

Chapter IX

This Land Is Our Land: The Environmental Threat of Army Operations

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Executive Summary

War by its very nature is destructive to the environment. Sometimes environmental damage is intentional, sometimes it is collateral. Some environmental damage might be necessary in the sense it is unavoidable. The effects can be seen now and throughout history. The effects are associated not only with the actual combat, but also with pre- and post- combat operations. The acute effects we can see on CNN, but the chronic threats to our environment are often elusive. The acute effects can be exacerbated if the source of the threat is not clearly understood. The chronic effects are difficult to determine because the *source - pathway - receptor* process that actually results in damage is complex and plagued with uncertainties.

The *source - pathway - receptor* model gives an analytical tool that helps us apply science to understand the threat military actions pose to the environment. The sources of the environmental hazards from combat operations are many: the chemical, biological, nuclear and explosive weapons, the damaged factories and war fighting infrastructure of the enemy, the collateral damage to the civilian infrastructure, destruction of habitat, and the targeting of historical or cultural treasures. Today, the most significant environmental threat is unexploded ordnance that threatens indiscriminately and persists long after conflict ceases. Our technology gives us the ability to better remediate and mitigate environmental threats, but there is still much we do not understand.

Many of the environmental threats of military operations go beyond the physical science of the *source - pathway - receptor* model. The development of an environmental ethic is an evolutionary process. The environmental stewardship ethic our Army has recently professed may not be shared by all. Although we may have the technology, financial resources, legal framework and awareness to minimize the environmental threats of our weapons, many countries possess the capability to use weapons of mass destruction or low technology weapons without these controls. Environmental terrorism can find a variety of sources and interesting pathways to threaten a wide variety of receptors.

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Military operations other than war (MOOTW) will require environmental stewardship and an understanding of the complex relationship people have with their environment. While we help nations for humanitarian reasons, we also need to provide them with affordable land management practices that can sustain their population and reduce adverse environmental impacts.

In this battle between Athens and the Theban confederacy, the genius of Greece found a new outlet: slaughter without ethical restraint.¹

In the battle of Delium, 424 B.C., the Athenians were at war with the Theban Confederacy. It was a custom at that time not to damage sacred areas, such as the waters at the Delium temple. In this operation, the normal customs gave way to more brutal military operations. The Athenians fouled the temple waters and also destroyed local vineyards and agricultural fields for a short-term military advantage.²

In the 2nd Century B.C., the Romans spread salt on the fields of Carthage to destroy crops and poison the soil.³ Sherman's march to the sea during the Civil War destroyed Confederate agricultural and industrial resources, impacting the South's ability to wage war by terrorizing the South into surrender⁴. During those earlier times, there were fewer hazardous chemicals being manufactured and fewer industries that generated hazardous substances.

During WW II, the Soviets used scorched earth tactics on their own territory to deny Germany the resources it needed to continue its offensive. Rebuilding the industrial base would take longer and cleaning up contamination in those areas of Russia is, in many cases, just beginning.

In the Vietnam War, modern herbicides were used to destroy vegetation to deny the enemy concealment. The long-term effects of these herbicides are still unclear. Additionally, mass bombing of vegetated areas with napalm, forest fires, and bomb craters also threatened the habitat over large areas of Vietnam. In the 1980s, the Soviets destroyed crops and fields in Afghanistan to deny food to the Mujahadeen rebels. During Operation Desert Storm, the Iraqis looted agricultural resources, destroyed irrigation capabilities, and destroyed oil processing facilities. Again, some of these effects will take years to remediate.

The threat to the environment posed by warfare has increased throughout history as nations have developed more sophisticated means to destroy vegetation and otherwise degrade the land in order to deny its use by enemies. The chemicals used are more efficient, last longer, and have a greater potential to harm the land and its people than those used at any time in the past.

War, or more generally combat operations, has as its goal inflicting great harm on the enemy. Coincidentally, it damages the immediate environment and can produce collateral damage over extensive space and time. As seen by the introductory historical examples, the environmental damages can have adverse

side effects. An equally important factor to consider, beyond the magnitude of the acute damage produced, is the chronic threat or longevity of the impact.

Modern combat with nuclear weapons, persistent toxic chemicals, long-lived contaminants such as dioxins, and unexploded ordnance can have impacts over generations. Many of us have seen the “sick humor” characterization of the lone soldier standing in the midst of Armageddon declaring, “We won.” As this paper will show, we have reached the point in our war fighting capability where we must consider the consequences as we develop and use these sophisticated weapons. We must also be very cognizant of the abilities of our enemies, because, as was proven at Delium, not everyone follows the rules.

