

Warfare and the Environment

Environment and Health: Impact of War

Dr. Jennifer Leaning

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War has marked human experience since the beginning of recorded time, and the demands of war have in many ways shaped and advanced the practice of medicine. Rhodes estimated the immense scope of war-related mortality in the 20th century and demonstrated the increasing fraction of civilian deaths. Levy and Sidel recently reviewed the broad public health consequences of preparing for, coordinating and cleaning up after contemporary wars. War rivals infectious disease as a global cause of morbidity and mortality. In the 1980s health professionals' concern about the effects of war on the environment was focused on the sweeping ecological consequences of nuclear weapons. In the 1990s the Gulf War and the Kosovo experiences demonstrated the environmentally destructive capacities of conventional weapons.

There remain enormous gaps in our knowledge about the relationship of war and health. Understanding is constrained by the lack of recorded information and the comparative absence of continuing systematic field research undertaken from within any one discipline. Work is underway to explore how environmental stress and resource constraints may contribute to conflict, but the topic lies outside the scope of this review.

The environmental impacts of war can be understood by examining the magnitude and duration of effects, involved ecosystems in specified geographic locations, the use of individual weapons systems, the results of particular production processes and the cumulative combined effects of specified military campaigns. From this perspective, 4 activities can be seen as having prolonged and pervasive environmental impact with significant consequences for human populations: production and testing of nuclear weapons, aerial and naval bombardment of terrain, dispersal and persistence of land mines and buried ordnance, and use or storage of military arms, toxins and waste.

Production and Testing of Nuclear Weapons

Nuclear weapons technology was developed during World War II and expanded as an industrial enterprise of vast scope and complexity in the Cold War between the United States and the Soviet Union. Nuclear weapons technology continues to dominate concerns regarding potential hazards to the environment. Radioactivity, released into the environment in many phases of production and testing processes, poses a serious threat to the health of biological species, including humans. Assessment of this threat begins with estimating the amount of radiation released, itself a difficult task, and then evaluating health risks on the basis of what can be found in epidemiological studies of exposed populations and ecosystems over time. These studies are based on relatively small samples and look at areas affected by above-ground tests, areas near nuclear weapons production and storage facilities and areas used for radioactivity tests. These studies raise concern in terms of human health effects, costs of environmental cleanup and continued environmental contamination.

Massive amounts of radioactivity have been released in the last half of the 20th century from the nuclear weapons testing programs of all the main nuclear powers. The testing phase of nuclear weapons included 423 atmospheric tests (conducted from 1945 to 1957) and about 1400 underground tests (from 1957 to 1989). The total burden of radionuclides released from these tests has been estimated at 16–18 million curies ($1 \text{ Ci} = 3.7 \times 10^{11} \text{ Bq}$) of strontium-90, 25–29 million curies of cesium-137, 400 000 curies of plutonium-239 and (for the atmospheric tests only) 10 million curies of carbon-14.

More is known from the United States than from other countries about radiation releases from the military production of nuclear weapons. Production sites that have been investigated and found to have caused significant environmental contamination include the Hanford Nuclear Reservation in Washington state (producing weapons-grade plutonium), the Oak Ridge Reservation in Tennessee (producing components for nuclear weapons), the Rocky Flats Plant in Colorado (producing plutonium triggers for warheads) and the Savannah River Plant in Georgia (producing tritium and plutonium). Accidental releases and continued emissions as part of daily operations have been reported at these and many other production facilities. Disputes regarding the human health effects of these exposures have not been entirely resolved, despite extensive study. The US government has recently acknowledged that occupational exposures to nuclear and other toxic materials at these plants justifies the awarding of compensation to over 3000 current and retired workers whose health has been adversely affected.

Aerial and Naval Bombardment

Bombardment of the urban infrastructure, which constitutes the environment for a significant fraction of the world's human population, has always caused forced displacement of survivors. During World War II, when air power for the first time was

deployed as the pivotal military technology, the practice of bombing civilian settlements became increasingly prevalent, and hundreds of thousands of people died as a result. In the aerial bombardments of Tokyo in March 1945, about 100 000 to 200 000 people were killed. In the fire bombings of 70 German cities, including Hamburg in 1943 and Dresden in 1945, it is estimated that 500 000 to 800 000 people died. About 200 000 people died from the acute effects of the atomic bombs in Hiroshima and Nagasaki in 1945.

