# 16. Chemical, Biological, Radiological, and Nuclear (CBRN)

## A. Hazard Profile

### i. Hazard Description

A hazardous materials (HAZMAT) incident is a situation in which harmful substances are released into the environment. These types of releases are often classified as chemical, biological, radiological, or nuclear—hence the abbreviation CBRN.

The cause of a release may be either accidental or intentional. Accidental incidents may result from human error, tainted food products, technological failure, or a natural disaster and may include spills, leaks, airborne releases, or seepage into uncontained areas. Asbestos released during building demolition or collapse is one example of this kind of incident; oil spills or raw sewage releases are others. A significant number of spills and leaks also result from accidents which occur during the transportation of hazardous materials to and from storage facilities or manufacturing plants. Intentional releases of hazardous materials include criminal acts such as purposeful dumping by industries to avoid regulatory requirements or terrorist acts that target a specific location, possibly involving the use of a dispersal device or explosive. Whether accidental or intentional, the impacts of a CBRN event can be significant.

*Chemical*

A chemical is generally considered hazardous if it exhibits toxicity, reactivity, corrosivity, or flammability. The chemical properties of these substances are such that they can react with and cause damage to living cells and tissue. Exposure pathways include inhalation, skin contact, ingestion, and injection. Commercially or industrially used hazardous chemicals (also known as Toxic Industrial Chemicals, or TICs) that may be released accidentally include petroleum substances (such as oil, gasoline, and liquid natural gas) and those with industrial applications (such as chlorine and pesticides).

Chemical weapons are often classified according to their effect on the body, based on the primary organ system affected by exposure. Nerve agents (e.g., sarin, VX, and VR) enter the body through the skin or lungs and affect the nervous system. Blood gases or systemic agents (e.g., hydrogen cyanide) enter the bloodstream either directly or indirectly and are transported throughout the body. Respiratory agents (e.g., chlorine, phosgene) are inhaled and can cause damage to the lungs. Blister agents (e.g., mustard gas, lewisite) damage the skin, and if they are absorbed they may also affect other parts of the body. Depending on the severity of exposure, impacts may include temporary illness or injury, permanent medical conditions, or death.

*Biological*

Biological hazards include disease-causing microorganisms and pathogens, such as bacteria and viruses. The distinguishing characteristic of these substances is their ability to multiply within a host and cause an infection. Some bacteria and viruses can be spread, or transmitted, from one individual to another. Infections typically occur as a result of airborne exposure, skin contact, or ingestion. In general, exposure to bacteria and viruses may occur through inhalation (as is the case with airborne B. anthracis spores, which cause anthrax), ingestion of contaminated food or water (the case with E. coli, which causes gastrointestinal infection), contact with infected individuals, or contact with contaminated surfaces (which may be harboring, for example, viruses that cause influenza). Ricin, a toxin found in castor beans, is also classified as a biological agent with the potential for use in an intentional attack.

*Radiological*

Radiological hazards involve exposure to harmful doses of radiation. According to the Centers for Disease Control (CDC), "external" radiation occurs when radioactive material in the form of dust, powder, or liquid comes into contact with a person's skin, hair, or clothing. "Internal" contamination occurs when people swallow or inhale radioactive materials. Sources of accidental radiation exposure include underground seepage of naturally occurring radioactive materials (such as radon gas) into homes and leakage from facilities storing radioactive waste (such as spent fuel rods from nuclear power plants).

Intentional releases may come from radiological dispersal devices (RDDs), such as dirty bombs, which trigger small-scale explosions that release radiation. They may also come from radiological exposure devices (REDs), which are not explosive and typically involve the use of a hidden radioactive source designed to unknowingly expose people to radiation.

The health effects of radiation depend on many factors, including the type of radiation, exposure pathway, concentration and amount of exposure, and duration of exposure. Large exposures delivered over a short period may cause acute radiation sickness and, in some cases, death. Lower exposures to radiation over time (e.g., over a working lifetime) increase the probability of developing chronic health problems, cancer, or having children with genetic defects, especially if the cumulative dose is significant.

*Nuclear*

Nuclear incidents are those that involve the release of large amounts of energy in the form of intense light, heat, pressure, and radiation. With a nuclear event, radiation exposure typically occurs on a larger scale than with radiological incidents.

