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Chapter Twenty-Five

ENVIRONMENTAL IMPACTS OF THE PERSIAN GULF WAR

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INTRODUCTION

The technological revolution of the twentieth century has enabled us to alter our environment on a scale never before possible. One inherent danger of living with twentieth century technology is that it may be abused, resulting in rapid, large scale damage to both human populations and remaining natural ecosystems of the Earth. Abuse of nuclear technology is a major source of concern; however, equally formidable environmental disasters may also result from abuse of modern industrial technologies. Three scenarios which may precipitate large-scale environmental damage are war, terrorism, and technological accidents.

This chapter examines significant man-made environmental damage which has resulted and which potentially may result from the Persian Gulf War of 1991. The intent of this chapter is not to belittle the tragedy of lost human lives during fighting of the war, but to point out some environmental problems associated with the war. Such environmental problems are often discounted at the time of war, in the wake of immediate loss of lives; however, in the long term, it may be the environmental problems which accrue the most substantial economic and human costs, including continued loss of lives long after commencement of the war.

Oil Spills

During the week of January 20, 1991, about 1.5 million barrels of oil (63 million gallons) were spilled in the Persian Gulf offshore of Kuwait.[1] The spill was more

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than five times larger than the 11 million gallon Exxon Valdez spill of 1989.[2] The 1991 Persian Gulf spill originated from at least two sources. The major source was a pipeline leading from Port Mina al Ahamari, Kuwait, to the Sea Island filling station 10 miles offshore.[3] The other, lesser source of spilled oil was 5 leaking supertankers off the coast of Kuwait. Oil from the supertankers may have been due to damage from Coalition force attacks, while oil from the pipeline is believed to have been deliberately spilled by Iraq.[3] On January 26, 1991, Coalition forces were able to reduce the flow of oil from the pipeline to a trickle through precision bombing, but not before a massive slick had formed.[3] Several possible motives for the deliberate spillage of this oil by Iraq included: discouragement of an amphibious invasion of Kuwait by Coalition forces with the potential damage to motors of amphibious landing vehicles and the potential for lighting beaches afire during an invasion[4]; damage of offshore naval vessels from oil drawn through water intakes of ships, resulting in contamination of the ships' drinking water and damage to steam turbines[5]; fouling of desalination plants in Saudi Arabia, depriving civilians and soldiers there of drinking water, and also possibly generation of electricity.[4,6]

While these tactical motives for the oil spill were largely unsuccessful, the environmental effects have been significant, with the full extent of these effects not yet known. In comparison to the oil spilled from the Exxon Valdez in Prince William Sound, the oil spilled in the Persian Gulf was a "light" crude, meaning that it contained a higher proportion of highly aromatic volatile compounds, which evaporate rapidly, especially in the warm Gulf waters, which range from 10°C to over 30°C.[3,7] However, it is the volatile compounds, which include benzene and toluidine, which are most toxic.[3] It has been estimated that 15% of the spill initially evaporated from the water surface, while eventually, after weathering, only 10% of this "light" crude will remain to contaminate beaches and sediments (as compared to 20-50% which remained from the Exxon Valdez spill).[3,8,9] Ecological effects of the spilled oil have been exacerbated however, by the conditions under which the spill took place, the water flow characteristics of the Persian Gulf basin, and the high diversity of marine organisms native to the Gulf.

Since the oil spill took place within the war zone, dangers of artillery fire and floating mines severely hindered both evaluation of the extent of the spill and remediation efforts.[2,3] This led to an original ambiguity as to the size and location of the spill and prevented many conventional clean-up measures such as containment of the spill within booms, skimming of the water by cleanup vessels and application of chemical dispersants.[3] While 5.4 million gallons of the spill have reportedly been recovered by an internationally-aided cleanup, the vast majority of the oil has been left for nature to disperse.[10]

The Persian Gulf basin is a nearly land locked body of water and has a low rate of mixing with the Indian Ocean.[7] Three to five years are required to flush surface waters of the Gulf to the Indian Ocean, as compared to only 28 days required to flush the water of the Prince William Sound, the site of the Valdez spill, into the Pacific.[7] A second basin-related factor is the depth of the Persian Gulf, which averages only 35 meters.[7] This shallow depth gives the Persian Gulf a relatively low water column volume available for dispersion of the oil and associated toxic com-

pounds. In addition, the relatively low wave action within the Persian Gulf will slow dispersion of the oil onto the shore line and may result in deposition of thick oil mats and tar balls over large areas of beach where the slick hits shore.[9] These thick deposits, especially tar balls, can release toxic compounds over long time periods.[3]

