Chapter 2
VULNERABILITY ANALYSIS

Vulnerability analysis is a systematic method for estimating friendly casualties and/or consequences from enemy or terrorist NBC attacks. Then end state of vulnerability analysis is the chemical staff's recommendation to the commander on vulnerability reduction measures and to provide the information needed to make decisions concerning the acceptable level of risk in mission accomplishment.

Enemy WMD Uses/ Targets

Strategic
- √ Break up coalitions.
- √ Inflict political defeat.
- √ Drive end-game bargains.
- √ Last act of defiance.

Operational
- √ Airfields and associated infrastructures/resources.
- √ Critical points of naval operations to include ships and supporting coastal facilities.
- √ Ground forces and their support facilities.
- √ Critical command, control, communications, and computer nodes.
- √ Logistics and supply depots.
- √ Civilian population centers, seats of government, industries.
- √ Overwhelm medical system.
- √ Disrupte sequence and timing of campaign.

Tactical
- √ Brak up assults.
- √ Facilitate attacks.
- √ Canalize forces.
- √ Shape the battlefield.

Section A, Nuclear

The proliferation of nuclear-capable nations in all contingency regions increases the likelihood of US and allied forces being targets of nuclear attack. Deploying forces must be capable of accurately assessing the nuclear or radiological threat imposed by the opposing force and be capable of addressing unit vulnerability to attack or contamination. To assess a unit's vulnerability to nuclear attack, the commander determines the unit's protection level and the type and size of weapon likely to be employed by the enemy. The commander then weighs various courses of action to determine which one presents an acceptable risk while allowing for mission accomplishment. Appendix A provides a nuclear attack risk checklist.

Nuclear weapons are similar to conventional weapons insofar as their destructive action is due mainly to blast or shock. However, there are several differences between nuclear and high-explosive weapons. Nuclear explosions can be millions of times more powerful than the largest conventional detonations. Second, for the release of a given amount of energy, the material mass required for a nuclear explosion would be much less than that of a conventional explosion. Consequently, in the former case, there is a much smaller amount of material available in the weapon itself that is converted into hot, compressed gasses. This results in somewhat different mechanisms for the initiation of a blast wave (a shock wave in the air resulting from the sudden increase in pressure). Third, the temperatures reached in a nuclear explosion are much higher than in a conventional explosion, and a fairly large proportion of the energy in a nuclear explosion is emitted in the form of light and hear, generally referred to as “thermal radiation.” This can cause skin burns and start fires at considerable distances. Fourth,the nuclear explosion is accompanied by highly penetrating and harmful invisible rays, called the “initial nuclear radiation.” Finally, the debris remaining after a nuclear explosion is radioactive, emitting similar radiation over an extended period of time. This in known as the “residual nuclear radiation,” “residual radioactivity,” or more commonly “fallout.”

Nuclear explosions also produce electromagnetic signals, referred to as “electromagnetic pulse (EMP).” These EMP induced currents and voltages can cause electronic component equipment failure, affecting communication equipment, global positioning systems, command and control nodes, vehicle ignition systems, avionics, and fire control systems.

Therefore, when addressing the unit’s vulnerability to nuclear weapons employment the chemical staff must consider blast or shock wave, thermal radiation, initial and residual radiation (fallout), and electromagnetic pulse. Remember, the potential exists for an enemy to employ a weapon that only produces one of these effects, for example radioactive dust particles or EMP. Consequently, the chemical staff must assess vulnerabilities to each effect, not just the greatest effect.

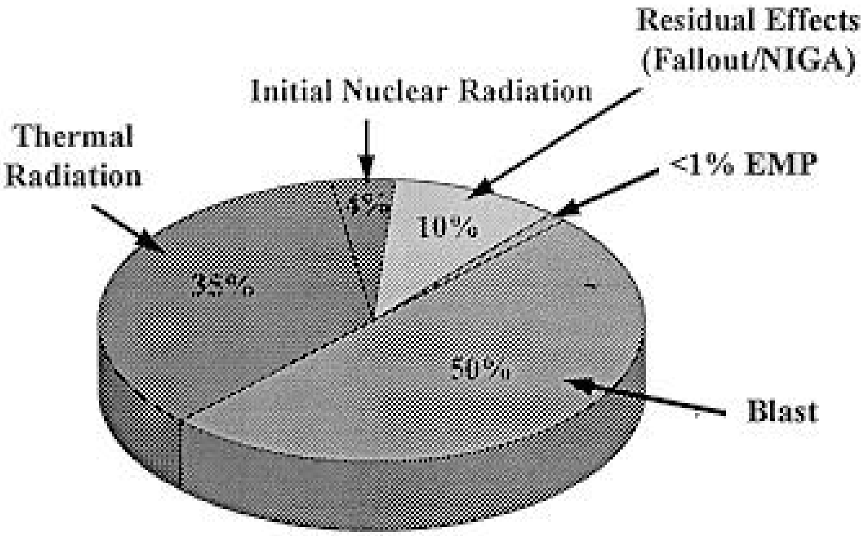


Figure 2-1. Nuclear Explosion Effects.

The immediate phenomena associated with a nuclear explosion, as well as the effects of shock, blast, and thermal and nuclear radiation, vary with the location of the point of burst in relation to the surface of the earth. For descriptive purposes, five types of burst are distinguished, although many variations and intermediate situations can arise in practice.

The main burst types are air (exploded below 100,000 feet, but the fireball does not touch the earth's surface), high-altitude (above 100,000 feet), underwater, underground, and surface. Although there are five types, there is no clear line of demarcation between them. As the explosion's height is decreased, a high-altitude burst becomes anairburst and an airburst will become a surface burst, and so forth.

The following descriptions mainly concern air and surface bursts, those strikes with the most military significance:

Blast (or shock) wave. A fraction of a second after a nuclear explosion, a high-pressure wave develops and moves outward from the fireball. This is the blast orshock wave that is the cause of much destruction accompanying anairburst. The front of the wave (the shock front) travels rapidly away from the fireball, behaving like a moving wall of highly compressed air. When the blast wave strikes the surface of the earth, it is reflected back, similar to a sound wave producing an echo. This reflected blast wave, like the original (or direct) wave, is also capable of causing material damage. At a certain region on the surface, the position depending chiefly on the height of the burst and the energy of the explosion, the direct and reflected wave fronts merge. This merging is called the "Mach effect." The overpressure (the pressure in excess of the normal atmospheric value) at the front of the Mach wave is generally about twice as great as that at the direct blast wave front. Strong transient winds are associated with the passage of the shock and Mach front. These blast winds are much stronger than the ground wind due to the updraft caused by the rising fireball, which occurs at a later time. The blast winds may have peak velocities of several hundred miles an hour fairly near to ground zero. It is evident that such strong winds can contribute greatly to the blast damage resulting from the nuclear weapon explosion.