Nuclear incidents may result from the detonation of a nuclear device or from an accidental or intentional release at a nuclear reactor site. Such incidents have the potential to cause catastrophic loss of life and direct damage to structures. In addition, an incident could significantly disrupt civil services and infrastructure.

While the nuclear devices that terrorist organizations may be able to fabricate under special circumstances are relatively small, in extreme circumstances they may still have the potential to cause mass casualties.

### ii. Severity

A CBRN incident becomes a citywide emergency when it poses a threat to human safety and welfare or to the environment. However, acute exposures to hazardous materials are often difficult to evaluate because people may experience a wide range of adverse health effects, the severity of which varies with intensity and duration of exposure. In a typical population, there is also significant variation in response among individuals. Furthermore, for many substances there is not enough available data on toxic responses in humans to allow for an accurate assessment of health impacts. Thus, the severity of the hazard will depend on the type and amount of material released, the location of the release relative to human populations, and the characteristics of the exposed population.

*Chemical*

For chemical hazards, severity is commonly measured using the National Fire Protection Association (NFPA) 704M rating system. This system uses numbers and primary colors on a label to define the basic hazards of a specific material (see Figure 3.16.103). The system represents the risk posed by a particular substance, using a diamond with four colors: blue for health, red for flammability, yellow for reactivity, and white for special hazards. These categories are ranked on a scale from 0 (no hazard) to 4 (extreme hazard).

*Biological*

The severity of a biological hazard will depend on the type, location, and amount of the release, as well as the size, density, and characteristics of the population affected. Virulence is the relative severity of the disease caused by a microorganism (the ratio of clinical cases to the number of infected hosts). Different strains of the same microorganism may cause different diseases with varying levels of severity.

*Radiological*

For radiological hazards, severity is dependent on a number of factors, including the size of the dose, the type of radiation emitted, duration of exposure, the ability of the radiation to harm human tissue, and the organs affected. Exposure to single, short-duration, high doses of radiation (a dose is the amount of energy absorbed by the body) can cause acute health effects, while relatively low doses over extended periods can accumulate in the body and cause chronic health im-