It may appear that examining the science of how war impacts the environment is making a simple subject hard, but there are underlying and controlling principles that can demonstrate that the problem goes well beyond initial death and destruction. The best manner to examine this problem is to follow the chronology of combat. We can group the effects into those that result from preparing for war, the damage done during combat, the acute hazards left after combat, and finally the chronic hazardous residuals from all of the previous actions. In this form, we can more accurately compile and then sum the effects of combat to better understand its full impact.

The largest body of scientific analysis in the area of assessing hazards and defining risks comes from risk assessment of hazardous waste disposal operations. Here, the general model to determine the hazard of any action is to analyze the entire process by developing a *source - pathway - receptor* model.

A simple military example can best describe this model—chemical nerve agents. Chemical nerve agents are among the most toxic chemicals to humans. Brief exposure to a small quantity of agent can be fatal, absent proper medical assistance. Most agents work by either inhalation or absorption through the skin. The agents are delivered either by explosive munitions or through aerial spraying. The agent is the *source*; air transport of the agent, soil dermal contact, inhalation or ingestion are *pathways*, and the soldier is the *receptor*.

A source is any physical, chemical, or biological agent that is capable of producing a specific harm or danger.

Explosives, projectiles, chemical weapons, biological agents, and nuclear weapons are obvious sources. There is a much longer and less obvious list of hazard sources, primarily chemicals, that are also essential in combat. They include: petroleum products, chemicals for biological and chemical decontamination, infectious wastes from medical facilities, spent batteries, pesticides, etc. The list is almost endless. Contaminant sources may also be an indirect result of military operations, such as waste water treatment facilities that discharge untreated domestic waste into water sources after being accidentally damaged by an artillery shell. The contaminant may be a direct result of military operations. This category

might include chemical weapons or destroyed war fighting materiel factories that result in contamination through spills of hazardous industrial material.

Each hazard source must be analyzed to determine its hazard potential, both acute and chronic, its persistence when released to the environment, usually referred to as *fate*, and its *transport* properties which define where and how it moves once released. Again, borrowing from the hazardous waste management process, we can classify hazards as corrosive, ignitable, reactive (explosive), toxic, and infectious. Most of these terms are self-explanatory.

Toxic substances are a complex group which has many subcategories. The first subgrouping of toxins is *acute* -those that can have an immediate impact on health; and second, *chronic* - those that require some period of time to produce an adverse affect. Another way to subdivide the broad classification of toxicity is by end point. *Carcinogenic* substances produce tumors, *non-carcinogenics* attack other organs and systems (Agent GB is a neurotoxin), and *genotoxic* substances can cause cells to mutate. Further, there are several classifications for substances which may produce birth or developmental effects.

Nations see and feel the immediate or acute effects of war and its hazards; however, it is fear and worry about the chronic effects such as seen with Agent Orange, nuclear exposure, or the unknown, such as the uncertainty associated with illnesses from the Persian Gulf, that can last decades. People fear and worry because there are no absolutes on cause/effect and uncertainties remain even when our conclusions are based on the best statistics. Effects on the ecosystem are equally uncertain.

We know that most agents—chemical, biological, or radiological—cause damage according to a dose/response equation—the amount of substance experienced per time of exposure. It is clear that a large dose of a substance over a short duration will cause harm, but less clear is that smaller doses for longer periods can also eventually produce damage.

For example, small doses of radiation over long periods are not seen as harmful. This is why there are allowable doses for x-ray technicians. There are also even larger allowable doses for patients receiving medical diagnostic x-rays because these exposures are less frequent. However, one time exposure to large doses, or long exposures to lower dosages, can and do cause harm. Even though the principle of the dose/response is completely accepted scientifically, the dose/response curve for chronic exposures is the least certain aspect of the very inexact science of risk measurement.

A pathway is necessary to transport a hazard from the source to a receptor. The pathway part of the model is the easiest to misunderstand or omit from consideration. The pathway will depend on the environmental conditions and the properties of the agent. Its importance can be well illustrated with our chemical agent example. Troops can sustain the fight in a chemical environment not because

of the source or the receptor, but because protective equipment interrupts the route of exposure (*i.e.*, inhalation, dermal contact). Our Mission Oriented Protective Posture (MOPP) gear protects a vulnerable receptor (the soldier) from an inhalation or percutaneous (through the skin) exposure to the agent, thus reducing the risk though the source remains an extreme hazard. Likewise, a non-mobile agent located in an area without receptors will not produce a risk because it lacks a mobile pathway.

Most agents are able to transport or move based on their inherent chemical and physical properties. The physical state of the substance can be classified as solid, liquid, or gas. Gases will disperse as dictated by the meteorological conditions and other properties like vapor pressure, diluting as they mix.