Nuclear Effects' Arrival Times

Time After Detonation		
Less than a second	Less than a minute	Min/hrs/days
Prompt gamma rays	Airblast	Residual radiation
Electromagnetic pulse	Ground shock	Communication/ radar blackout
Neutrons	Dusk/Debris	Firestorms
Initial thermal radiation	Cratering	High-altitude dust
Major portion of thermal radiation		

Thermal radiation. In an ordinary airburst, roughly 35 to 40 percent of the total energy yield of the explosion is emitted as effective thermal radiation. A nuclear airburst can cause considerable blast damage, but thermal radiation can result in serious additional damage by igniting combustible materials, thus creating fire hazards. In addition, thermal radiation is capable of causing skin burns and eye injuries to exposed persons at distances at which fuels are not ignited. One of the serious consequences is the production of "flash burns" resulting from the absorption of radiant energy by the skin. In addition, because of the focusing action of theeyelens, thermal radiation can cause permanent eye damage to personnel who happen to be looking directly at the burst. However, suchdirsct viewing will be rare. Yet, the temporary loss of visual acuity (flash blindness or dazzle) resulting from the extreme brightness, especially at night, will be much more frequent. This may be experienced no matter what direction the individual is facing.

Initial radiation. The initial nuclear radiation generally refers to the radiation emitted within 1 minute of the detonation. This radiation consists of gamma rays, neutrons, beta particles, and a small proportion of alpha particles. Most of the neutrons and part of the gamma rays are emitted in the fission and fusion reactions, simultaneously with the explosion. The remaining gamma rays are produced in various secondary nuclear processes, including decay of the fission products. The beta particles are also emitted as the fissionproducts decay. Some of the alpha particles result from the normal and radioactive decay of the uranium or plutonium that has escaped fission in the weapon, and others (helium nuclei) are formed in fusion reactions. The ranges of alpha and beta particles are comparatively short and they cannot reach the surface of the earth from an airburst. The range of an alpha particle depends on its initial energy, but even those from plutonium which have a moderately high energy have an average range of only 1.5 inches in air. Many of the beta particles travel a distance of about 10 feet before they are absorbed. Even when the fireball touches the ground, the alpha and beta particles are not very important. Thus initial radiation may be regarded as consisting only of gamma rays and neutrons produced during a period of 1 minute after the explosion. Gamma rays and neutrons can travel considerable distances through the air and cause significant injuries, regardless of the fact that the energy of the initial gamma rays and neutrons is only about 3 percent of the total explosion energy.

This initial nuclear radiation can also affect material, especially that used in electronics, such as communication systems and computers. These effects are commonly referred to as transient radiation effects (TRE). The effect on electronics is referred to as transient radiation effects on electronics (TREE). The adjective “transient” applies to the radiation since it persists for a short time. However, the damage can be temporary or permanent.

Residual radiation. The residual radiation is defined as that which is emitted later than 1 minute from the instant of the explosion. The primary hazard of the residual radiation results from the creation of fallout particles that incorporate the radioactive weapon residues and the induced activity in the soil, water, and other materials in the vicinity of the explosion. These particles may be dispersed over large areas by the wind and their effects may be felt at distances well beyond the range of the other effects of a nuclear explosion. A secondary hazard may result from the neutron-induced gamma radioactivity (NIGA) on the earth’s surface in the immediate vicinity of the burst point. Fallout is broken into early (local) and delayed, with early defined as that which reaches the contamination over large areas and can represent an immediate physiological hazard. Delayed fallout consists of very fine, invisible particles which settle in low concentrations over a considerable portion of the earth’s surface. The radiation from the fission products and other substances is greatly reduced as a result of radioactive decay during the relative long time the delayed fallout remains suspended in the atmosphere. Consequently, delayed fallout radiation pose no immediate danger to health, although there may be long term hazards.

Electromagnetic pulse. The instantaneous gamma rays emitted in the nuclear reactions and those produced by neutron interactions with weapon residues or the surrounding medium are basically responsible for the processes that give rise to EMP in the lower atmosphere. The gamma rays interact with air molecules and atoms and produce an ionized region surrounding the burst point. Nuclear explosions of all types are accompanied by an EMP. The strongest electric and magnetic fields are produced near the burst by explosions at or near the earth's surface, but for those at high altitudes, the fields at the earth's surface are strong enough to be of concern for electrical and electronic equipment over a very much larger area. Space-based nuclear bursts can damage ground-based electronic equipment, however, and are usually employed to destroy communications or monitoring satellites.

A unit's vulnerability to nuclear attack depends on the warhead yield, the unit's available protection, and its dispersion. Table 2-2 assists in estimating the damage caused by a nuclear detonation. The table is safesided and simplified and assumes the worst case of a ground zero (GZ) nuclear burst and uniformly dispersed equipment/positions.

Nuclear explosion's biological effects are measured according to the amount of centigrays to which personnel are exposed. For the biological effects of radiation refer to Appendix F, Table F-1. Radiation casualty criteria are divided into three levels (Table 2-1).

Table 2-1. Radiation Casualty Criteria.

Response	Criteria Initial Dose (cGy)
	Physically Demanding/Physically Undemanding
Immediate Permanent Ineffectiveness (IPI)	8,000 for both
Immediate Transient Ineffectiveness (ITI)	3,000/3,800
Latent Ineffectiveness (LI)	450/600

- Immediate Permanent Ineffectiveness (IPI) At 8,000 cGy, personnel become ineffective within 3 minutes of exposure and remain ineffective until death (usually within one day).
- Immediate Transient Ineffectiveness (ITI). At 3,000 cGy for physically demanding tasks or 3,800 cGy for physically undemanding tasks, personnel become ineffective for any task within 3 minutes of exposure and remain so for approximately 7 minutes. Personnel recover to greater than 75 percent of their pre-exposed performance levels after about 10 minutes and remain so for about 30 minutes. Their performance degrades for around 5 hours for undemanding tasks or 2 hours for demanding tasks, when radiation sickness becomes so severe that they are ineffective. They remain ineffective until death (usually 5-6 days).
- Latent Ineffectiveness (LI). At 450 cGy for physically demanding tasks or 600 cGy for physically undemanding tasks, personnel will become performance degraded (PD) within 3 hours and remain so until death some weeks post-exposure, or become combat ineffective (CI) at any time within 6 weeks post-exposure).