**Figure 3.16.103: NFPA 704M Rating System for Chemical Hazards (Source: Compliance Signs).**

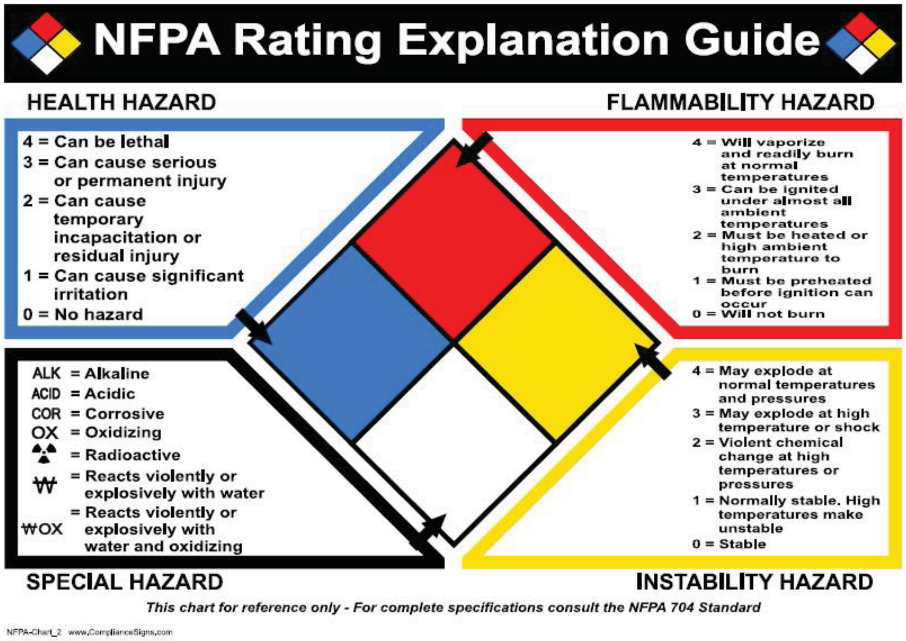



**Table 3.16.72: Symptoms of Radiation Exposure (Source: Next Big Future).**

| | |
|---|---|
| Chest X-ray | 0.1 mSv |
| Average background exposure in one year | 3 mSv |
| Abdominal X-ray | 4 mSv |
| Living on the Colorado Plateau for one year | 4.5 mSv |
| Typical yearly dose for a uranium miner | 5-10 mSv |
| Full-body CT scan | 10 mSv |
| Lowest dose for any statistical risk of cancer | 50 mSv |
| Mild radiation sickness (headache, risk of infection) | 0.5-1 Sv |
| Light radiation poisoning (mild to moderate nausea, fatigue, 10% risk of death after 30 days) | 1-2 Sv |
| Severe radiation poisoning (vomiting, hair loss, permanent sterility, 35% risk of death after 30 days) | 2-3 Sv |
| Severe radiation poisoning (bleeding in mouth and under skin, 50% risk of death after 30 days) | 3-4 Sv |
| Acute radiation poisoning (60% fatality risk after 30 days) | 4-6 Sv |
| Acute radiation poisoning (bone marrow destroyed, nearly 100% fatality after 14 days) | 6-10 Sv |
| Acute radiation poisoning (symptoms appear within 30 minutes, massive diarrhea, internal bleeding, delirium, coma) | 10-50 Sv |
| Coma in seconds or minutes, death within hours | 50-80 Sv |
| Instant death* | >80 Sv |

pacts. The unit of measurement for absorbed dose is the rad (radiation absorbed dose).

However, since certain types of radiation are more dangerous than others, the absorbed dose must be multiplied by a "quality factor" to produce a "dose equivalent" that reflects the type of radiation to which an individual is exposed. The units of measurement for dose equivalent are the rem (roentgen equivalent man), Sv (Sievert), and mSv (milliSievert), with one Sv equivalent to 100 rem and 1,000 mSv. Doses greater than 100 rem/1 Sv/1,000 mSv received over a short period are likely to cause acute radiation syndrome, leading to possible death within weeks. Table 3.16.72. describes some symptoms of radiation exposure from different levels of dose equivalent.

*Nuclear*

The severity of a nuclear hazard will depend on the type, location, and amount of the release, as well as the size, density, and characteristics of the population affected.

### iii. Probability

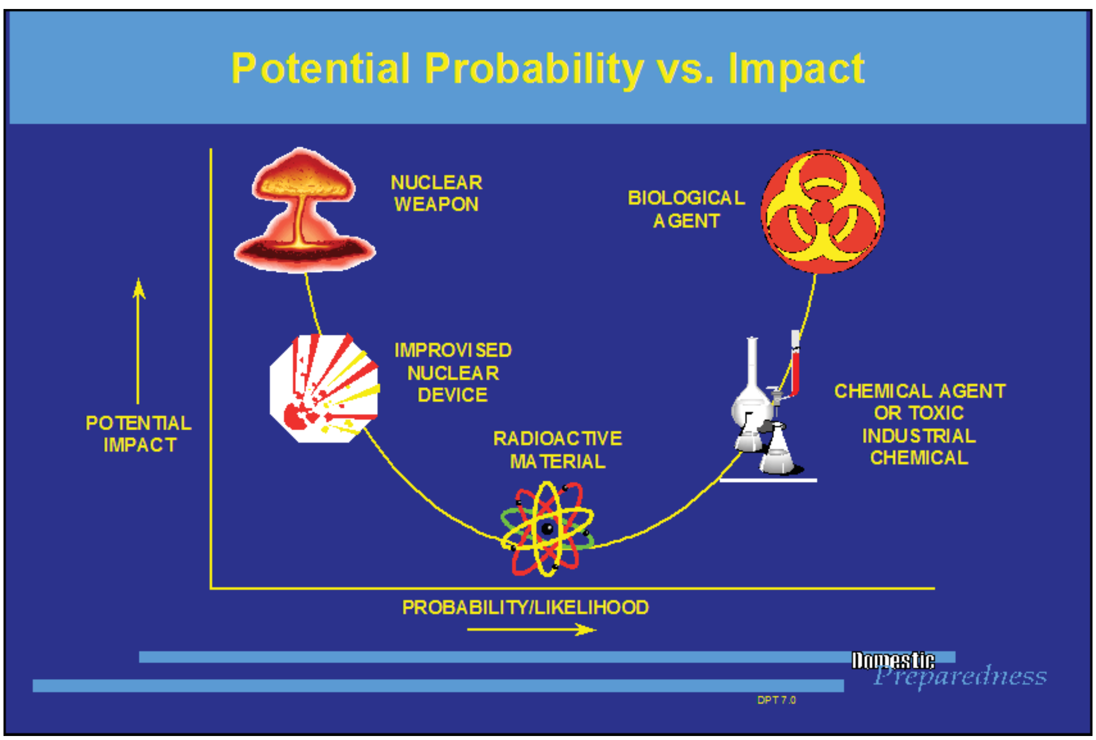
Since CBRN releases are generally not predictable, it is difficult to calculate the probability or recurrence intervals for specific events. The probability of an event will be higher near facilities that are not routinely maintained or inspected, at potential targets for an intentional attack, and at ports or other facilities where high volumes of hazardous materials are moved on a frequent basis.

