CHAPTER 3

Biological Agents and Nuclear Detonations

In a general war, US forces may be faced by an enemy capable of employing nuclear or biological weapons. The effects of weather and terrain on biological agent aerosols and on nuclear weapons follow.

Biological Agents

In a general war, US forces may be faced by an enemy capable of producing and employing biological agents. These include disease-causing microorganisms (pathogens) and toxins. Toxins are biologically derived chemical substances that have desirable characteristics for use as biological warfare agents. Toxins may be natural or synthetic.

Biological agents will most likely be disseminated as an aerosol. Therefore, a basic knowledge of their field behavior is essential for estimating friendly vulnerability. These agents differ from chemical agents in some aspects of field behavior. Pathogens decay as a result of factors such as weathering. They also require time to invade a body and multiply enough to overcome the body's defenses. This is known as the incubation period. This period may vary from hours to months, depending on the type of pathogen.

The following paragraphs discuss biological agent dissemination, weather effects, and terrain influences, and they briefly summarize the influence of these on biological agent field behavior.

Dissemination

Pathogens are most likely to be disseminated as aerosols. Toxins, on the other hand, may be disseminated as either aerosols or large liquid drops. An aerosol is composed of particles containing pathogens or toxins. The force of the wind moves it along. At the same time, the aerosol spreads by turbulent diffusion.

Biological agents that die rapidly are said to have a high decay rate. High wind speeds (10 to 20 knots) carry these agents over more extensive areas during the agent survival period. Multiple wind shifts occur at low wind speeds. These shifts may cause more lateral spread and downwind diffusion than higher speeds. Optimum effect depends on the nature of the agent and atmospheric conditions. Highly virulent (malignant) agents with low decay rates can spread over large areas (by low or high wind speeds) and still present a casualty threat. Virulent agents with higher decay rates employed under the same atmospheric conditions are much less effective.

Weather Effects

Air stability, temperature, relative humidity, pollutants, cloud coverage, and precipitation have an effect on biological agents.

Air Stability

Atmospheric stability influences a biological cloud in much the same way it affects a chemical cloud. However, biological agents may be more effective in lower concentrations than chemical agents. This is because of their high potency. A stable atmosphere results in the greatest cloud concentration and area coverage of biological agents. Under unstable and neutral stability conditions, more atmospheric mixing occurs. This leads to a cloud of lower concentration, but the concentration is sufficient to inflict significant casualties. The coverage area under unstable stability conditions is also reduced.

Temperature

Air temperature in the surface boundary layer is related to the amount of sunlight the ground has received. Normal atmospheric temperatures have little direct effect on the microorganisms of a biological aerosol. Indirectly, however, an increase in the evaporation rate of the aerosol droplets normally follows a temperature increase. There is evidence that survival of most pathogens decreases most sharply in the range of -20°C to -40°C and above 49°C. High temperatures kill most bacteria and most viral and rickettsial agents. However, these temperatures will seldom if ever be encountered under natural conditions. Subfreezing temperatures tend to quick-freeze the aerosol after its release, thus decreasing the rate of decay. Exposure to ultraviolet light—one form of the sun's radiation—increases the decay rate of microorganisms. Ultraviolet light, therefore, has a destructive effect upon the biological aerosol. Most toxins are more stable than pathogens and are less susceptible to the influence of temperature.

Relative Humidity

The relative humidity level favoring employment of a biological agent aerosol depends upon whether the aerosol is distributed wet or dry. For a wet aerosol, a high relative humidity retards evaporation of the tiny droplets containing the microorganisms. This decreases the decay rate of wet agents, as drying results in the death of these microorganisms. On the other hand, a low relative humidity is favorable for the employment of dry agents. When the humidity is high, the additional moisture in the air may increase the decay rate of the microorganisms of the dry aerosol. This is because moisture speeds up the life cycle of the microorganisms. Most toxins are more stable than pathogens and are less susceptible to the influence of relative humidity.

Pollutants

Atmospheric pollutant gases can also affect the survival of pathogens. Pollutant gases have been found to decrease the survival of many pathogens. These gases include nitrogen dioxide, sulfur dioxide, ozone, and carbon monoxide. This could be a significant factor in the battlefield over which the air is often polluted.

Cloud Coverage

Cloud coverage in an area influences the amount of solar radiation received by the aerosol. Thus, clouds decrease the amount of destructive ultraviolet light the microorganisms receive. Cloud coverage also influences factors such as ground temperature and relative humidity, as discussed in Chapter 1.