The bombardment of cities and the destruction of forests, farms, transport systems and irrigation networks during World War II produced devastating environmental consequences, and by the end of the war there were almost 50 million refugees and displaced people. In the last year of the war the land of coastal and northern France was torn up, Holland south of the Zuyder Sea was flooded with the destruction of dikes, and many ports were clogged with unexploded ordnance and sunken ships. Great damage had been done to most cities in Europe, with the hardest hit including Warsaw, Berlin, Hamburg, Dresden, Dusseldorf, Boulogne, Le Havre, Rouen, Brest, Pisa, Verona, Lyons, Budapest, Leningrad, Kiev and Cracow.

All visitors to central Europe reported a feeling of unreality; lunar landscapes dotted with enormous heaps of rubble and bomb craters, deserted and stinking ruins that had once been business centres and residential areas. To find housing for the survivors was the most urgent problem, but in Germany about a quarter of all houses were uninhabitable, and almost as many in Poland, Greece, Yugoslavia, and the European part of the Soviet Union. In the American zone of Germany 81 per cent of all houses had been destroyed or damaged. In the German-occupied parts of the Soviet Union the homes of six million families had been destroyed, leaving about 25 million people without shelter.

Estimates of war damage in Japan noted that 66 cities had suffered major damage, with about 40% of their area destroyed; throughout Japan about 9 million people were left homeless. Comprehensive data are not available, but limited evidence from the first 2 post-war years suggests that, because of vast food shortages and the failure of the 1945 rice harvest, hunger and malnutrition afflicted the majority of the population and thousands died from causes related to starvation.

This sequence of aerial bombardment, destruction of home and urban and rural infrastructure, and progressive waves of dislocated or homeless people, can be seen in all wars subsequent to World War II. In the 15 years of the war in Southeast Asia, the US bombardment of Vietnam, Laos and Cambodia forced about 17 million people to become refugees. In the Gulf War, the allied forces crippled the urban support systems of major cities in Iraq. In the conflicts of the post-Cold War era, marked by sieges of cities, attacks on safe havens and pulverization of towns to effect ethnic cleansing, millions of people have been forced to flee within or across national borders. In 1999 about 35 million people were counted as refugees or internally displaced people as a result of war or internal crisis.

Land Mines

As a result of the last 50 years of wars in Europe, Africa, Asia and Latin America, an estimated 70–100 million antipersonnel land mines are still active and in place worldwide, and another 100 million exist in stockpiles. Almost 400 million have been strewn across continents since World War II, and with the proliferation of civil wars waged by irregular forces, the use and spread of land mines as a preferred method of securing and denying land has accelerated. Land mines are placed now without regard to requirements under international law to mark, map, monitor and remove them. Hence, the majority of the victims of land-mine explosions are civilians engaged in daily farming or foraging activities. Reliable regional estimates of incident rates of injury and death are difficult to come by; one frequently cited statistic is that land mines injure or kill about 500 people every week.

The countryside of Kosovo was rimmed and internally laced with land mines laid by all sides; after a year of international efforts to remove them, an estimated 1415 known or suspected minefields remain. Since the June 1999 ceasefire and the return of the civilian population, the monthly toll killed from land-mine or cluster-bomb explosions has dropped from 44 deaths and 109 serious injuries in June 1999 to no deaths and 15 serious injuries in April 2000.

Land mines accelerate environmental damage through 1 of 4 mechanisms: fear of mines denies access to abundant natural resources and arable land; populations are forced to move preferentially into marginal and fragile environments in order to avoid minefields; this migration speeds depletion of biological diversity; and land-mine explosions disrupt essential soil and water processes.