Broader categories of releases can be considered on a more general continuum. Figure 3.16.104 is an unclassified and commonly used reference chart for the probability of CBRN events.

### iv. Location

Locations vulnerable to CBRN releases vary according to the type of release and whether the incident is accidental or intentional.

**Figure 3.16.104: Probability vs. Impact from Different Categories of CBRN Releases.**



*Chemical*

The most at-risk locations for accidental chemical releases include neighborhoods and recreational or natural areas near chemical plants, industrial facilities/storage sites, warehouses, fuel stations, and brownfields/Superfund sites (such as Newtown Creek in Brooklyn/Queens and Gowanus Canal in Brooklyn). Common household chemicals (such as cleaning solutions) or materials present in most buildings (such as heating oil) may also pose a risk to human health. The most likely targets for intentional releases are densely populated and crowded areas (such as tourist attractions, public transportation facilities, and entertainment venues) and critical facilities (water supply reservoirs and distribution systems, power plants, ports, and hospitals). Financial centers and government offices are also potential targets for an intentional release.

*Biological*

Accidental biological incidents may occur anywhere in the city, although the risk of spread will be highest in the most densely populated areas. These outbreaks could potentially start from, for example, restaurants or food markets selling tainted food, or from a combined sewer overflow (CSO) outfall that exposes the public to raw sewage. The most vulnerable locations for intentional biological attacks are the same as for chemical attacks.

*Radiological*

Accidental radiological incidents are most likely to occur near facilities storing radioactive materials or waste, and in buildings built above or near natural sources of radiation, such as radon gas. The most likely targets for an intentional radiological attack are the same as for chemical and biological attacks.

*Nuclear*

While there are no nuclear power facilities within New York City, a leak at a nearby facility (whether accidental or intentional) could potentially expose New York City residents to harmful radiation. Likely targets for an intentional nuclear detonation are the same as for chemical, biological, and radiological attacks.

### v. Historic Occurrences

Although data on CBRN releases is limited, certain types of events (such as CSOs/raw sewage releases and oil spills) are relatively common occurrences, especially during heavy precipitation and flooding. Table 3.16.73 includes examples of significant known CBRN releases in recent decades (details vary based on amount of information available).