Liquids are the most common and the most difficult to analyze for fate and transport properties. Liquids at standard temperatures and pressures possess inherent properties of volatility and water solubility. These properties give liquids the opportunity to move through the environment. Henry's Law predicts the amount and rate of volatilization for chemicals. Highly volatile liquids are those that will rapidly transform to a gas at ambient temperatures, creating an air hazard. Unfortunately, the most volatile can also be the most toxic. Liquids exposed to or mixing with water will tend to flow with and/or dissolve into the water based on the solubility product of the substance. Toxic substances that are reasonably soluble can be transported by water and create hazardous surface water and groundwater plumes. This situation abets the transport of the contaminated water which then becomes the pathway for exposure. Liquids also partition into the soil through a series of chemical and adsorption reactions. There are considerable published data on partition coefficients which can help predict the fate of chemicals released to the soil. However, these data are very incomplete in comparison to the number of chemicals available today. A final fate for a liquid is through uptake into the biota of the environment. Here, it can be bioaccumulated (concentrated) until it becomes toxic to the environment or a pathway to another host becomes available. The biological response to chemicals is a difficult toxicological factor to quantify.

A solid may transport by air if the particles are small, can dissolve into water based on its solubility, or may react chemically or biologically in the soil. The most significant hazard from solids is the inhalation hazard from particulate forms of hazardous materials. In combat operations these exposures are generally short lived, and therefore will tend to be acute. Depending on the persistence of the solid particles and where they settle, there is a potential for chronic risk.

One important physical/chemical property of risk agents is their environmental persistence. Chemical, biological, and radiological agents may transform when released to the environment. These processes can be chemical reactions, physical degradation, or biologically driven reactions. The products of these reactions may

be more or less hazardous than the original agents. The persistence of an agent determines how long the agent will be hazardous to a receptor. This time is a function of the agent's decay properties and of the concentration that the agent stops being hazardous to the receptor.

There are numerous mechanisms that influence the decay or change of an agent in the environment. A few of the most common reactions are discussed in this paragraph. Hydrolysis is a reaction with water or water vapor which yields a different chemical. Photolysis reactions in air are those powered by sunlight which transform vapors and aerosols. Biological agents will either grow, die, or mutate based on the environmental conditions they encounter. Chemicals in the water and the soil are susceptible, under the proper conditions, to degradation, transformation, or bioaccumulation. For example, bioaccumulation of PCBs in fish that live in contaminated streams represents a hazard to organisms that eat the fish. Inorganic mercury in river sediments can be transformed by biological reactions from this immobile form into the soluble and extremely toxic methyl mercury form.

The acute impacts on people, the environment and other receptors from the active phases of combat can be immediately evident. The hidden impacts, particularly the lasting damage and persistent hazards, are just as real, but much more difficult to assess and quantify.

A receptor is any susceptible target that can be damaged by the agent. It may be man, but can also be the ecosystem of an area, or a species that is endangered by actions, such as the destruction of habitat. After the contaminant reaches the receptor, the contaminant may be ingested, inhaled, or come in direct dermal contact with the receptor. These methods of entry into the body are termed routes of exposure. The amount of contamination that reaches the receptor through each of these exposure routes, and the rate at which it is absorbed, are determined by many factors, as is the effect of various levels of accumulation.

It is important to characterize the conditions under which the receptors may be exposed. Physical characteristics of the receptor, such as body weight, lung capacity, and skin surface area, influence the amount of contaminant which actually enters the body. Inhalation rate, water uptake rate, and duration of exposure are three equally important variables.

Table 1 presents examples of application of the hazard model to the phases of military operations: pre-mobilization/mobilization, military operations, and post-conflict operations. It would be interesting to attempt to construct a more complete table, but that would require excessive time and research.

In the pre-mobilization/mobilization phase, explosives must be manufactured and assembled into bombs, mortars, grenades, etc. Manufacturing represents an acute and a chronic risk to workers. Workers continue to be injured in these operations. Further, the waste products of these processes represent acute and

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Pre-Mobilization Mobilization	Source	Hazard Classification	Pathway	Receptor
Acute	training	physical damage	soil, water, air	training lands and flora/fauna
Chronic	spills during exercises, maintenance garrison operations	chemical, physical, biological	soil, water, air	training lands, humans, flora, fauna
Acute	industrial, production, accidental releases, explosions	chemical, physical, biological	air, water, soil	workers, population in the vicinity, flora, fauna
Chronic	releases of hazardous materials used in industrial production	chemical, physical, biological	air, water, soil	workers, population in the vicinity, flora, fauna
Military Operations				
Acute	explosives	physical	contact	soldiers, civilians, flora, fauna, land
	medical wastes	biological, physical, chemical	water, air, soil	soldiers, civilians, flora, fauna, land
	POL/hazardous waste spills	chemical, physical	water, air, soil	soldiers, civilians, flora, fauna, land
	chemical decon	chemical, physical	water, air, soil	soldiers, civilians, flora, fauna
	NBC weapons employment	biological, chemical, physical	air, water, soil	soldiers, civilians, flora, fauna, land
	war damage to industrial facilities that produce military items	biological, chemical, physical	air, water, soil	soldiers, civilians, flora, fauna, land
Post-Conflict Operations				
Acute	unexploded ordnance	explosive, chemical, physical	contact	civilians, land flora, fauna, soldiers
Chronic	disposal of contaminants, leaking weapons	biological, chemical, physical	air, water, soil	soldiers, civilians, flora, fauna, land