Review of experiences in the 20th century indicates that the persistence of active mines and unexploded ordnance haunts old battle areas and that, despite intensive efforts at clearance and deactivation, millions of hectares remain under interdiction in Europe, North Africa and Asia. In Libya one third of its land mass is considered contaminated by land mines and unexploded munitions from World War II. When these mines do explode, in addition to causing serious injury and death to humans, domestic animals and wildlife, they shatter soil systems, destroy plant life and disrupt water flows, accelerating ecosystem disruption. Interactions between natural disasters and buried land mines slow attempts to demine areas and protect populations. For instance, the floods in Mozambique in 1999 and 2000 are feared to have displaced the hundreds of thousands of land mines left from the civil war, and concern about their whereabouts has delayed recovery operations. Painstaking efforts

to mark known minefields have been set back considerably by the flood waters, and a new mapping team has been sent out by the international community.

Defoliation and Toxic Pollution

Attempts to damage the environment as a tactic of war against the formal enemy and as a means of instilling terror in the general populace have been described throughout history. During World War II instances of dike disruption, dam destruction and scorched earth retreats have been well documented. Interactions between natural disasters and buried land mines slow attempts to demine areas and protect populations.

It is generally accepted that the extensive use of environmental destruction as a strategic practice in war can be seen to date from the use of defoliants during the war in Southeast Asia. From 1965 to 1971 the United States sprayed 3640 km² of South Vietnam's cropland with herbicides, using a total estimated amount of 55 million kg. The stated rationale was to deny the enemy sources of food and means of cover. This widespread use of chemicals to destroy farmland, forest and water sources is unprecedented, and the environmental consequences are still relatively unexplored. International teams have been granted access for field assessments only in the last few years.

Of the many wars waged since Vietnam, the Gulf War during January and February 1991 demonstrates the ways in which the technologies of war and industry can be used to wreak widespread environmental havoc. Iraq's release of about 10 million barrels of Kuwaiti oil into Gulf waters⁶² caused great stress to an ecosystem already suffering from decades of abuse (oil spills, the Iraq-Iran war, freighter traffic and industrial waste). Scientific assessments of this ecological loss and the catastrophe resulting from the Iraqi firing of 732 Kuwaiti oil wells are underway, although constrained by incomplete data and controversy.

More recent wars, or what the humanitarian relief community terms "complex humanitarian emergencies," have been assessed for their potential, through the creation of large refugee camps, to inflict harm on the local environment in which the camps are situated. In the cases of the refugee camps in the African Great Lakes region from 1994–1997, Mozambique, Sudan and the Afghanistan–Pakistan border areas, a number of studies are now looking at issues of deforestation, encroachment on vulnerable ecosystems and national parks, water pollution and sanitation degradation, air pollution and loss of endangered species.

Future work on the environmental effects of war must address 4 main issues: information, threat assessment, vulnerability assessment and the role of international law.

- *Information:* Insufficient information exists about the effects of war on natural ecosystems, both in the immediate aftermath of war and over the long term. Methods for historical and contemporaneous reporting are incompletely developed and lack robust institutional support. Without improvement in these areas, assessments of the environmental damage of war will continue to be fragmentary.

- *Threat assessment:* Escalation in numbers of weapons, advances in technology and widespread proliferation, including threats, of terrorist use now place the local, regional and global environment in greater jeopardy than ever before. Nuclear weapons, the most extreme technology, have been shown in careful theoretical studies to be capable, even in limited regional use, of destroying vast sections of the world's environment. Despite the fact that our capacity to contain and mitigate environmental effects of current weapons systems used in war is grossly underdeveloped, the world community continues to permit, and even support, a multiplicity of regional and international arms races.

- *Vulnerability assessment:* Historical data on the destruction of coral reefs during the war in the Pacific and enduring changes in desert terrain from the North African campaigns of World War II provide faint and isolated hints that fragile environments take a long time to recover from war. Burdened by rapid population growth in many parts of the world, unrestrained settlement and economic exploitation, regional ecosystems are increasingly threatened.⁸¹ As we encroach upon the margins of our environment into the 21st century, post-war ecological resilience cannot be assumed to be present in all places, particularly within a human timeframe.

- *International law:* The legal and ethical framework within which the medical and public health profession works during wartime is defined by the Geneva Conventions and related documents. The current discussion is whether existing law to limit the environmental effects of war is sufficient, if fully enforced, or whether new law is needed. Proposals to set up environmental surveillance systems, as enforcement mechanisms to support current law, were developed during the Gulf War.

The increasing participation of health care professionals in these 4 areas of work may lend impetus to the development of research and policy leading to more positive outcomes.