eight people presented local radiation injuries and 104 individuals showed evidence of internal contamination mainly due to ingestion or absorption of Cs-137 (8).

Biological Effects of Ionizing Radiation

Radiation injuries are primarily caused by ionizations within the tissues of the body. When radiation interacts with a cell, ionizations and excitations are produced either in biological macromolecules or in the medium in which the cellular organelles are suspended, predominantly water. Based on the site of interaction, the radiation-cellular interactions may be termed as either direct or indirect. Direct action occurs when an ionizing particle interacts with, and is absorbed by, a macromolecule in a cell (Deoxyribonucleic acid [DNA], proteins, enzymes, etc.). These macromolecules become abnormal structures, which initiate the events that lead to biological changes. Indirect action involves the absorption of ionizing radiation in the medium in which the molecules are suspended. The molecule that most commonly mediates this action is water. Through a complex set of reactions the ionized water molecules form free radicals that can cause damage to macromolecules. The most important target for radiation in the cell is DNA in the nucleus. Biological effects result when DNA damage is not repaired or is improperly repaired. Extensive damage to DNA can lead to cell death. Large numbers of cells dying can lead to organ failure and death for the individual. Damaged or improperly repaired DNA may develop into lymphoma and cancers in somatic cells. The assumed risk associated with chronic, low-level occupational radiation dose is an increased risk of cancer. The known risks associated with acute, high-level radiation doses can include radiation sickness and death. Table I summarizes the effects of acute radiation doses to humans.

Table I Effects of acute radiation doses to humans

Radiation Dose	Effects
100 Grays (Gy) (10,000 rads); single dose, whole body	Death occurs within hours from apparent neurological and cardiovascular breakdown (Cerebrovascular syndrome).
5 - 12 Gy (500 – 1,200 rads); single dose, whole body	Death occurs within days and is associated with bloody diarrhea and destruction of the intestinal mucosa. (Gastrointestinal syndrome).
2.5 - 5 Gy (250 - 500 rads); single dose, whole body 50% death rate	Death occurs several weeks after exposure due to damage to bone marrow (Hematopoietic syndrome).
0.5 - 3.5 Gy (50 – 350 rads) and higher; single dose, whole body	Can produce various degrees of nausea, vomiting, diarrhea, reddening of skin, loss of hair, blisters, depression of immune system.
1 Gy (100 rads); Single dose, whole body	Mild radiation sickness, diminished white blood cell count.
4 - 5 Gy (400 - 500 rads); local, low energy x-ray	Temporary hair loss.
6 - 9 Gy (600 - 900 rads); local to the eye	Cataracts.
5 – 6 Gy (500 - 600 rads) to skin; local single dose, 200 keV	Threshold erythema in 7 - 10 days, followed by gradual repair and dull tanning.
15 – 20 Gy (1500 – 2000 rads) to skin; local single dose, 200 keV	Erythema, blistering, depressed scar.
0.25 Gy (25 rads); single dose, whole body	Lymphocytes temporarily disappear from circulating blood.
0.1 Gy (10 rads); single dose, whole body	Elevated number of chromosomal aberrations in peripheral blood; no other detectable injury or symptoms.

Therefore, if FRs were to receive acute radiation doses in excess of the occupational limit during a radiological emergency, the onset of first observable effects, diminished red blood cell count, may occur at a dose of approximately 1 Gy (100 rads). The lethal dose for humans where 50% of the exposed population may die from a one-time dose of the whole body (LD_{50}) is about 5 Gy (500 rads), assuming no medical intervention.

"Dirty bombs" versus "atomic bombs" in Hiroshima and Nagasaki

For purposes of comparison and clarification, a "dirty bomb" is in no way similar to a conventional nuclear weapon. The nuclear explosions that occurred in Hiroshima and Nagasaki were conventional nuclear weapons involving a fission reaction. A "dirty bomb" is designed to spread radioactive material and contaminate a small area. It does not include the enriched uranium-235 or plutonium-239 necessary to create a large detonation like those seen in Hiroshima and Nagasaki. Therefore, the presumed purpose of a "dirty bomb" would not be as a Weapon of Mass Destruction but rather as a Weapon of Mass Disruption.