TABLE 1 - The Environmental Threat of Military Operations

chronic risks to people and the environment. We can mitigate these risks with engineering, but the mitigation is costly. The bottom line is that the more bullets you need, the larger the production capacity and the greater the potential for contamination. The long-term environmental effects of previous contamination are very complex and costly to mitigate.⁵

The Office of Technology Assessment, U.S. Congress, had this to say about the weaknesses in the nuclear weapons production systems that lead to contamination:

Many factors have contributed to the current waste and contamination problems at the nuclear weapons sites: the nature of manufacturing processes, which are inherently waste producing; long history of emphasizing the urgency of weapons production in the interest of national security to the neglect of environmental contamination; a lack of knowledge about, or attention to, the consequences of environmental contamination; and an enterprise that has operated in secrecy for decades, without any independent oversight or meaningful public scrutiny.⁶

In military operations, explosives represent a physical risk to our enemies, the civilian population, and to our own troops through friendly fire and accidents. Our explosives can also cause secondary adverse environmental effects by improper weapons storage practices that release hazardous materials.

The effects of explosives are not only immediate, but can last into the post-conflict phase. Explosives represent a continuing acute hazard after conflict in the form of unexploded ordnance. Mines are the most obvious and well-publicized problem in the area. Cahill⁷ estimates that as many as 100,000,000 mines have been emplaced in over 60 countries. The continuing death and destruction they are causing is well documented.⁸ A second part of this problem is the bombs, rockets, artillery shells, etc., that did not explode and are now lost in the environment. Even today, European governments continue to identify and remove these types of ordnance from World Wars I and II battlefields. Fort Monroe, one of the older Army posts, still has unexploded ordnance from our Civil War that periodically are uncovered and have to be removed and properly disposed of as hazardous waste.

Table 1 shows a chronic hazard for explosives and unexploded ordnance. This risk comes from the release of hazardous substances from buried munitions as aging containers decay and leak. These released chemicals can dissolve into the groundwater where they can be transported to receptors who use this water for drinking.

The effects of Agent Orange during Vietnam show the far reaching environmental threats of military operations. During the military operation phase:

At least 4.5 million acres of countryside, including 470,000 acres of farmland, were decimated by the 42 million kilograms (46,200 tons) of herbicides sprayed from

planes, trucks, and boats between 1962 and 1970. About 5 percent of the country's hardwood forest and 744 square miles of mangrove forests were destroyed.⁹

The long term health risk for our soldiers, legal battles over liability, and resources diverted from other defense programs, are some of the post-conflict operations phase effects. The economic effects are still being felt. A recent article in the *Environmental Reporter* discusses a 100 million dollar cleanup bill from one of the factories that produced this herbicide. In addition to the health problems and legal liability issues, there is still the problem of the destruction of the forests and the ability of the land to recover.¹⁰

The effect of 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD), the harmful component of Agent Orange, is dependent on numerous factors discussed previously. Its persistence measured in half-life (the time it takes for half the quantity of the component to decay) is from two hours¹¹ for leaves and foliage to ten years for soil.¹² Its toxicity, as previously mentioned, is extreme, with an LD₅₀ (the dosage required to kill 50 percent of the test group) as low as 0.02 milligrams per kilogram. After the Gulf War, *Audubon* magazine asked four different authors to write a series of essays on "War and the Environment." One of the authors, Mr. James M. Fallows, discussed a trip to Vietnam. The time is not mentioned, but it appears to be in the late 1980s. He observed:

Along Vietnam's central coast, in Da Nang and Nha Trang, I have seen a surprisingly large number of children whose limbs are missing or malformed. They are far too young to have been wounded in combat and because there are so many of them, it is hard not to think, as the Vietnam Government contends, that Agent Orange is to blame.¹³

He did not observe the acute effects of defoliation, but he did observe the chronic effects. Depending on original concentration levels and because of the chemical nature of TCDD, health problems in children years after Agent Orange was used could result.