Combat ineffective personnel, function at less than 25% of their pre-irradiation performance levels. CI is manifested by shock and coma at the high-dose levels. At lower dose levels, CI is manifested by a slowed rate of performance resulting from physical inability and/or mental disorientation.

Performance degraded personnel, while not CI, function at between 25% and 75% of their pre-irradiation performance levels. They suffer acute radiation sickness in varying degrees of severity and at different times. Radiation sickness is manifested by various combinations of projectile vomiting, propulsive diarrhea, hypertension, dry heaving, nausea, lethargy, depression, and mental disorientation. In an active nuclear environment, the more concentrated a unit is, the more lucrative a target it becomes. If the unit itself is not the target but falls within the fallout pattern, unit monitors will be capable of providing the commander with essential information regarding the hazard. Nuclear hazard prediction is addressed in FM 3-3-1/FMFM 11-18, Nuclear Contamination Avoidance.

Based on vulnerability radius and unit size, commanders may determine risk to the unit from a nuclear attack and whether or not to adjust unit dispersion. However, personnel may not be the target. Often a unit's equipment, due to sensitivity and vulnerability, becomes the target.

The information in Table 2-2 is for planning purposes only. For actual vulnerability radii refer to Joint Publications (JP) 3-12.2 (Secret Restricted Data (SRD)).

Two techniques to evaluate friendly unit vulnerability to nuclear detonations are (1) a technical approach in which unit dispersions are compared with the effects of an expected weapon yield, and (2) and operational approach in which unit dispositions are compared with targeting criteria used by the threat target analyst.

The primary tool for analyzing friendly dispositions is the radius of vulnerability (RV). RV is the radius of a circle within which friendly troops will be exposed to a risk equal to, or greater than, the emergency risk criterion 5 percent combat ineffectiveness) and/or within which material will be subjected to a 5 percent probability of the specified degree of damage (see the RV tables in JP 3-12.2(SRD) or JP3-12.3).

The GZ for the R V is always assumed to be the point where detonation will do the greatest damage to the friendly unit or installation. Delivery errors are not considered. For RV of categories not given, see comparable table chard in JP 3-12.2 (SRD) or JP 3-12.3.

Analyzing then vulnerability of friendly dispositions and installations consists of:

- Determining the appropriate threat yields based on current intelligence.
- Determining the disposition of friendly unit personnel.
- Obtaining the appropriate vulnerability radii from the RV table.
- Estimating fractional coverage for each target category, using the visual, numerical, or index technique. For information concerning these techniques reference JP 3-12.2 (SRD) (visual technique is discussed below).
- Recommending ways to decrease vulnerability and increase protection.

To determine vulnerability using the visual technique, outline the unit battle position. Use a compass, a piece of plastic with the RV drawn to scale on it, or a circular map scale. Superimpose the RV chosen from Table 2-2 or JP 3-12.2 (SRD) over the predicted targeted area.

The GZ used for the analysis is the location that would result in the highest fractional coverage of the target. From this worst case GZ and the appropriate RV, an estimation of the percentage of casualties or materiel damage that might result from an enemy nuclear strike may be determined.

Using the center point of the compass, template, or circular map scale as the GZ, choose the GZ that would result in the highest fractional coverage of the target area. Visually estimate the percent of the unit covered by the RV.

If this fractional coverage yields unacceptable losses of personnel or equipment, the commander must then make a decision of how to best reduce this casualty rate. This may be done by adding shielding or enacting vulnerability reduction measures (see Chapter 3).

If a mechanized battalion occupies a battle position 5 km wide and 2.5 km deep, it could be positioned as in Figure 2-2. Target elements are uniformly dispersed in the area. In this example, the RV for personnel is armored personnelcarriers from a 5-kiloton weapon is 1250 meters (as determined from Table 2-2). Worst cast the RV by placing the GZ where it provides the highest target coverage. Fifty percent of the battalion is covered by the RV, thus up to 50 percent of the battalion's personnel in armored personnel carriers could become casualties. When the same battalion deploys in three company battle positions in depth, the distances between positions significantly reduce the damage possibility, even assuming the weapon detonates at the worst case GZ. In Figure 3-4, although one company is 100 percent vulnerable, the battalion overall is only 33 percent vulnerable.

Table 2-2. Radii of Vulnerability (RV)(meters). Notes: a) To obtain RV, enter yield column at nearest listed yield, b) Unclassified, For Planning Purposes Only.

Category	Personnel In - (Latent ineffectiveness, based on governing effect.)					Moderate Damage				Severe Damage		
						Wheeled Vehicles		Tanks	Towed Arty	Supply Depot	Randomly Parked Helicopters	
Yield (kt)	Open	Open Fighting Position	APC	Tank	Earth Shelter	Exp	Shld				Cargo Transport	Light Observ
0.1	700	600	600	500	300	200	150	100	100	100	400	500
0.5	900	800	800	700	450	300	250	200	200	200	500	800
1	1200	900	900	800	500	400	350	300	250	250	700	1100
2	1700	1000	1100	900	600	500	450	400	300	300	850	1300
3	2000	1100	1200	1000	700	600	500	500	400	450	1000	1600
5	2500	1200	1250	1100	800	700	600	600	500	500	1200	1900
10	3200	1300	1300	1250	900	800	700	700	600	600	1500	2500
15	3700	1400	1400	1300	950	900	800	800	700	700	1800	2800
20	4000	1500	1450	1400	1000	1000	900	900	800	800	1900	3400
30	5000	1600	1500	1500	1100	1200	1100	1000	900	950	2200	3700
40	5500	1700	1600	1600	1200	1400	1250	1100	1000	1200	2500	4100
50	6000	1800	1700	1700	1300	1700	1500	1200	1200	1400	2700	4500
100	8000	1900	1800	1800	1400	2200	1900	1300	1300	1700	3200	5700
200	12000	2000	1900	1900	1500	2500	2000	1500	1500	1900	3700	6200
300	14000	2100	1950	1950	1600	3000	2100	1600	1600	2000	3800	7100

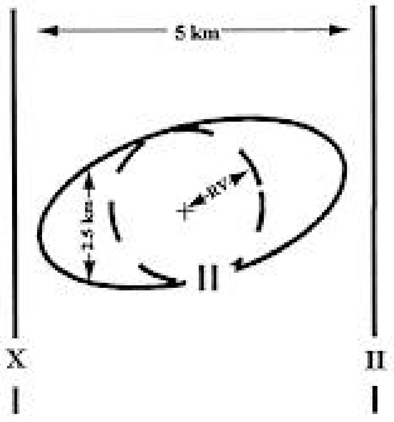


Figure 2-2. Single Position (not to scale).