Sources of radioactive material

There is continued speculation regarding how and where terrorists can obtain radioactive material to place in a "dirty bomb." The most concentrated radioactive materials yielding a high dose rate are found in nuclear power plants and nuclear weapons sites. However, increased security at these facilities makes obtaining materials from them very unlikely (9). Because of the dangerous and difficult aspects of obtaining high-level radioactive materials from a nuclear facility, there is a greater chance that the radioactive materials used in a "dirty bomb" would come from other sources. These sources are widely used in hospitals, research facilities, construction sites, and at food irradiation plants. The sources are used for diagnosing and treating illnesses, sterilizing equipment, measuring either the density or thickness of materials, inspecting welding seams, and irradiating food to kill harmful microbes. For example, the Nuclear Regulatory Commission (NRC), together with 32 states that regulate radioactive materials, have over 21,000 organizations licensed to use such materials. However, the vast majority of these sources are neither very useful nor practical for constructing a "dirty bomb" or RDD because of their low abundances, short half lives, and non-penetrating decay energies. However, typical "process" mega-curie sources considered for a "dirty bomb" scenario would likely consist of cobalt-60, strontium-90/yttrium-90, cesium-137/Ba-137m and iridium-192. Table II provides information about possible "dirty bomb" sources, their half lives and decay energies.

Table II Characteristics of possible "Dirty Bomb" sources (10)

Radionuclide	Half Life	β-avg, Decay/Energy	γ Decay/Energy
Cobalt-60	5.27 years	β-avg, 95.8 keV (99.9%)	1173.2 keV (99.9%) 1332.5 keV (99.9%)
Strontium-90 & Y-90	28.74 years 64.10 hours	β-avg, Sr-90, 195.8 keV (100%) β-avg, Y-90, 933.7 keV (99.9%)	None
Cesium-137 & Ba-137m	30.04 years 2.55 minutes	β-avg, Cs-137, 174.3 keV (94.4%) β-avg, Cs-137, 416.3 keV (5.6%)	661.6 keV (85.1%) from Ba-137m
Iridium-192	73.83 days	β-avg, 209.9 keV (48.0%) β-avg, 162.1 keV (41.4%) β-avg, 71.6 keV (5.6%)	316.5 keV (82.7%) 468.1 keV (47.8%) 308.5 keV (29.7%) 296.0 keV (28.7%) 604.4 keV (8.2%) 612.5 keV (5.3%) 588.6 keV (4.5%)

Controlling access to radioactive sources

In order to prevent radiation injuries, the NRC and state regulations require licensees to secure radioactive material from theft and unauthorized access. These measures have been enhanced since the attacks of September 11, 2001. Licensees must promptly report lost or stolen material, and local authorities must make a determined effort to find and retrieve such sources. Most reports of lost or stolen material involve small or short-lived radioactive sources not useful for an RDD.

Past experience suggests there has not been a pattern of collecting such sources for the purpose of assembling a "dirty bomb." Only one high-risk radioactive source comprised of iridium-192 has not been recovered in the last five years in the United States. However, this source would no longer be considered a high-risk threat because much of the radioactivity has decayed away since it was reported stolen in 1999. In fact, the combined total of all unrecovered sources over a 5-year time span would barely reach the threshold for one high-risk radioactive source.

In order to aggressively recover and manage the estimated 18,000 sealed source devices that will become excess and unwanted over the next decade, the Off-Site Source Recovery (OSR) Project operating from Los Alamos National Laboratory recovers and manages unwanted radioactive sealed sources and other radioactive materials. These items: 1) present a risk to public health and safety, 2) present a potential loss of control by a Nuclear Regulatory Commission (NRC) or agreement state licensee, or 3) are in excess, unwanted and are owned by the Department of Energy (DOE) (11).