Targeting of certain large facilities that support a nation's warfighting capabilities can have tremendous short-term effects and uncertain long-term effects on the environment. An example of such destruction is the RAF bombing of the Mohne Dam on 16 May 1943. Initial planning did not necessarily look at the environmental damage, but focused on the probable damage to the industrial base and the ability of Hitler to wage war.

It is impossible to state the raid's exact effect on the German economy. Local German sources for the Mohne episode indicated that 1,294 people were dead or missing (including 573 foreigners, mostly Ukrainian women workers) and that 1,000 houses had been destroyed or damaged. Among other results, 11 factories had been destroyed and 114 damaged, 2,822 hectares (6,973 acres) of farmland damaged, 6,316 cattle and

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pigs killed, 25 road bridges destroyed and 10 damaged, and various power stations, pumping stations, water and gas facilities put out of action.¹⁴

Although the Germans claimed minimal damage, some 20,000 personnel from the labor corps working on the West Wall were diverted to repairing damage done by the breaching of the Mohne Dam. It is easy to see why the dam was targeted and the definite military advantages that accrued to the Allies. The acute effect was significant. However, the long-term environmental effect is unknown. The damage to the environment was not analyzed at the time, and is difficult to assess retrospectively. It is unknown what types of factories were destroyed and what hazardous materials entered the Ruhr River. From the science presented above, we know some would hydrolyze, others would settle out, still others would bioaccumulate in organisms or biologically degrade.

We can leverage technology to limit the threat of military operations to the environment. Toffler and Toffler note that today, one F117 aircraft, flying a single sortie and dropping one bomb, can accomplish what it took B-17 Bombers flying 4,500 sorties and dropping 9,000 bombs to do during WWII, or 95 sorties and 190 bombs during Vietnam.¹⁵ "In 1881, for example, the British fired 3,000 shells at Egyptian forts near Alexandria. Only ten hit their target."¹⁶ During Operation Desert Storm, although the technology was present for the use of precision bombing, 93% of the bombs, representing 85,000 tons of TNT, were gravity type with 70% missing the target.¹⁷ The fact that technology can provide more precise weapons does not mean that the technology will be used in all cases. However, it provides an additional option to the commander. With careful targeting and precision delivery, it is possible to limit some environmental damage without jeopardizing the success of the military operation.

The oil spills and deliberate destruction of the oil facilities in Kuwait is the most notable example of environmental damages from war in recent history. Most early coverage included dire predictions on the magnitude and duration of the impacts of this "environmental terrorism," as it was characterized by world opinion. Numerous articles covered the potential threat soon after the war. The attention dropped off quickly, however, as the oil fires were extinguished. It is interesting to compare the projections with later, more confirmed data. For example, the original estimate to stop the oil fires in Kuwait was 2-5 years.¹⁸ Innovative technology developed in response to this problem was able to reduce this time to less than nine months.¹⁹

The original predictions of the impact of the smoke suggested large regional and even global damage. However, a final analysis found that meteorological conditions limited the impacts to the immediate region and fortunately also limited the ground concentrations to levels well below acute standards²⁰. The shortened duration of the event greatly reduced the chronic risk to troops and the

local population. This is not to downplay the adverse effects that did occur, but there is a tendency to exaggerate war damage in all areas, not just environmental. Technology in this case prevented a more severe impact on the environment. The long term impacts of the oil residues on the desert are still being examined.

Oil was released into the Persian Gulf, supposedly to foul the water source for the Saudi Arabian water plants on the Gulf. The acute threat to the desalination plants that was originally feared was prevented by Coalition forces' efforts to minimize the environmental impact. On one occasion, a leaking oil system was specifically targeted so that the oil would stop flowing.²¹ The long-term impacts of the oil on the aquatic ecology of the Gulf was a question of significant debate, again with early predictions suggesting large damage. Studies continue on the final impacts on the oil residues in the Gulf. The long-term ecological and economic impacts are uncertain.²²

A similar spill in the Persian Gulf from the Al-Nowruz Oil Field in 1983 during the Iran-Iraq conflict allows a longer term analysis of the ability of the ecosystem to recover. Monitoring in 1989 showed no trace of pollution even at the lowest detectable levels. The absence of pollution was attributed to the presence of certain microorganisms that fostered biodegradation. Additionally, the climate and geological uniqueness of the Persian Gulf allows sunlight to penetrate the water for most of the year, which aids in the degradation process.²³

Although the effects of the Operation Desert Storm oil fires and spills were minimal on a global scale, the long-term effects of military operations in the local area were more significant. The destruction of urban infrastructure in Kuwait destroyed waste water treatment facilities, resulting in raw sewage being emptied into the Persian Gulf. Resultant metal and pathological contamination levels differed depending on the specific outfall. Locally, this caused damage to fishing and recreation that depend on water quality. Destruction of water plants and electrical generators also had a large impact on the cultural environment.