The flow of water within the Gulf is generally counter-clockwise, which will cause the slick to move south, past Saudi Arabia and eventually towards India.[9,11] In Saudi Arabia, much of the peoples' water supply is derived from desalination plants along the coast. The desalination plant at Jubail uses about 3 billion gallons of water per day from the Persian Gulf to provide 270 million gallons of fresh water to the people of Riyadh and surrounding communities.[12] Although the slick itself has not clogged the plant's intake pipes, the plant may take in water which has been contaminated with trace amounts of dissolved toxic compounds from the oil, which could affect the safety of the water for drinking.[10] By the time the oil reaches India, it is likely to be well dispersed, however, the possibility remains that the oil could affect shrimp, lobster, oyster and scallop harvests, which provide a large source of income to many people.[11]

The Persian Gulf contains a high diversity of ecosystems, which include coral reefs, mangroves, and sea grass communities.[3] There are 450 animal species associated with coral reefs alone.[10] Also, 180 species of mollusks, 106 species of fish, 5 species of dolphins, 113 species of overwintering birds, 3 species of whales and numerous sea turtles, dugongs, and sea snakes have been scored in the Gulf.[6,10,13] The effects of oil on sea birds may be most devastating. During the first six months after the spill, 20,000 avian casualties have been reported.[14] Oil can coat the birds' feathers, hindering flight and causing loss of the feather's insulating properties. At the same time, birds ingest oil from contaminated food or while cleaning their feathers.[15] This oil is then delivered to young hatchlings as food, which, even in trace amounts, greatly increases hatchling mortality.[16] The oil-soaked cormorant has become symbolic of the ecological damage caused by the spill.[7]

The Gulf War oil spill was probably not the largest spill on record (that notoriety belongs to the Ixtoc spill of 1979-1980 during which 140 million gallons were released into the Gulf of Mexico[6]). Neither was the Gulf War spill the only recent spill in the Persian Gulf, as there have been 125 major spills in the Persian Gulf since 1978.[6] However, the Gulf War spill was unique in that it was a deliberate act. This act resulted in immediate threats to human lives through loss of drinking water, and may continue to threaten humans if water from desalination plants becomes tainted with trace hydrocarbons or other oil pollutants, or if marine food harvests are affected.[10,11] At the same time, many marine animals were lost and delicate ecosystems may have been altered, perhaps forever.

Oil Well Fires

Over 700 of Kuwait's approximately 800 oil wells were set ablaze by Iraqi invaders.[18,19] As a result, heavy smoke clouds covering most of Kuwait have been observed by satellite. On some days, smoke clouds were visible over a 42,000 km^2 area including parts of Iraq, Iran, Qatar, Pakistan, Turkey, Sri Lanka, India,

Bulgaria and even the Soviet Union.[10,20,21] While the consensus among atmospheric scientists is that no measurable global effect will result, local effects have been severe and regional damage is a threat. Prior to the Gulf War, there had been a record of 3 simultaneous oil well fires in Kuwait.[22] The Gulf War oil fire disaster was two to three orders of magnitude higher than this record and was compounded by Iraqi placement of mines around wells and the destruction of well depth and configuration plans.[23]

Since most of Kuwait's wells are under natural pressure, extinguishing by explosives and/or capping is required to put out each fire.[24] Globally, eight teams have had experience in the dangerous art of extinguishing oil well blazes and they have been working in Kuwait since the end of the war.[25] One blaze can take up to two weeks to extinguish at a cost of up to 10 million dollars.[18,25] Approximately 1-3 years will be required to extinguish all fires.[19] Estimates of the amount of oil burning in Kuwait in 1991 range from 1.5 to 6 million barrels per day.[26] Assuming the lower rate of burning, the cost of the fires in oil loss alone exceeds 10 billion dollars annually, assuming 1991 oil values.

Oil well fires release large amounts of hydrocarbons and particulates which are most likely to have local effects. On many afternoons, it has been common to see pitch black skies over large areas of Kuwait, including Kuwait City.[10] The smoke particulates absorb and/or reflect much of the sun's radiation to outer space, which has resulted in decreases in average peak daily temperatures to as much as 10°C below normal over areas of Kuwait and Iraq.[26] In Bahrain, for example, 400 km from the fires, the averge temperature in May 1991 was 7.5°C below normal, making it the coldest May in 35 years.[27] Although it is difficult to establish an absolute cause and effect relationship between the fires and the unusually cool weather, the observed temperature changes are consistent with atmospheric models, which have predicted temperature reductions of 5-8°C at 250 km from the smoke source and reduction of 1-2°C at distances as far as 750 km.[26]