PROTECTION OF FIRST RESPONDERS AND THE GENERAL PUBLIC

The approach to any potentially hazardous substance must be made with a plan that includes an assessment of, and protection against any hazard and exposure potential, including the use of respiratory protection, entry conditions, boundary controls, exit routes, and decontamination strategies. Therefore, any plan involving a chemical, biological or radiological hazard should be based on relevant safety recommendations by the CDC (6) and professional organizations such as the Health Physics Society <www.hps.org>. Nevertheless, by taking a conservative approach to protect FRs against external and internal radiological hazards associated with a “dirty bomb” scenario, FRs would be adequately protected against any chemical and biological hazards as well.

PROTECTING AGAINST EXTERNAL AND INTERNAL RADIOLOGICAL PATHWAYS

Coming in contact with radioactive materials can result in external and internal doses. Each pathway must be evaluated carefully and precautions must be taken prior to handling these materials directly.

External Radiation Hazards and Personnel Monitoring

External radiation hazards arise when radiation from an external source causes either a localized or a whole body dose. These doses can be from X rays, gamma rays, neutrons, or beta particles; they are dependent upon both the type and energy of the radiation. X and gamma rays, along with neutron radiation, are very penetrating and are of primary importance when evaluating shielding requirements.

Most beta particles do not normally penetrate beyond the skin, but when sufficiently intense, can cause skin and/or eye damage. Very energetic beta particles, such as those emitted by yttrium-90, can penetrate several millimeters into the skin. Shielding would be needed in order to reduce the external radiation exposure. Typically, a maximum of 1.3 cm- (0.5 inch-) thick sheet of plastic (e.g., Plexiglas®) is an effective shield for most beta particles.

Alpha particles, because of higher mass, slower velocity and greater electrical charge compared to beta particles, are capable of traveling only a few centimeters in air and rarely penetrate the outer dead skin layer of the body. Therefore, alpha particles typically are not an external radiation hazard. Still, external radiation doses can be controlled by limiting the time allowed in the radiation field, working at a distance from the source of radiation, and inserting shielding between the FR and the source, i.e., time, distance and shielding.

In the commercial and governmental sectors, thermoluminescent dosimeters (i.e., TLDs) are worn by employees handling radioactive sources. The purpose of the TLD is to provide legal documentation of an employee’s whole body dose while working with radioactive materials during a given situation. The TLDs are exchanged every quarter. However, TLDs are not very practical during emergency situations, especially when trying to locate a lost radioactive source. Since it can take up to 24 hours to analyze and report a person’s whole body dose from a TLD, situations like this require real-time information. Therefore, a direct-read dosimeter, such as an electronic pocket dosimeter (EPD), is used to record the dose from X rays and gamma radiation in real time. An EPD has a digital display and is more durable (e.g., shock resistant) than pocket dosimeters. In addition, the EPD will alarm (i.e., chirp) when either a preset dose limit or dose rate is exceeded, thereby notifying a FR immediately if they are entering a high radiation field.

Internal Radiation Hazards and Personnel Monitoring

Radioactive materials may be deposited internally when an uptake occurs through the following routes of entry: inhalation, ingestion, and absorption/injection through skin contact. Although external doses are primarily caused by X rays, gamma rays, high-energy betas and neutrons, all forms of radiation (including low-energy beta, gamma and alpha emitters) can cause internal radiation doses. Once these particles get inside the body, damage can occur since there is no protective dead skin layer to shield the organs and tissues. Alpha particles, when inhaled or ingested, create a high concentration of ions along their path and thus cause severe damage to internal organs and tissues. Also, internal doses are not limited to the intake of large amounts of radioactive materials at one time (i.e., acute exposure). Chronic exposure may arise from a gradual accumulation and intake from small amounts of radioactive materials over a long period of time. In addition, radioactive materials taken into the body will accumulate in certain body organs. For example, iodine will accumulate in the thyroid gland. When iodine is inhaled or ingested, the body cannot distinguish stable iodine from radioactive iodine; a significant portion of the inhaled iodine will be deposited in the thyroid gland within 24 hours.