The Iraqi infrastructure was also damaged during Operation Desert Storm. Embargoes on materials needed to rebuild facilities to ensure sanitary conditions for the Iraqi population is a long-term and somewhat indirect effect of military operations. Without the ability to fix sanitary problems, the population is subject to the pathogens which cause disease and epidemics. Because of the embargo, effects of military operations in Iraq will be more long lasting than those in Kuwait.²⁴

The largest impact was the abandoned and unexploded ordnance scattered throughout Kuwait and in southern Iraq. The cost of finding and removing the ordnance inside Kuwait drains resources for other rebuilding. A continuing threat to the population remains because finding and removing the unexploded materials to 100 percent "clean" are not possible.

The requirement to dispose of war debris quickly causes the mixing of industrial and domestic waste. These facilities have an increased threat of methane gas problems and chronic pollution because the normal quality and regulatory controls were not enforced. PCBs from destroyed transformers pose an additional risk. Hazardous waste at abandoned or damaged industrial sites must be properly disposed of, requiring the expenditure of funds which are competing for other infrastructure projects. Untreated pathological waste from hospitals require special disposal to protect future health concerns.

Some eighty ships were believed to be sunk during the Persian Gulf War²⁵. The contents of these ships and potential for pollution is uncertain. Testing has indicated higher levels of trace metals and hydrocarbons in the vicinity of one sunken tug. This demonstrates that these vessels are a potential source for long-term damage.²⁶

The effect on the land and agriculture is uncertain. It took most European nations an average of 4.6 years to return to their pre-WW II production levels.²⁷ During the Persian Gulf War, normal practices were interrupted as farmers were displaced or were called to serve in the armed forces. As a result, crops were not harvested, irrigation stopped, top soil eroded away, and pest control ceased. Furthermore, deposition from the oil fires interacts with the soil and effects its fertility.²⁸ Irrigation, dependent on pumping, further suffers as power is interrupted and not available.

Without the constant care and application of pesticides and integrated pest management, the pest problem increased. Pesticides were looted and less available. New pests have been observed. New strains of species and new habitats were allowed to develop because the normal treatment of pests was interrupted by military operations.

Another long-term effect of military operations that is difficult to quantify is the loss of talented people, historical records and scientific equipment that could be used to provide better analysis of environmental problems and better strategies to recover.

Much research has been done on the environmental impact of massive armor movement in the desert environment, both in the Persian Gulf and in our national training center. The migrating sand caused by the disturbance of the delicate "desert pavement" could have long-term effects: dune movement, sand storms, closing of airports, and encroachment on agricultural settlements.²⁹ Vehicle tracks can remain for years depending on climatic conditions. The desert vegetation is quite sensitive to vehicle traffic and deposition of pollution caused by oil spills or fallout from oil burning.³⁰ Fifty-year old tracks are still visible in California desert areas where General Patton conducted exercise maneuvers.³¹ In general, the soil in a desert environment is prone to more long-term effects than other soils.

Endangered species can be threatened by military operations. Habitats can be damaged and destroyed by military exercises causing long-lasting or irreparable harm to species. Long-term effects depend on the extent of the damage, contaminant residues, and ability of species, both flora and fauna, to recuperate.

The near-extinction of the European buffalo due to unmanaged killing to feed the German army during World War II is an example of direct impacts that can threaten species' existence. The lobster harvest in Vietnam was severely impacted because of military operations. Civilians overharvested the lobsters to meet U.S. in-theater demand and because military operations rendered their previous civilian occupations too dangerous. Short-term economic gains caused long-term depletion of the lobster supply. In World War II, upon finding out that Japan was using elephants to resupply their armies, elephants were targeted by military operations.³² The cruelty of war to animals was again seen in Operation Desert Storm as the Kuwait Zoo was subjected to indiscriminate slaughter of animals by Iraqis.

Targeting or accidentally damaging chemical and nuclear facilities could pose a serious threat to the environment.

Russian forces pummeled a Chechen oil refinery and sent shells dangerously close to an ammonia plant yesterday, raising the specter of a catastrophic explosion in the breakaway capital.³³

In the Bosnian conflict, war damage to some fifty factories has polluted the Danube.³⁴ Hazardous chemicals involved in the manufacturing of weapons and explosives, metal plating and refining oil,³⁵ released into the environment pollute surface and groundwater. These pollutants can be passed down stream or settle in the river bottom to be a future problem once disturbed or dredged. Power plants that run treatment facilities are destroyed. The embargo policy of the current conflict in Yugoslavia also impacts the environment.³⁶ Because the necessary resources cannot be acquired, contamination continues unabated.