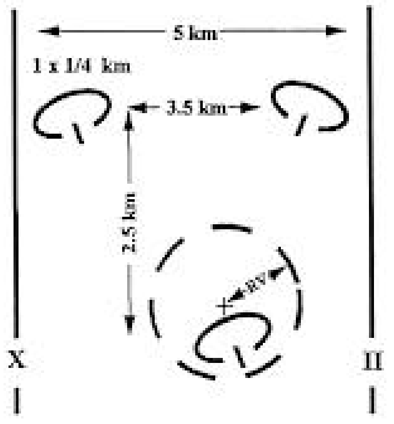


Figure 2-3. Multiple Positions (not to scale).

Section B,
Low-Level Radiation (LLR) and Depleted Uranium(DU)

LLR. In addition to the nuclear detonation threat, there exists, in all operations, the possibility of a low level radiation threat. This threat can exist in certain expended rounds, damaged or destroyed equipment, or contaminated shrapnel. It also may occur from inadequate nuclear waste disposal, deterioration of nuclear power facilities, damage to facilities that routinely use radioactive material/sources, and terrorism. Commanders must be aware threat forces could use radiological hazards to increase tensions.

LLR exposure produces a risk to soldiers of long term health consequences. The doses received from these exposures are higher than those routinely received by heath physics workers and the general public and are in the range from background radiation to 70cGy. The primary consequence of exposure may be induction of cancer in thelonger term post exposure with several additional risks. These hazards may result from alpha, beta, or gamma radiation.

DU. All uranium extracted from ore is composed of three primary isotopes of uranium. Thes are U-234, U-235, and U-238. Natural uranium contains 99% U-238, .72% U-235, and .005% U-234. Depleted uranium is uranium that has had some of the U-235 removed, resulting in a change in the isotopic composition.

Depleted uranium has qualities that lend themselves to military and industrial uses. Uranium metal is very dense, even more than lead, and has a relatively high melting point, 1132 degrees Celsius. It is a lustrous metal resembling iron and is ductile and malleable. It can be rolled and drawn into rods, tubes, wire, sheets, and so forth. It is an inexpensive by-product of nuclear fuel production, essentially a waste product. It has a very low specific activity, although it is radioactive. DU is pyrophoric (it will spontaneously burn and ignite) and produces large quantities of heat.

Because of its qualities, DU is used for counterbalances for rotating mechanisms, counterweights, ballast, dampening, vibration, and balancing control surfaces. It is particularly effective when used as a penetrator in anti-tank and armor-piercing munitions, as in the M1 Abrams tanks and M2/3 Bradley vehicles. It can also be used as spotter rounds and in nuclear weapons.

There are disadvantages to DU, which is where the vulnerability arises. As stated earlier, it is radioactive and must be treated as such. DU found in munitions does not present significant radiation hazards as long as the round is intact. However, care must be taken around vehicles that have been hit or destroyed by FU munitions and any resulting fires or explosions. Internal exposure is the primary hazard. This internal hazard is caused by DU's heavy metal toxicity and radiological hazard. Alpha radiation, the principle radiation emitted from uranium, is easily shielded. However, if the uranium is inhaled or ingested into the body, there is no shielding between the radiation and living cells. If inside the body, all the radiation (alpha, beta, and gamma) irradiates body tissues. In addition, since the source is inside the body, irradiation is continuous. See Chapter 3 for vulnerability reduction measures.

BACKGROUND HISTORY

During WW II, the US implemented an all-out effort to develop a nuclear weapon, the atomic bomb. This effort was called the "Manhattan Project." Part of the processes required fissionable material to produce the bombs. Two isotopes were identified as being fissionable, U-235 and plutonium-239. The fissionable isotope of uranium, 235, was extremely difficult to separate from the other uranium isotopes. It could not be done chemically since all uranium reacts the same in chemical processes. Gas diffusion was developed. It was very slow, tedious, and costly; however, the final product was a highly purified U-235. The waste was uranium from which much of the 235 isotope had been removed, that is, depleted uranium.

Section C, Biological

The potential for biological attack against US forces is greater today than at any time in modern history. The variety of biological agents and their delivery systems make a careful, thorough IPB a necessity. Biological delivery systems have the potential to cover larger areas than any other weapon system, in the order of thousands of square kilometers. Very large numbers of infective doses can be provided by a very small volume of biological agent due to the organism's microscopic size, its ability to replicate in victims, its potential transmissibility, and the extreme toxicity when compared to classical chemical weapons.

Biological agents are generally directed against the respiratory system to maximize the organism's effect to diffuse directly into the bloodstream and bodily tissue. While none of the recognized biological warfare (BW) agents are thought to be developed for their percutaneous effects, some secondary hazards are unavoidable and must not be overlooked.

Expect dissemination in the early morning and late evening when air stability is optimal and direct sunlight (ultraviolet (UV) rays) is minimal. Once settled out of the air, reaerosolization is minimal.

Most BW agents decay rapidly when exposed to the environment, especially in direct UV rays. Anthrax spores are an exception in that they may blend in with the soil that provides protection from natural decay for long periods, months to years. Tables F2 through F6, Appendix F in this manual, list possible biological agents and diseases (not all-inclusive).

This section addresses the tools required for the chemical staff to conduct an effective biological vulnerability analysis and provide a feasible recommendation to the supported commander.