Other elements such as calcium, strontium, radium and plutonium accumulate in the bones. Here, high doses to bones can occur over very long periods of time since the body eliminates these materials very slowly once they are incorporated into the bone structure. The blood-forming organs, such as the bone marrow, are very radiosensitive since bone marrow cells are in the S-phase of mitotic activity more often than other cells. Hence, if there is a significant long-term exposure to radioactive materials, chronic diseases such as leukemia and/or osteosarcoma can occur. The induction time for the onset of these types of diseases is typically in excess of 20 years. A rule of thumb used to assist in biological risk assessment for radiation is the Law of Bergonie and Tribondeau. It states that most mature cells are radioresistant, while all immature cells are very radiosensitive. It is very important for FRs to be aware of these hazards and take precautions to prevent exposures. Monitoring for internal deposition of radioactive materials is commonly performed by either direct (*in vivo*) measurements of radioactivity in the body or indirect (*in vitro*) measurements of material excreted or removed from the body. Based on the amount measured using either of these two techniques, an internal dose can be determined and assigned to the FR.

Control Measures: Engineering, Administrative and Personal Protective Equipment

Engineering controls, administrative controls and personal protective equipment (PPE) controls are used to reduce FR exposure to biological, chemical or radiological constituents, as follows:

Engineering Controls: These controls reduce doses by modifying the source or reducing the quantity of contaminants released into the environment. For example, the use of remote operations to handle sources, the use of shielding or ventilation to minimize airborne constituents can reduce external and internal doses to FRs and the general public.

Administrative Controls: The overall objective of protective actions and protective action guides is to minimize radiation doses to FRs and the general public. Depending on the type of radioactive hazard, different protection guidelines and techniques may be used. For example, employee doses can be controlled by job rotation or time spent away from the contaminant of concern. Information is typically disseminated using standard operating procedures, chemical hygiene plans, and safety manuals.

However, certain situations may require a FR to receive a significant whole body dose in excess of the 0.05 Sievert-per-year (5 rem-per-year) limit in order to save a human life, minimize significant dose to others, or protect major property typically valued in excess of $100,000 (12). Participation is strictly voluntary. The FR would need to be briefed on the hazards and understand the risks associated with this type of rescue. In all cases, the expected dose, typically 0.1-0.25 Sv (10-25 rem), shall be justified by the importance of the emergency tasks to be performed. From both an injury and a radiation dose viewpoint, for example, the decision to rescue a person from a high-radiation field should be made promptly to maximize the chance of survival. Rescues should only be authorized if it is possible to estimate the dose to the FR using direct-read survey instrumentation (refer to Monitoring for Radioactive Materials discussed below). During an on-site emergency, the Incident Commander (IC) has the highest level of authority and shall direct the emergency response actions (1). Throughout the emergency, the FRs act as a valuable technical resource to the IC through communication and feedback.

Personal Protective Equipment (PPE): Personal safety equipment is designed to protect the FR from hazardous constituents. Typically, FRs use self-contained breathing apparatus (SCBA) respirators with a full facepiece operated in the pressure demand mode. This type of SCBA is used when hazards and airborne concentrations are either unknown or expected to exceed pre-determined limits (4) and thus provides the highest level of protection against any biological, chemical, or radiological airborne hazard. Under these conditions, the SCBA reduces exposure to the hazard by a factor of at least 10,000. This reduction is true whether the hazard is from airborne particles, a chemical vapor, or a gas. Respirators providing lower levels of protection are generally allowed once conditions are understood and airborne hazards have been quantified and reduced to lower concentrations.

FR may use the SCBA in conjunction with a Level A fully-encapsulated protective suit in responding to an unknown suspected agent. Also, FRs may use a Level B protective suit with an SCBA if the suspected agent is no longer being generated. Full-facepiece respirators or powered air-purifying respirators (PAPRs) with high-efficiency particulate air (HEPA) filters can be used as an alternative when the airborne hazards have been quantified. Methods for justifying various levels of PPE have already been addressed elsewhere by Hylko, Thompson, Walter and Deecke (13).

There is the potential for FRs wearing layers of PPE while working in a hot environment and be affected by heat stress. Contributing factors to heat stress conditions include, for example, heat combined with physical labor, loss of fluids and fatigue. An assessment of each task and time of year (i.e., summer versus winter) can assist in developing a strategy to prevent heat-related problems.