**Table 3.16.73: Selected CBRN Releases in New York City 1973 to 2013**

| Date | Event/Substance | Location | Description |
|---|---|---|---|
| February 10, 1973 | Liquefied natural gas explosion | Staten Island | • 40 workers killed in an explosion while cleaning an empty LNG tank in Bloomsfield, Staten Island |
| November 15, 1979 | Oil spill | Brooklyn | • Oil refinery tank explosion in Greenpoint, Brooklyn, releases 17 to 30 million gallons of oil into Newtown Creek<br>• Spill area covers up to 100 acres<br>• Newtown Creek designated a Superfund site in 2010<br>• No direct fatalities or health effects linked to spill |
| August 7, 1980 | Liquefied petroleum gas | Manhattan | • A truck carrying 9,000 gallons of liquefied petroleum gas leaks on the George Washington Bridge traveling from New Jersey to New York City<br>• Bridge cleared for 8 hours out of fear of an explosion, creating massive traffic jam |
| September 2, 1986 | Cyanide (intentional) | Manhattan | • 21 injured when cyanide is released in Metropolitan Opera |
| August 24, 1989 | Asbestos | Manhattan | • Steam pipe explosion results in evacuation of Gramercy Park area in Manhattan after discovery of "extremely high" levels of asbestos |
| September 18, 2001 | Anthrax (intentional) | Manhattan | • Letters sent to various media offices in New York City contain anthrax spores<br>• Part of larger coordinated attack that also infects people in other cities and states<br>• 5 people killed, 17 others infected (not all in New York City) |
| December 3, 2004 | Chlorine | Bronx | • An SUV collides with a tractor-trailer carrying barrels of chlorine on the Cross Bronx Expressway, causing chlorine to leak onto the roadway<br>• 3 firefighters and 2 police officers are exposed to high levels of chlorine and treated at the hospital |
| July 18, 2007 | Asbestos | Manhattan | • Steam pipe explosion with asbestos found in the debris |
| August 15, 2010 | Hydrogen peroxide | Manhattan | • Spill in a high-rise building due to machine malfunctioning releases about 30 gallons hydrogen peroxide |
| July 20, 2011 | Raw sewage | Citywide | • Four-alarm fire at North River Wastewater Treatment Plant on the Hudson River and 135$^{th}$ Street in Manhattan<br>• 15 to 20 million gallons of raw sewage released into Hudson River<br>• Forced closure of 3 beaches in Staten Island and 1 beach in Brooklyn due to high levels of harmful bacteria in the water<br>• DEP treats water with chlorine to reduce concentration of bacteria |
| October 29, 2012 | Release of various hazardous substances during Hurricane Sandy | Citywide | • 10 of 14 DEP wastewater treatment plants are damaged or lose power, releasing approximately 560 million gallons of untreated sewage mixed with stormwater into local waterways<br>• Floodwaters contain numerous other toxic substances such as oil, household chemicals, pesticides, and industrial pollutants |
| October 22, 2013 | Oil spill | Manhattan | • Approximately 50 gallons of home heating oil spill into the street at West 36$^{th}$ Street and 7$^{th}$ Avenue in Manhattan<br>• 3 people are contaminated and treated on-scene |

### B. Vulnerability Assessment

#### i. Social Environment

CBRN incidents could potentially compromise the safety and health of any person who resides in, works in, or visits New York City. Specific impacts will vary according to the type of material released, the geographic area affected, and the demographics of the population within that geographic area. Additional impacts may stem from long-term isolation of affected areas. Human fear or panic may also cause mental health impacts or disruptions to society, even if the real danger is not particularly severe.

To evaluate the existence and/or magnitude of health problems resulting from exposure to a hazardous substance, health risk assessments are utilized. There are generally four steps in the health risk assessment: health problem identification, toxicology (dose response), exposure assessment, and health-risk characterization. Health problem identification is the process of determining whether human exposure to a hazardous substance could cause adverse health impacts. Toxicology is the process of characterizing the relationship between the dose received and the adverse health effect in exposed populations; it also involves estimating the incidence of effects as a function of exposure and considers factors such as intensity of exposure, age, sex, and lifestyle. Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of exposure to a substance currently in the environment, or to a hypothetical release of a substance into the environment. The main purpose of exposure assessment is to determine the concentration of hazardous materials over time and space in each environmental media where people may be exposed. The final stage of a health-risk assessment is risk characterization, which involves estimating the incidence of health effects under various conditions of exposure described in the exposure assessment. The risk characterization combines the exposure and dose-response assessments.

*Chemical*

Populations who live or work near sites that contain hazardous materials or potential terrorist targets are at elevated risk of exposure to chemical hazards.

*Biological*

Densely populated residential areas, crowded business districts, and tourist attractions are at increased risk from biological hazards due to closer human contact and the potential for increased rates of transmission. The elderly, young children, persons with mobility impairments, and individuals with pre-existing medical conditions or weakened immune systems are at a heightened risk if exposed (for more information on vulnerable populations, see Section 3.4: New York City's Hazard Environment).

*Radiological*

The entire population is potentially at risk from radiological hazards, but the elderly, young children, the immobile, and those with pre-existing medical conditions are especially vulnerable. The elderly, young children, and those with pre-existing medical conditions are more likely to have a lower threshold dose of radiation to experience health issues.