Precipitation

Precipitation may wash suspended particles from the air. This washout may be significant in a heavy rainstorm but minimal at other times. High relative humidities associated with mists, drizzles, and very light rains are also an important factor, These may be either favorable or unfavorable, depending upon the type of agent. The low temperatures associated with ice, snow, and other winter precipitation prolong the life of most biological agents.

Terrain Influences

Soil, vegetation, and rough terrain influence a biological agent aerosol.

Soil and Vegetation

Soil influences a biological agent aerosol as related to temperature and atmospheric stability. Appendix C discusses the interrelationship between soil and these weather elements.

Vegetation reduces the number of aerosol particles. Impact of the suspended particles upon trees and grass causes some particles to settle, and this settling reduces agent concentration. However, vegetative cover reduces exposure to ultraviolet light, increases relative humidities, and may reduce temperatures (while fostering a neutral temperature gradient). All these factors favor the survival of wet aerosols.

Rough Terrain

Rough terrain creates wind turbulence, and turbulence influences the vertical diffusion of aerosol. This turbulence reduces agent effectiveness and area coverage. Terrain affects the path of the aerosol and the distribution of surface concentration.

Nuclear Detonations

When a nuclear explosion occurs, blast radiation and heat or thermal effects will occur. The influence of weather and terrain on these effects will be discussed in this section. When a nuclear weapon detonates at low altitudes, a fireball results from the sudden release of immense quantities of energy. The initial temperature of the fireball ranges into millions of degrees, and the initial pressure ranges to millions of atmospheres. Most of the energy from a nuclear weapon detonation appears in the target area in the form of three distinct effects. These are nuclear radiation, blast, and thermal radiation.

Nuclear Radiation. Neutron and gamma radiation from the weapon detonation produces casualties and, in many cases, material damage as well. Ionized regions, which may interfere ‘with the propagation of electromagnetic waves associated with communication systems and radars, result when the atmosphere absorbs nuclear radiation.

Blast. A blast wave with accompanying drag effects travels outward from the burst.

Thermal Radiation. Intense thermal radiation emits from the fireball, causing heating and combustion of objects in the surrounding area.

In the detonation of a typical fission-type nuclear weapon, the percentage of the total energy appearing as nuclear radiation, blast, or thermal radiation depends on the altitude at which the burst takes place (subsurface, surface, or air) and on the physical design of the weapon. For bursts within a few kilometers above the earth's surface, slightly more than 50 percent of the energy may appear as blast, approximately 35 percent as thermal energy, and approximately 15 percent as nuclear radiation.

Certain weather conditions will influence the effects of nuclear weapons. Likewise, different types of terrain will also influence the effects of nuclear weapons. In addition to these considerations, the type of operation can have a direct bearing on weather and terrain effects on nuclear weapons use.

Nuclear Radiation

When a nuclear explosion occurs, one usual result is the well-known mushroom-shaped cloud. This cloud may extend tens of thousands of meters, and in the case of a surface burst or shallow subsurface burst, it is a tremendous vertically developed aerosol cloud bearing radioactive material. The effect of wind speed and direction at various altitudes is of particular interest. These factors are of great importance in predicting the location(s) of the fallout that may result from a nuclear explosion.

The effects of weather and terrain apply to both the initial and residual effects of nuclear explosions, although this section will primarily address the residual aspects. For more information on the effects of weather on both initial and residual effects, refer to FM 3-3.

Precipitation

Precipitation scavenging can cause the removal of radioactive particles from the atmosphere. This is known as rainout. Because of the uncertainties associated with weather predictions, the locations that could receive rainout cannot be accurately predicted. Rainout may occur in the vicinity of ground zero or the contamination could be carried aloft for tens of kilometers before deposition. The threat of rainout especially exists from a surface or subsurface burst. Vast quantities of radioactive debris will be carried aloft and be deposited downwind. However, rainout may cause the fallout area to increase or decrease and also cause hot spots within the fallout area.

For airbursts, rainout can increase the residual contamination hazard. Normally, the only residual hazard from an airburst is a small neutron induced contamination area around GZ. However, rainout will cause additional contaminated areas in unexpected locations.

Yields of 10 kilotons or less present the greatest potential for rainout, and yields of 60 kilotons or more offer the least. Additionally, yields between 10 kilotons and 60 kilotons may produce rainout if the nuclear clouds remain at or below rain cloud height.

Rain on an area contaminated by a surface burst changes the pattern of radioactive intensities by washing off higher elevations, buildings, equipment, and vegetation. This reduces intensities in some areas and possibly increases intensities in drainage systems; on low ground; and in flat, poorly drained areas.