Prior to conducting vulnerability analysis, we must first determine the unit's risk of biological attack or the enemy's capability and probability of use (Figure 2-4). A checklist format is provided in Appendix B, while possible employment indicators can befount in Appendix D.

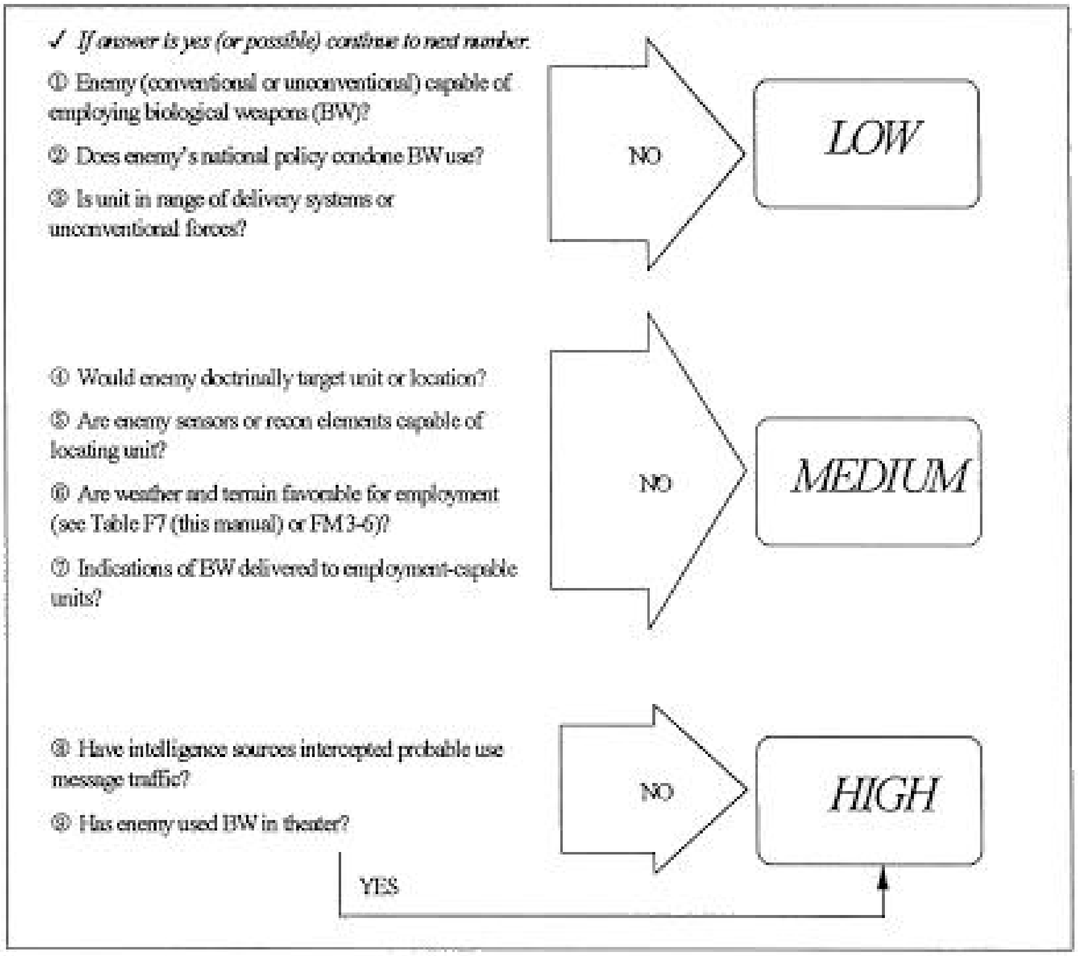


Figure 2-4. Biological Attack Risk

Once you have determined the enemy has the capability and the possible willingness to employ biological weapons (remember, even if an enemy has no capability to employ biological weapons, the unit is still vulnerable to endemic diseases), the next step is to determine the unit's vulnerability to an attack (Table 2-3):

- Determine immunization levels in relationship to predicted agents.

- Unit’s protective posture
- Current or projected maneuver status.
- Unit’s hygienic practices, such as are troops provided means to bathe/cleanse regularly?

Begin at the left column and successively add the values from each following column.

Table 2-3. Biological Vulnerability Rating Matrix

IMMUNIZATION (AGAINST PREDICTED AGENTS)	PROTECTIVE POSTURE	HYGIENE	DISPOSITION
COMPLETE (>=90%)-2	MOPP 3, 4-2	GOOD -2	MOBILE-2
INCOMPLETE (<90%)-4	*MOPP 1, 2, MASK ONLY-4	AVERAGE -2	SEMI-MOBILE-2
NONE-6	MOPP READY, ZERO-6	POOR-3	STATIC-3
RELATIVE VALUES TOTAL	SUBJECTIVE VULNERABILITY RATING		
6-10	LOW		
11-14	MEDIUM		
15-18	HIGH		
* If “mask only” protective posture provides required protection for predicted agent, use a value of 2.			

Ratings are subjective in nature. Apply rating measures in relationship to probable agent of use. Also, ratings do not consider troop motivation/moral factors.

The final rating provides a general vulnerability analysis and should be used as a basis for a thought-process leading to sound recommendations to the commander on vulnerability reduction measures. See example on following page.

EXAMPLE: BIOLOGICAL VULNERABILITY ANALYSIS

1. Biological attack risk: Enemy is capable of employing biological agents, national policy condones use, would doctrinally target and can locate unit, and is trained and equipped to operate in BW environment; however, weather is not favorable. These factors place unit in medium category for attack risk.

2. Vulnerability analysis: Go to unit vulnerability rating matrix; approximately 30% of Unit has been immunized against predicted agents (value of 4), unit is currently in MOPP ZERO (6), practices good hygienic measures (1), and is in a static position (3). Adding the values shows a relative values total of 14; therefore, the unit would be at a high vulnerability rating. This simple analysis provides the chemical staff a basis to advise the commander on his unit's vulnerability (and the reasoning used) and, more importantly, provide vulnerability reduction measures (Chapter 3).

Section D, Chemical

The purpose of chemical vulnerability analysis is to determine how susceptible a unit is to enemy chemical attack, thereby identifying possible reduction measures.

The enemy generally employs nonpersistent agents over terrain that is planned for crossing or occupation. Nonpersistent fires force troops to assume and maintain protective posture for prolonged periods, thereby degrading combat effectiveness.