There is not a large volume of data describing the impacts of environmental damage from attacks on industrial facilities; however, examining the impacts of well-documented industrial accidents gives us an insight into what the likely results will be. Jiri Matousek, writing in 1990, identified ninety-nine chemical accidents this century with fifty-eight of them occurring between 1960 and 1990.³⁷ The following are a couple of examples.

In 1928, a ten-ton tank of phosgene gas (COCl_2) ruptured at a Muggenburg chemical plant. The effect was acute, with eleven dead and over 200 injured within a fourteen kilometer area.

On 3 December 1984, an explosion at a Union Carbide plant in Bhopal, India killed 2,300 and injured 30,000 to 40,000 people. The accident was due to a small amount of water being released into a storage tank of methyl isocyanate.

Collateral damage from military operations could cause a similar tank to rupture and be exposed to water. The Bhopal plant was an insecticide manufacturing plant similar to those in many countries.

The number of these types of chemical and nuclear facilities has increased dramatically this century. The effects of the nuclear accident at Chernobyl could also demonstrate the potential contamination and environmental effects of a nuclear facility damaged as part of a military operation.

Increased awareness of the environment has produced domestic legislation that added liability impacts to the environmental threats of military operations.

The environmental protection laws in the 1970s can be attributed to political pressure from the American people brought on by increased awareness of the environmental threat in general. In 1960, with the writing of *Silent Spring* by Rachel Carson, the environmental threats of the chemical industry were exposed. She observed that the 500 chemicals that were being added annually might have an effect on our ecology.³⁸ With increased legislative activities came sanctions and an increased awareness for both the military and civilian populations. Realization of the military threat to the environment lagged somewhat. However, by the time of the Persian Gulf War, the environmental threat of military operations was well discussed. The potential for the loser to compensate the victor for environmental damage is now possible. In its report to the Congress on the Gulf War, the Department of Defense stated that:

The Ottawa Conference of Experts also noted UNSC Resolution 687 (3 April 1991), which reaffirmed that Iraq was liable under international law to compensate any environmental damage and the depletion of natural resources.³⁹

From petrochemicals to complex inorganics, from chemical and biological contaminants to nuclear weapons, the environmental threat of military operations has increased dramatically. The threat to the environment posed by military operations is now a concern of the Army.

We have experienced a social change, an ethical change, in our concern for the environment. Roderick Nash, in his article "Do Rocks Have Rights?,"⁴⁰ presents an ethical evolution from the pre-ethical past of concern for self through a future ethical view that concerns the environment. It is an evolutionary awareness and adjustment in ethical thinking. The ethics move from an individual ethic, concern for self, through family, tribe, nation and race, until a sense of humankind is reached. The future ethical direction is one in which our flora and fauna have worth and a sense of stewardship and responsibility is accepted. Much like Maslow's hierarchy of need, the steps are evolutionary and require the movement from one stage to the next.

Our world is in all the different stages of ethical evolution. Our potential adversaries may not share our ethical frame. Some underdeveloped nations, like

Somalia, are in the family/tribal stages of ethics and warfare. Rogue nations are on the rise. Military operations in Russia against the Chechen rebels can be seen as a national conflict, maybe even civil war. In South Africa we can see a racial ethical frame evolving, a concern for the equality of the different races.⁴¹

Our armed forces must adapt to a more advanced ethic that elevates concerns for the environment. The current military trend in armed conflict doctrine, as described in *Force XXI*,⁴² stresses information processing and technological innovations which reduce the size of the forces, increase precision and lethality, and increase the land area of operations.⁴³

Although our technology is advanced, that of our enemy may run the spectrum. It is likely that environmental threats and impacts on the land caused by U.S. forces could decrease, but the statistics on Operation Desert Storm bombing show the continued practice of using less sophisticated weapons that more adversely affect the environment. Additionally, the U.S. Army may have to devise ways to deal with the environmental threats posed by our adversaries.

We are in a constant transitional stage where warfare and ethics are connected. Our warfare evolution and our ethical evolution do not mean that everyone else is on the same level. An ethic that accepts a sense of responsibility for the animals, plants, and environment is not shared by all. The result is a variety of military operations that will have differing degrees of effects on the environment. As ethics and stewardship continue to play a more dominant role, effects of modern warfare on the environment can be minimized.

National and international laws protect the environment and could pose liability and adverse financial impact on military units not complying with prescribed norms. Pollution prevention initiatives reduce cost, reduce quantities of hazardous materials, reduce the number of hazardous materials, and engineer-in less environmentally threatening operations. Good training practices can minimize adverse environmental impacts and increase awareness of environmental effects. Technology provides the ability to identify impacts through remote sensing and increases our ability to remediate environmental effects.