Wind Speed and Direction

Wind speed and direction at various altitudes are two factors that determine the shape, size, location, and intensities of the fallout pattern on the ground because contaminated dirt and debris deposit downwind. The principles and techniques of fallout prediction from winds-aloft data are in FM 3-3. Surface winds also play an important role in the final location of fallout particles. Just as snow falls on pavements or frozen surfaces and surface winds pile it in drifts, so, too, can local winds cause localization of fallout material in crevices and ditches and against curbs and ledges. This effect is not locally predictable, but personnel must be aware of the probability of these highly intense accumulations of radioactive material occurring and their natural locations.

Clouds and Air Density

Clouds and air density have no significant effects on fallout patterns.

Terrain Contours

Ditches, gullies, small hills, and ridges offer some protection against the gamma radiation emanating from the contaminated area. Terrain contours also cause local wind systems to develop. These wind systems will affect the final disposition of fallout on the ground, creating both hot spots and areas of low-intensity within the pattern.

Heavy Foliage

Heavy foliage can stop some of the fallout from reaching the ground. This may reduce the intensity on the ground.

Soil

Soil surface materials (soil) at the burst site determine particle size (large or small). The particle size helps determine when and where most of the fallout will reach the ground, the larger particles settling first. Composition of the soil near ground zero will materially affect the size and decay rate of the pattern of residual radiation induced by neutrons from the weapon.

Type of Operation

Temperature and terrain can also influence the effects of nuclear radiation on tactical operations. The effects of cold weather, desert, jungle, mountain, and urban operations on nuclear defense planning follow.

Cold Weather Operations

Weather conditions limit the number of passable roadways. Radiological contamination on roadways may further restrict resupply and troop movement. Seasonal high winds in the arctic may present a problem in radiological contamination predictions. These winds may reduce dose rates at ground zero. At the same time, they extend the area coverage and create a problem for survey/monitoring teams. Hot spots or areas of concentrated accumulation of radiological contamination may also occur in areas of heavy snow and snow drifts.

Desert Operations

Desert operations present many varying problems. Desert daytime temperatures can vary between 90°F to 125°F (32°C to 52°C). These temperatures create an unstable temperature gradient. However, with nightfall, the desert cools rapidly and a stable temperature gradient results. A possibility of night attacks must be considered in all planning.

Nuclear defense planning in a desert is generally much the same as in other areas, with a few exceptions. Lack of vegetation and permanent fixtures, such as forests and buildings, makes it necessary to plan for and construct fortifications. Construction may be difficult because of inconsistencies of the sand. However, sand, in combination with sandbags, gives additional protection from radiation exposure. Blowing winds and sand make widespread radiological survey patterns likely. The varying terrain may make radiological survey monitoring very difficult.

Jungle Operations

Radiation hazards also may be reduced because some of the falling particles are retained by the jungle canopy. Subsequent rains, however, will wash these particles to the ground and concentrate them in water collection areas. Radiation hot spots will result.

Mountain Operations

In the mountains, the deposit of radiological contamination will be very erratic because of rapidly changing wind patterns. Hot spots may occur far from the point of detonation, and low-intensity areas may occur very near it. Limited mobility makes radiological surveys on the ground difficult, and the difficulty of maintaining a constant flight altitude makes air surveys highly inaccurate.

Urban Operations

Buildings provide a measure of protection against radiological contamination. Taking this into consideration, troops who must move in or through a suspected contaminated urban area should travel through buildings, sewers, and tunnels to reduce contamination risk. However, they should consider the dangers of collapse because of blast. They should also consider hazards of debris and fire storms resulting from ruptured and ignited gas or gasoline lines.

Blast

Most of the materiel damage and a considerable number of the casualties caused by an airburst result from the blast wave. For this reason, it is desirable to consider the phenomena associated with the passage of a blast wave through air.

The expansion of the intensely hot gases at extremely high pressures within the fireball causes a blast wave to form in the air, moving outward at high velocities. The main characteristic of the blast wave is the abrupt rise in pressure above ambient conditions. This difference in pressure with respect to the normal atmospheric pressure is called the overpressure.

Initially, the velocity of the shock front is many times the speed of sound. However, as the front progresses outward, it slows down and moves with the speed of sound.

The magnitude of the air blast parameters is dependent on the yield of the weapon, height of burst, and the distance from ground zero.

The blast wave may last from tenths of a second to seconds, depending on the yield and the distance from the burst. Weather, surface conditions, topography, and the type of operation being conducted all affect the blast wave.

Weather

Rain and fog may lessen the blast wave because energy dissipates in heating and evaporating the moisture in the atmosphere.