ENEMY USE OF NONPERSISTENT AGENTS

- Produce immediate casualties among unprotected troops.
- Restrict friendly use of terrain or objectives (limited).
- Degrade friendly combat effectiveness by forcing protective posture and creating confusion and stress, especially among leaders.

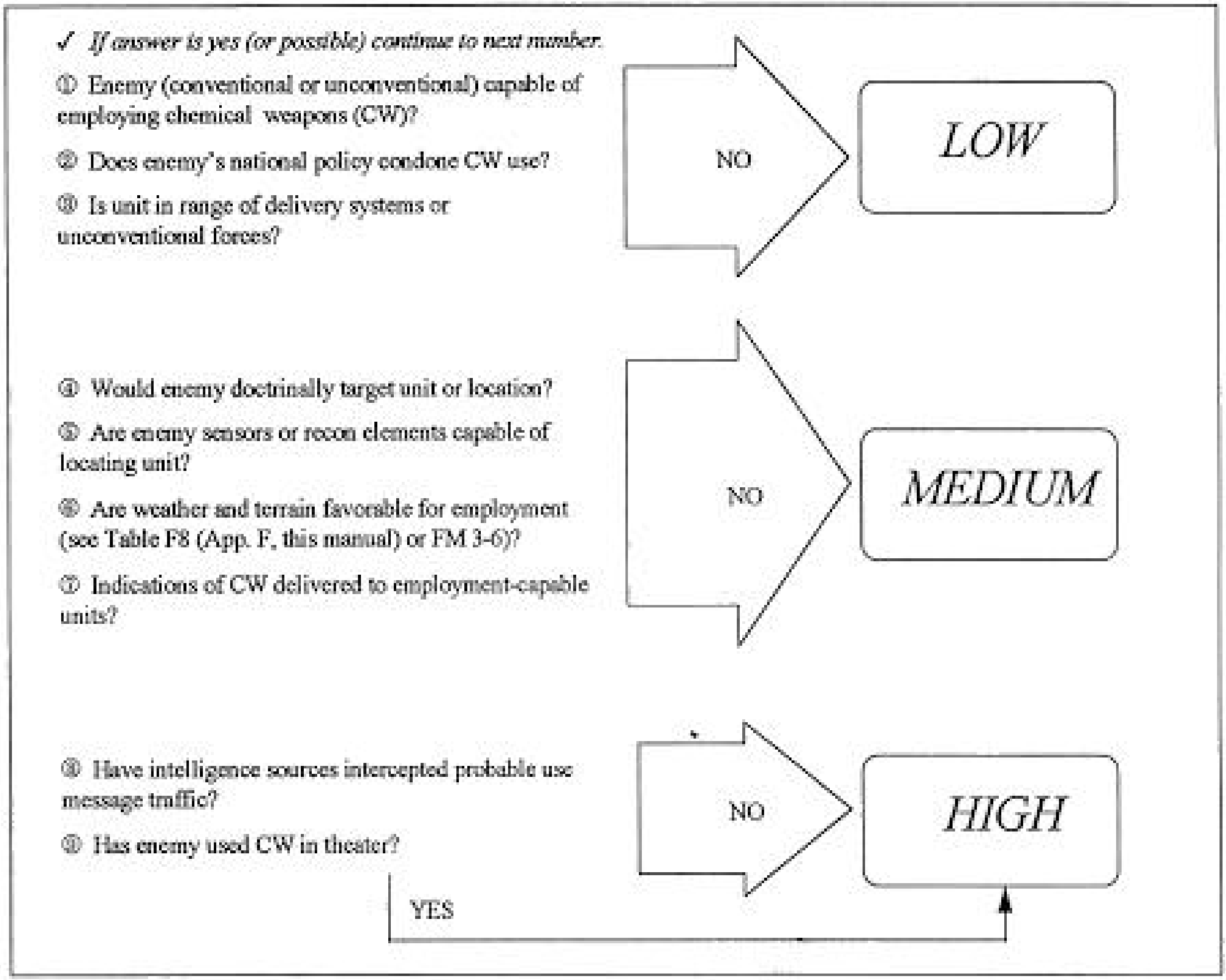
The enemy employs persistent agents over terrain he plans to avoid or against rear area targets. These fires force troops into protective posture for extended periods, force decontamination operations, disrupt logistical operations and deny ports of entry.

ENEMY USE OF PERSISTENT AGENTS

- Produce casualties among unprotected troops.
- Restrict use of terrain, facilities, such as ports and airfields, and equipment.
- Degrade friendly combat effectiveness by forcing protective posture and creating confusion and stress, especially among leaders.

- Delay friendly movement, such as repositioning or flanking moves.

Prior to conducting vulnerability analysis, we must first determine the unit's risk of chemical attack or the enemy's capability and probability of use (Figure 2-5). A checklist format is provided in Appendix C, while Appendix E provides possible enemy employment indicators.



✓ *If answer is yes (or possible) continue to next number.*

① Enemy (conventional or unconventional) capable of employing chemical weapons (CW)?

② Does enemy's national policy condone CW use?

③ Is unit in range of delivery systems or unconventional forces?

④ Would enemy doctrinally target unit or location?

⑤ Are enemy sensors or recon elements capable of locating unit?

⑥ Are weather and terrain favorable for employment (see Table F8 (App. F, this manual) or FM 3-6)?

⑦ Indications of CW delivered to employment-capable units?

⑧ Have intelligence sources intercepted probable use message traffic?

⑨ Has enemy used CW in theater?

Figure 2-5. Chemical Attack Risk.

If the possibility exists for the enemy to employ chemical agents, the chemical staff must conduct a vulnerability analysis. Conduct the analysis in two parts. First, make an estimate of the treat's capability to employ chemical munitions in the unit's AO/AI within a specific time period. Second, use this information to generate simplified effects information.