*Nuclear*

Nuclear incidents could potentially impact any person who resides in, works in, or visits New York City.

#### ii. Built Environment

Although the most significant impacts of CBRN releases are on the human population and the natural environment, some materials may cause damage to the built environment. Impacts will depend on the type of material released and the specific buildings, equipment, or infrastructure exposed.

*Chemical*

Corrosive chemicals have the potential to damage building materials and infrastructure. Sensitive equipment and electronics may also be vulnerable to damage or explosions if they come into contact with reactive chemicals. Water distribution and filtration systems and air ventilation systems may be damaged or destroyed if contaminated with certain substances.

*Biological*

Biological hazards are an inherent danger to living organisms but generally do not pose a significant threat to the built environment.

*Radiological*

The most significant impacts of a radiological release to the built environment would come from the explosion of an RDD and not from the radiation itself. However, radioactive contamination of certain structures may necessitate demolition to prevent exposure of occupants.

*Nuclear*

The entire built environment could suffer severe damage from a nuclear blast or detonation. The extent of damage would depend on the magnitude and location of the blast.

### iii. Natural Environment

The impacts of CBRN releases on the natural environment will depend on the type of material released, the magnitude of the release, the location of the release relative to critical natural resources or habitats, and the existence of pathways which would allow substances to spread throughout the environment. Exposure may occur via contact with contaminants in the water supply or ambient air. The remediation of the natural environment after a release poses unique challenges and could be lengthy and costly.

*Chemical*

Certain chemicals may be toxic to many species of plants and animals. Even if the only exposure is to species that are low on the food chain, these chemicals could indirectly impact other species because the concentration of the chemicals increases due to bioaccumulation. This may ultimately result in the loss of critical natural resources and ecosystems and negatively impact the human food supply. Depending on the type and size of the release, permanent damage or destruction of critical ecosystems may occur.

*Biological*

Biological releases could also be devastating to plants and animals. Since different microorganisms and pathogens affect different hosts, the severity of impacts will depend on the type of material released. A significant release has the potential to cause wide-ranging impacts on a scale similar to what might occur from a significant chemical release.

*Radiological*

Exposure to significant doses of radiation damages cells and living tissues in plants and animals. Overall risks may include genetic defects, mutations, and death. If the absorbed dose of radiation is relatively low, it may not have significant impacts on the plants and animals directly exposed, but could accumulate in the food chain and ultimately contaminate the human food supply.

The disposal of radiological waste from environmental cleanup is a particular concern. There are only a few designated radiological waste depositories in the United States, and radiological waste can persist in the environment for hundreds or thousands of years.

*Nuclear*

Nuclear releases pose the same threats to the natural environment as radiological releases do, with the additional risk of damage resulting from a nuclear blast.

### iv. Future Environment

The threat of CBRN releases in the future will depend on a number of factors that are currently uncertain.

*Chemical*

Increased or decreased reliance on products containing certain types of chemicals could affect the risk of exposure. Shifts in the market or industrial trends may also change the number or distribution of facilities where hazardous chemicals are stored. New or emerging chemicals may have toxicological effects and pose challenges to preventing and controlling exposure. New technologies, such as safer storage, could decrease the likelihood of a release.

*Biological*

Shifts in population density and distribution may affect the number of people impacted and the transmission rate for biological hazards. Medical advances in antibiotics and vaccines could also decrease the risk of exposure to certain types of diseases. However, these changes also have the potential to promote genetic mutations in microorganisms and pathogens, which could cause deadly new resistant strains of diseases.

*Radiological*

The future risk of radiological releases will depend on changes in the need for these types of materials for usage in industrial processes or power generation. New technologies, such as increased or improved radiation screening and the development of alternatives for the storage of radioactive waste will also play a role in determining future vulnerability.

*Nuclear*

The future risk of accidental nuclear releases will depend, at least in part, on trends in power generation. New technologies could potentially make nuclear facilities either safer or obsolete. Technological advances could also result in the development of more sophisticated nuclear explosives. The threat from such devices would depend on the availability of this technology and the pursuit of political aims through intentional harmful acts. However, advances in security may also go a long way in preventing intentional attacks.

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