Monitoring for Radioactive Materials

Radioactive material in an unwanted or unplanned location is called contamination. The potential for spreading radioactive contamination on equipment, building surfaces, and the general population is very high following the detonation of a "dirty bomb." Therefore, it will be necessary to monitor these items accordingly. Radiation detection instrumentation used for contamination surveys must therefore be readily available and operating properly to detect contamination. These instruments are very useful when monitoring for alpha, beta and gamma emitters and should alarm when the radiation levels rise significantly or exceed a predetermined action level.

To assure the availability of these instruments, the U.S. Departments of Justice and Energy in a cooperative effort called the Homeland Defense Equipment Reuse (HDER) Program provides surplus radiological detection instrumentation and other equipment to state and local emergency FR agencies nationwide. This agreement enhances domestic preparedness capabilities and is part of the larger federal effort to enhance the equipment and training available to our nation's FRs. Training is available to FRs through the Department of Homeland Security's Domestic Preparedness Equipment Technical Assistance

Program (DPETAP). If requested, DPETAP provides detailed technical information and hands-on equipment operation and maintenance training. Local support for the equipment, including annual calibration, maintenance and follow-up refresher training is available through a partnership with the Health Physics Society <www.hps.org>, a 6,000 member national organization of radiation safety professionals (14). Training in other emergency response areas, such as using industrial hygiene monitoring equipment, explosive detection kits and chemical detection (e.g., HAZCAT) equipment to evaluate non-radiological sources further enhance FR response and mitigation capabilities.

Decontamination

Depending on the weather conditions at the time of an event involving radioactive material, FRs or the general public may be contaminated on their hands, shoes, and exterior clothing from radioactive particulate matter. In addition, support areas handling contaminated patients should be monitored to determine the presence of contamination. If radioactive contamination is found, the area or equipment must be decontaminated. Decontamination removes any biological, chemical or radiological contamination that may have accumulated on the outer layer of PPE or clothing. Decontamination sequences currently used for hazardous material emergencies are performed by dedicated decontamination crews. PPE for decontamination crews should be equivalent to or a maximum of one level below the PPE used for emergency response. For example, if Level B PPE (e.g., SCBAs) is used during the emergency response, either Level B PPE (e.g., SCBAs) or a maximum of one level below consisting of Level C PPE (e.g., PAPRs) will be used by the decontamination crews.

Concentrated liquid decontaminating agents for all types of surfaces, radionuclides, or chemical forms are available from commercial vendors. These agents typically consist of detergents diluted with water to remove all types of contamination rapidly and easily using mild wiping or scrubbing without excessive effort. Foam spray or seal-and-peel decontamination products used on equipment and property should be allowed to cure for a few minutes before they are removed. Material Safety Data Sheets (MSDSs) corresponding to these detergents shall be available for review in accordance with OSHA's hazard communication (HAZCOM) standard (2).

Lukewarm (not hot or cold) water and a mild cleaning agent, such as soap, is used to remove skin contamination. Scrubbing with abrasives are avoided to prevent irritating or breaking the skin surface. The affected area is cleaned in a downwards fashion "going with the grain" of the skin and hair, not against it, and towards the tips of the extremities. A large-scale decontamination of a FR crew and/or the general public can be accomplished using two fire engines or ladder trucks. For example, the trucks are positioned to create a giant shower and thus remove any external contamination. The affected areas would need to be resurveyed after gentle drying. If the affected areas are still contaminated, the cleaning process is repeated. When running water is not readily available, waterless antiseptic hand cleansers, antiseptic towelettes, along with single-use emergency eye wash dispensers can be used as substitutes. FRs should still followup with a soap-and-water wash as soon as feasible after field activities have been completed.

If decontamination capabilities are not immediately available, the radioactive particulate matter can be secured to PPE and clothing using duct tape. In most instances, the individual will not receive a significant exterior whole body dose as compared to a significant internal dose if the material is inhaled or ingested accidentally through resuspension.