ESTIMATE DELIVERY CAPABILITY

Step 1. Determine time periods of interest. Time periods of interest are determined based on the commander's operational concept and situation variables ((METT-T) mission, enemy, terrain, troops, and time available). The time period is determined by the chemical staff in coordination with the intel and operation officers. They will normally conform to phases or the expected duration of an operation; however, it may be desirable to use other criteria. For example, a light infantry unit may want to use the expected time lag between an anticipated enemy chemical attack and the arrival of their protective gear (as in "MOPP READY" protective posture) as the time period of interest. A time period may also be based on factors relating to enemy tactics, such as the expected arrival time of a second echelon force. Further, significant weather changes could also influence the selection of time periods. The time period of interest can range from 6 to 48 hours. Vulnerability analysis is generally conducted in support of the planning process, not in support of current operations. A brigade-planning window usually focuses on a 12 to 48 hour period, with time periods of 24 hours or greater used when IPB allows. Time periods of less than 6 hours are generally not used. For short-term actions, shorter time periods could be used to estimate the effects of initial enemy preparation fires or to estimate the effect of a single chemical attack.

Step 2. Associate weather data with each time period. Associate each time period with a temperature, wind speed, and stability category. All required information can be obtained from the CDM. Temperature will impact primarily on agent persistency. For each time period, temperature should be expressed as one of the following (all in degrees Celsius): 55, 50, 40, 30, 20, 10, 0, -10, -20, -30. Determine temperature by taking the average of the temperatures from each CDM line applicable to the time period of interest. Use this average temperature for all calculations except for one condition – when estimating persistency for agents expected to last beyond the time period of interest, use the average daily temperature of the day in which the attack may occur. Wind speed will impact on casualty production, persistency, and downwind agent travel. It should be expressed as one of the following: 3, 6, 9, 12, 15, 18 kmph. As a rule of thumb, for any wind speed above 18 kmph, use 18 kmph. Calculate wind speed in the same manner used above for temperature. In some situations it may be necessary to modify this number for casualty estimate purposes. For example, if a 24-hour period contains 6 hours of expected high wind speeds (unstable conditions), you will probably elect to disregard those figures and develop a separate (lower) average for casualty estimation. Then chemical staff estimates an enemy would not employ chemicals for casualty effects during that 6-hout period of high winds. Base the decision on the magnitude and duration of the wind change and the expected enemy COA. Stability categories also affect casualty production and downwind agent travel. However, their impact is minor compared to temperature and wind speed. Expressed as stable, neutral, unstable, determine the stability category in the same way as temperature and wind speed.

Other environmental factors exist that could impact the analysis. For example, terrain and vegetation could affect the estimate. However, these factors have been incorporated in the persistency estimate process.

Step 3. Estimate delivery capability. Estimate the number of chemical munitions likely to be employed in your AO for each required time period. Coordinate with the intelligence officer and / or fire support officer (FSO) to produce the estimate. The chemical staff provides the intel officer with the time periods of interest. He can produce information concerning the threat's capability to deliver chemical munitions in your AO. The estimate should indicate the number of delivery units, by type, and the number of rounds by agent types if available. The intel officer also provides estimates on when, where, and what types of agent the enemy will use in unit's AO. If the situation or event template does not yield needed information, assume the enemy can optimize his agent mix. For example, to determine the threat's capability to create contamination barriers, we assume they will fire all persistent agents. Likewise, to predict casualty effects, assume the enemy will fire agents that have the greatest casualty producing effects.

When the primary threat is covert or unconventional, express enemy delivery capability in terms of agent weight or as agent weight times some expected delivery means, for example ten kilograms of nerve agent delivered by an agricultural sprayer.

If threat estimates indicate limited agent supply, it will be difficult to estimate how much of that supply will be used each day. As an option for this situation, conduct the analysis for a single enemy attack based on the treat's maximum employment capability during the selected time period.

The intelligence officer considers a number of factors in making his estimate:

- Number of employment assets within range of unit.
- Other AOs the enemy force must service. Do not assume every delivery system within range will be firing into unit's AO.
- Enemy locations of chemical munitions.
- Weather effects on probably agents.
- Threat forces' capability to delivery chemical munitions to delivery systems.
- Impact of threat attacks on civilians.

The intelligence estimate should provide a range of numbers based on estimated COA for each time period. For example, the estimate should provide the enemy's maximum capability and its likely delivery capability. Alternatively, different estimates can be provided that would support various enemy COAs. Estimates should not be based on friendly COA unless they would significantly impact on enemy delivery capability. It is not necessary to assess every possible situation and enemy option. To do so would result in inefficient us of available time. The goal is to provide estimates to the commander/staff, which can be alter refined. Continuously assess the situation and look for events and options with the potential of changing the outcome of the battle.

GENERATE EFFECTS INFORMATION

At this point you have a set of time period / munition delivery estimate combinations. For each of these combinations you can now develop a set of effects information: casualty estimates, contamination barriers, persistence, and times and locations of downwind agent effects. Effects information will provide the following estimates:

- Casualty effects.
- Downwind agent effects.

DETERMINE CASUALTY ESTIMATE

Step 1. Determine probable friendly targeted size.

a. Based on the chemical staff's S2/G2 IPB, select and area / unit the enemy would probably target then determine target size. For example, determine the area occupied by a maneuver company in a defensive position, in this case 400m X 600M.

b. Calculate number of hectares (ha) in target area. One hectare is 10,000 square meters. For the example, 400 X 600 = 240,000 square meters or 24 hectares.

Step 2. Determine probable agent. Unless it is known which agents the enemy will employ, assume the most effective casualty-producing agent available.

Step 3. Estimate casualties.

a. Estimate, based on IPB, the number of rounds the enemy will engage a specific target and predicted temperatures (From CDM or other sources), then referto Table 2-4, 5 and 6 for casualty estimates. The casualty estimates are valid for wind speeds less than 20 kmph. Other factors such as air stability category, humidity, variations in wind speeds under 20 kmph, and delivery errors were found to have minimal effect on casualty estimates for a given time period as opposed to a specific point in time.

For example, the templated target area is 24 hectares, predicted agent is GB, the temperature is 10 degrees Celsius and the weapon is 152 mm. Intelligence analysis estimates the enemy will fire 240 round at the target. 240 rounds divided by 24 hectares is 10 rounds per hectare. Go to Table 2-4 and extract approximate casualty percentage (50%).

b. To determine blister agent casualties, use same procedures and Table 2-6. However, use MOPP level rather than temperature.

Note: For Tables 2-4, 5 and 6, if the number of rounds falls between given numbers, worse case by rounding up.

Table 2-4. Sarin (GB) Casualties.