Surface Conditions

The reflecting nature of the surface over which a weapon is detonated can significantly influence the distance to which blast effects extend. Generally, reflecting surfaces, such as thin layers of ice, snow, and water, increase the distance to which overpressures extend.

Topography

Most data concerning blast effects are based on flat or gently rolling terrain. There is no quick and simple method for calculating changes hilly or mountainous terrain produce on blast pressures. In general, pressures are greater on the forward slopes of steep hills and are diminished on reverse slopes when compared with pressures at the same distance on flat terrain. Blast shielding is not highly dependent on line-of-sight considerations because the blast waves will bend or diffract around obstacles. The influence of small hills or folds in the ground is considered negligible for target analysis. Hills may decrease dynamic pressures and offer some local protection from flying debris.

Type of Operation

Temperature and terrain can also influence the effect of blast on tactical operations. The effects of cold weather and jungles or forests on operations follow.

Cold Weather Operations

At subzero temperatures, the radius of damage to material targets can increase as much as 20 percent. These targets include such items as tanks, APCs, artillery, and military vehicles. An increased dynamic pressure can result from a precursor wave over heat-absorbing surfaces. However, tundra, irregular terrain features, and broken ice caps break up the pressure wave.

Blast effects can drastically interfere with troop movement by breaking up ice covers and causing quick thaws. These effects can cause avalanches in mountainous areas. In flat lands, the blast may disturb the permafrost to such an extent as to restrict or disrupt movement.

Jungle or Forest Operations

Initial effects of nuclear detonations are not significantly influenced by the dense vegetation. However, the blast wave will probably cause extensive tree blowdown and missile effects. Forests, in general, do not significantly affect the overpressure but do degrade the dynamic pressure of an air blast wave.

Thermal Radiation

Thermal radiation results from the heat and light produced by the nuclear explosion. During a nuclear explosion, the immediate release of an enormous quantity of energy in a very small space results in an initial fireball temperature that ranges into millions of degrees. For a given type of weapon, the total amount of thermal energy available is directly proportional to the yield.

Within the atmosphere, the principal characteristics of thermal radiation are that it—

- Travels at the speed of light.
- Travels in straight lines.
- Can be scattered.
- Can be reflected.
- Can be easily absorbed.

The thermal effects will be influenced by weather, terrain, height of burst, and type of operation.

Weather

Any condition that significantly affects the visibility or the transparency of the air affects the transmission of thermal radiation. Clouds, smoke (including artificial), fog, snow, or rain absorb and scatter thermal energy. Depending on the concentration, they can stop as much as 90 percent of the thermal energy. On the other hand, clouds above the burst may reflect additional thermal radiation onto the target that would have otherwise traveled harmlessly into the sky.

Terrain

Large hill masses, forests, or jungles, or any opaque object between the fireball and the target may provide some protection to a target element. Trucks, buildings, or even another individual may protect an individual from thermal radiation. Foxholes provide good protection. However, personnel protected from direct line-of-sight radiation from the fireball may still receive thermal injury because of reflection from buildings or other objects. Good reflecting surfaces, such as water, snow, or desert sand, may reflect heat onto the target and intensify the thermal radiation effect. Even the backs and sides of open foxholes will reflect thermal energy. The reflective capability of foxhole materials varies from 8 percent for wet black soil to 93 percent for snow. Because of atmospheric scattering and reflections, thermal casualties may result at a greater range than casualties from other effects.

Height of Burst

The amount of thermal radiation that a surface target receives from a nuclear burst of a given yield will vary with the height of burst. The maximum thermal effect at the target will usually be produced by an airburst. A surface burst produces about half the amount of the thermal radiation that would be produced by an airburst because of the interaction of the fireball with the surface. Thermal radiation from a subsurface burst where the fireball is not visible is insignificant.

Type of Operation

Temperature and terrain can also influence the effect of thermal radiation on tactical operations. The effects of cold weather and mountains on thermal radiation follow.

Cold Weather Operations

The high reflectivity of ice and snow may increase the minimum safe distance as much as 50 percent for unwarned troops and even warned, exposed troops. Reflectivity may also increase the number of personnel whose vision is affected by the brilliant flash, or light dazzle, especially at night. The pale colors normally used to cover material in a cold weather environment give an advantage. Their low absorption properties may make personnel less vulnerable to thermal effects. Cold temperatures also reduce thermal effects on materials. Snow, ice, and even frost coverings on combustible materials greatly reduce the tendency of the materials to catch fire. However, thermal effects will dry out exposed tundra areas, and grass fires may result.

Mountain Operations

The clear mountain air extends the range of casualty-producing thermal effects. Within this range, however, the added clothing required by the cool temperatures at high altitudes reduces casualties from these effects.