Shipping Radioactive Material

All shipments of radioactive materials must comply with Department of Transportation regulations (e.g., container type, labeling) and can only be made to institutions that are authorized to receive and possess radioactive material (15, 16, 17). When shipping to another licensee, prior authorization is required from the Radiation Safety Office (or equivalent point of contact) at the receiving location, preferably the Radiation Safety Officer or designee. License information must be on record or obtained before the shipment is sent in order to keep track of materials once in transit and confirm receipt upon arrival at its destination. To initiate this process, the person sending the material must have the following information:

- The name of the person sending the material,
- Facility name and address,
- The name of the person receiving the material,
- The Radiation Safety Officer's (or designee's) name and phone number,
- The nuclides, activities, and chemical forms, if possible,
- Number of containers in the shipment, and
- Any special conditions.

What the General Public Should Do to Reduce Exposure to a WMD Containing Radioactive Materials

Compared to most biological and chemical agents, the human senses cannot detect radiation. Therefore, if members of the general public are present at the scene of an explosion, they will not know whether radioactive materials are involved. If people are not too severely injured by the initial explosion, they should:

- Leave the immediate area on foot and do not use public or private transportation such as buses, subways, or cars. If radioactive sources were involved in the explosion, the various modes of transportation can spread the contamination.
- Go inside the nearest building. Staying inside will reduce exposure to any airborne radioactive contamination.
- Remove the exterior layer of clothing as soon as possible, place the items in a plastic bag, and then seal the bag to confine the radioactive contamination. Saving the contaminated clothing allows for identifying the radionuclides involved and performing internal and external dose analyses without invasive sampling.
- Shower or wash as soon as possible to reduce the amount of radioactive contamination on the body. This will effectively reduce total exposure to any type of contaminant.
- Stay alert for information updates. Once FRs have assessed the situation, they will be able to determine if radioactive materials were involved in the explosion.

Even if FRs do not know immediately whether radioactive materials were involved, following these steps can reduce exposure from other biological or chemical agents that might be also be present following an explosion (6).

RADIATION RISKS TO FIRST RESPONDERS AND THE GENERAL PUBLIC

Risk studies from exposure to low levels of ionizing radiation (i.e., radiological risk) are continually being studied and revised accordingly. Therefore, in accordance with current knowledge of radiation health risks, quantitative estimation of health risks should not be performed when an individual dose is below 0.05 Sv (5 rem) in one year or a lifetime dose is below 0.1 Sv (10 rem) in addition to background radiation. Risk estimation in this dose range should be strictly qualitative, accentuating a range of hypothetical health outcomes with an emphasis on the likely possibility of zero adverse health effects. The current philosophy of radiation protection is based on the assumption that any radiation dose, no matter how small, may result in human health effects such as cancer and hereditary genetic damage. There is substantial and convincing scientific evidence for health risks at higher doses. Below 0.1 Sv (10 rem), which includes environmental and occupational exposures, risks of health effects are either too small to be observed or are non-existent. This realistic approach of using current knowledge of radiation health risks will help distinguish between perceived radiological risks and real risks from an explosion that, in reality, are materially significant and affect the population directly (18).

CONCLUSION

While being first on the scene, "street-level" FRs are responsible for assessing and mitigating apparent incidents or threats. Therefore, FRs must be adequately prepared and trained to address common threats that typically consist of biological and chemical hazards without putting themselves in danger. Existing FR training (e.g., engineering, administrative and PPE controls) is sufficient to address these common threats. For example, FRs are already highly trained to minimize direct contact with any hazardous substance, use emergency equipment (e.g., fire extinguishers, emergency eyewash and shower stations), and perform decontamination after handling hazardous substances. Some FRs are trained to administer emergency medical treatment and are familiar with symptoms of exposure. These practices are designed to protect and minimize FR health risks as well as protect the general public.

However, scenarios involving WMDs or uncontrolled radioactive sources are very unique to the FR since the human senses cannot detect radiation. FRs must be equipped to address this hazard using direct-read, alarming dosimeters, survey instrumentation, and a proper PPE ensemble using respiratory protection, if necessary. Threats involving radioactive materials can then be quantified and mitigated accordingly without putting the FR or the general public in any unnecessary danger. Furthermore, the decision to authorize doses greater than 0.05 Sv (5 rem) should be voluntary and commensurate with understanding the risks associated with saving a human life, protecting property, or averting additional onsite or offsite doses.

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FOOTNOTE

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