Munitions in Rounds per Hectare (10,000 m ^{2})			Temperature (degrees Celsius)			
MLRS	150-155 mm	120-122 mm	-12	0	10	20
			Casualty Percentage			
1	2	4	10	16	24	33
2	4	7	14	22	30	40
3	6	10	19	27	37	47
4	8	14	25	34	43	54
4	10	17	31	40	50	60
Based on 15 liter/minute breathing rate (rest or light work) and 15 second masking time.						

Associated risks from downwind hazards (see ATP-45 (A)/FM 3-3 for downwind prediction models) can be broken into three categories:

a. High casualty risk. Occurs at winds speeds of 10 kmph or less during slightly stable, stable or extremely stable atmospheric conditions. Agent clouds will produce very narrow and very long hazard clouds. Dosages over 100 times the lethal levels are possible in the hazard area.

Table 2-5. Thickened Soman (TGD) or VX Casualties.

Munition in Rounds				Temperature (degrees Celsius)			
Missiles per 1000 ha	Missiles per 150 ha	Bombs per 1000 ha	Bombs per 150 ha	-12	0	10	20
				Casualty Percentage			
6	1	26	4	5	14	20	21
9	2	40	6	8	18	25	25
12	2	54	8	12	24	31	31
15	2	68	10	16	28	36	36
18	3	80	12	19	32	40	41
21	3	94	14	21	35	42	43
24	3	106	16	23	37	44	45
Based on MOPP ZERO. At higher levels, agents are not as effective due to increased skin protection.							

Table 2-6. Blister Agent Casualties.

Munitions in Rounds per Hectare (10,000 m^2)		Protective Features	
		Casualty Percentage	
150-155mm	120-122mm	MOPP ZERO	MOPP 1
4	7	17	13
7	14	24	18
11	20	34	23
14	27	43	28
18	33	51	32
21	40	57	36

b. High degradation risk. Occurs during stability categories of neutral to very unstable and wind speeds less than 10 kmph. Agent clouds will produce wide hazard areas with lethal effects rarely extending as far as 10 kilometers. The casualty risk to warned, unmasked personnel is low. However, due to the large cloud width it is possible for every unit in the downwind hazard area to be forced to mask for several hours.

c. Low casualty risk. Occurs at wind speeds of 10 kmph or greater at stability categories of neutral to very unstable. The casualty risk is very low outside the area of immediate effects. Although a significant number of units will be forced to mask, agent duration will be short and will not extend as far as in previous category.

Section E, Toxic Industrial Chemicals (TIC)

On 22 April, 1915, the German Army attacked Allied Forces by releasing 150 tons of chlorine from cylinders on a 4-mile front in the Ypres salient. Although the numbers of dead will never be known, estimates vary from 500 to 5,000 dead and 20,000 casualties, the military effect was to cause a deep and wide penetration of the salient with only minimal casualties to the attacker. On 3 December 1984, 30 to 35 tons of methylisocyanate were accidentally released from the Union Carbide plant at Bhopal, India. It killed an estimated 2,500 people and injured up to 200,000 more.

In both of these incidents casualties resulted from the release of toxic industrial chemicals. Although less lethal on a gram for gram basis than current chemical warfare agents, industrial chemicals are often available in enormous quantities, do not require extensive research programs, are easily mass produced, and do not violate the Chemical Weapons Convention. Toxic industrial chemicals could be released from industrial plants or storage depots through battle damage, as consequence of a strike against a particular facility, or as a desperation measure during military operations. They could also be attractive as improvised chemical weapons and have potential for inclusion in clandestine programs or contingency plans.

Chemical warfare agents are highly toxic and lethal compounds designed specifically for military purposes. However, the countries possessing chemical warfare agents are generally known and are relatively few in number. By contrast, industrial chemicals are almost universal in their distribution and available in quantities that dwarf the amounts of chemical warfare agents ever produced. Industrial chemicals include chlorine, ammonia, solvents, pesticides, fertilizers, and petrochemicals and are extensively used in plasticmanufacturing . Industrial chemicals are used within industrial plants as well as sold and transported to other plants and distributed through commercial and retail outlets. They can be found in almost every town, city, or country in the word, in chemical industries, warehouses, rail yards, or agricultural supply companies. Any military mission is virtually assured to encounter industrial chemicals.

It is estimated over 25,000 commercial facilities worldwide produce, process, or stockpile chemicals that fall within the scope of the Chemical Weapons Convention. These include dual use chemicals that can be used both for legitimate industrial purposes and as chemical warfare agents. Each year, more than 70,000 different chemicals amounting to billions of tons of material are produced, processed, or consumed by the global chemical industry. Many of these chemicals may be sufficiently hazardous to be a threat, either by deliberate or accidental release, in military situation. If deployed in less traditional but increasingly significant stability and support operations, forces will often deploy into highly populated regions where industrial chemicals are produced, distributed, or used.

A variety of actions can result in industrial chemicals being deliberately or accidentally released in a military situation. During peace operations, ordinance expended by warring factions could go off-target and impart an industrial site or hazardous material container resulting in the release of harmful chemicals or fires. Warring factions may deliberately release a hazardous chemical against an adversary or the peacekeeping forces. Deliberate actions by terrorists are difficult to predict or defend against because these acts can be performed by small groups with ill-defined objectives and motives.

During Operation Joint Endeavor in Bosnia-Herzegovinia, chemical and preventative medicine personnel coordinated efforts to collect samples of suspected industrial hazards for analysis.

Based on this information, it is imperative the chemical officer can identify potential hazards, conduct risk assessment and vulnerability analysis from TIC in the AO. Issues include but are not limited to—

- Identifying possible industrial plants, storage sites, and shipment depots. What forces are conducting operations in vicinity or sites?
- Identifying chemicals routinely produced, used, or processed in the area.
- Identifying the chemical processes used to produce chemicals.
- Assessing whether deliberate release of TIC is realistic for a given situation.
- Determining if terrain and weather are favorable for overt or covert employment of TIC?
- Determining if the political environment is conducive to TIC attacks or releases?
- Assessing if the threat would gain a military advantage, either through military, civilian casualties or psychological means?
- Determining probable friendly response actions?

The chemical staff may obtain critical information from coordination with civilian authorities, host nation support personnel, or governmental agencies within the specific area of operation. Early coordination with these and other possible information sources will greatly improve the vulnerability analysis process, thereby minimizing possible contamination effects with early warning and enhances unit preparation.