Current environmental practices of our military during non-combat operations can mitigate the environmental threat. The nature of military operations other than war (MOOTW) puts importance on improving the infrastructure, public health, sanitation, environmental conditions, and quality of life for the nation we are assisting. We can expect to see our military in humanitarian operations and operations that place the military in a position of "stop the dying." Conflicts can be caused by adverse environmental impacts and scarcity of resources. The resolution of the conflict may depend on correcting/mitigating the environmental damage so the land can sustain its people.⁴⁴ The mission of U.S. forces is often not to seize land, but to return someone else's nation to a democratic form of government. The land must be returned to the nation with minimal

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environmental cleanup requirements. Most nations we assist cannot afford costly environmental cleanup and infrastructure repair bills. Additionally, citizens, both in the nation we are assisting and at the home front, will only accept an environmental stewardship ethic.

In conclusion:

a. The environmental impact of military operations can be exaggerated in the short-term and very difficult to estimate in the long-term. It is therefore essential to apply science to accurately predict the impact of military operations and develop doctrine. Commanders can make the correct choice in military operations only when fully aware of the risks and uncertainties of the environmental consequences of their plans. There are times where military necessity dictates that military operations will adversely affect the environment. Our responsibility is to make that decision with as much accurate information as possible.

b. Our ability to mitigate the effects of pre-mobilization/mobilization activity has grown immensely, particularly in comparison with World War II standards. From the 1980s to the 1990s, waste generation in the defense industry was reduced by more than 60 percent. We are now much better suited to mitigate the damages from training activities.

c. Our ability to cleanup unexploded ordnance, particularly buried mines, continues to challenge available resources and technology. Mines are problems in countries throughout the world; they continue to claim even the most innocent victims. Detection and removal remains tedious, dangerous, and costly.

d. A full range of warfare is possible, and even though the U.S. military may be capable of mitigating the environmental impact brought on by armed conflict, there are other nations that are in different stages of the evolution of "environmental ethics"⁴⁵ which can pose a greater threat to the environment. The use of terrorist attacks specifically to damage the environment is also possible. An enemy might target a cultural or historical symbol for psychological effects much as the Athenians did at Delium.

e. To the maximum extent possible, we (the American military) must succeed in leading by example. Military operations must be accomplished in concert with environmental stewardship.

Notes

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3. *War and the Environment, a Collection of Essays*, Audubon, Sep.-Oct. 1991 at 88.

4. *The War of Rebellion: A Compilation of the Official Records of the Union and Confederate Armies*, Series 1, Vol. XLIII (1893).

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9. Goldfarb, *Will Environmental Degradation be a Feature of International Conflicts in the Future*, in *TAKING SIDES, CLASHING VIEWS OF CONTROVERSIAL ENVIRONMENTAL ISSUES*, 342 (5th ed. 1993).
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13. Fallows, in *Audubon supra* n. 3 at 94.
14. RICHARDS, *THE HARDEST VICTORY, RAF BOMBER COMMAND IN THE SECOND WORLD WAR* 178 (1995).
15. TOFFLER & TOFFLER, *WAR AND ANTI-WAR* 84 (1993).
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17. Kahu, in *Audubon supra* n. 3 at 92.
18. *A Case Study of Crimes Against the Environment—Kuwait*, in *ENVIRONMENTAL PROTECTION COUNCIL, STATE OF THE ENVIRONMENT REPORT* 17 (Nov. 1991).
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20. *Id.* at 562.
21. U.S. Department of Defense, *Final Report to Congress, Conduct of the Persian Gulf War*, App.O, at 625 (Apr. 1992).
22. *Supra* n. 18 at 35.
23. Khordagui & Al-Ajmi, n. 19 at 562.
24. Pearce, *Water in the War Zone*, *New Scientist*, Dec. 17, 1989 at 13-14.
25. *Supra* n. 18 at 36.
26. *Id.*
27. *The Military Impact on the Human Environment*, 1978 Stockholm Intl Peace Research Inst. Y.B., at 77.
28. *Supra* n. 18 at 41, 43.
29. Holden, *Kuwait's Unjust Desserts: Damage to its Desert*, *News & Comment*, Mar. 8, 1991, at 1175.
30. *Supra* n. 18 at 41.
31. Fisher in *Audubon*, n. 3 at 96.
32. Browne in *Audubon*, n. 3 at 90-91.
33. *Chechen Oil Refinery Burns*, *Times Herald Record*, Dec. 31, 1995, at 7.
34. *Supra* n. 24 at 13-14.
35. *Supra* n. 19 at 557. In this article the authors claim the environmental impact was exaggerated and that "unlike water and air, soil pollution is likely to persist for years to come."
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