Children and eldery are most susceptible to respiratory problems due to inhalation of smoke components.[10] Days with low wind and high barometric pressure are worst for all since smoke dispersion is decreased and concentrations of air pollutants become dangerously high.[18] Included in the smoke particulates are hydrocarbons and traces of lead, arsenic, and copper, which are known to be carcinogenic or neurotoxic through chronic inhalation or ingestion.[28,29] Tens of millions of people are expected to ingest toxic residue from smoke and, over the next generation, some are likely to develop chronic respiratory problems. The incidence of cancers may increase due to both inhalation and ingestion.[14,22,30] Various other effects also prevail. While fires continue to burn, people and animals cannot drink rainwater in Kuwait.[31] Persistent fumes of burning diesel and burning rubber have been reported throughout Kuwait, and an oil film covers buildings and automobiles.[30,32] Black and white cows have been reported to appear gray.[23] The effects of the oily film on vegetation is unknown, however a decrease in temperature of as little as 2°C is known to reduce crop growth rates, possibly affecting fruit and agriculture production in Iraq and Iran.[7,33] Since most particulates in the smoke are hygroscopic and have short atmospheric half lives (4-6 days), the major health and environmental

threats of smoke particulates are limited to local and small regional effects.[26,27]

On a larger regional scale, acid precipitation, at a pH of 3.0-3.6, is predicted as far as 2000 km downwind from the oil fires.[26] This acid precipitation is likely to affect at least Iraq, Saudi Arabia, Bulgaria, Afghanistan, and Pakistan.[26,32] Acidic precipitation may cause damage to crops, although alkaline soils in some areas may reduce this effect.[6,26] In higher areas where snow falls, such as mountains in south Iran and the Himalayas, snow has been reported to be gray with acidic soot.[14,22,26] During the spring, snow melt may be more rapid than usual due to higher radiation absorbance of the darkened snow, resulting in flooding and acid shock in certain streams and irrigation systems, possibly causing death of sensitive aquatic species and crop damage.

Global effects due to the oil fires have not been observed yet, primarily because the majority of the smoke has been confined to the troposphere (the average smoke injection height has been below 2 km[26]). Although there was reported a 20-times-normal carbon soot reading over Hawaii in April 1991,[34] it appears that most smoke did not reach the stratosphere, where its atmospheric effects would have been much more pronounced. If smoke had been ejected with sufficient force, or had a great degree of lofting occurred, then a longer atmospheric retention time of particulates, a larger and more rapid distribution of smoke, and a greater effect of blocking incoming solar radiation could have had disastrous global implications.[3] Fortunately, smoke from the oil fires is not ejected nearly as forcefully as that from volcanoes or nuclear explosions, and the stratosphere remained largely unaffected.[26] Effects of the fires on the summer monsoon over the Indian subcontinent are expected to be negligible.[26,34]

In terms of global increases of atmospheric pollutants in the troposphere, the Kuwaiti oil fires are expected to increase the world carbon dioxide output by about 1% in 1991, and the sulfur dioxide output of the fires is predicted to be the equivalent to output of the United Kingdom in 1991.[26] While these atmospheric inputs are minor on a global scale, the small region from which they originate has suffered high local concentrations of atmospheric pollutants on scales not before caused by man, with the possible exception of burning of tropical rainforests in the Amazon.[26]

Desert Disruption and Damage

The desert of Kuwait harbors its own unique ecosystem which has been affected detrimentally by the war. The ecosystem consists of animals such as snakes, camels, gazelles, spiders, scorpions and sheep, and is stabilized by an upper layer of sand, pebbles and microorganisms which has been referred to as the "desert shield".[18,35] Pebbles ranging in size from about 0.5 cm to 2 cm in diameter form the natural upper layer of the ecosystem and are large enough to resist movement during most wind storms, thus holding in place the smaller grains below.[35] In addition, a network of microorganisms including bacteria form an interlocking mesh among the smaller upper sand grains, which allows resistance to wind disturbances[18]

Military fortifications and massive-scale vehicle movements have disrupted this

"desert shield" in Kuwait, and it may require decades to recover.[18,35] The result may be increased sand storms, as have been documented after the Iran-Iraq wars of the 1980's. Dunes may move, most likely to the south, where they may engulf agriculture areas, cities, or airports.[35] To prevent such disasters, it may be necessary to construct large windbreaks and funneling systems to direct sand around sensitive areas.[35]

Another problem in most of Kuwait may be ground water contamination. Hydrocarbon deposition from oil well smoke and deliberate spilling of oil in trenches and irrigation channels throughout Kuwait is expected to contaminate ground water, making water from natural wells unsafe to drink.[32] Finally, mines left buried throughout the desert will pose a hazard to travelers for years to come, however, it has been suggested that the mine threat may be beneficial to nature in that it may allow the desert ecosystem to recover more rapidly by discouraging further human disruption.[18]

Hazardous Debris

A final environmental threat lies in the debris and wreckage left by Coalition attacks on Iraq. Coalition forces bombed all known chemical factories and chemical weapons storage depots throughout Iraq. Hazardous chemicals have been released into the areas surrounding many chemical factories and storage sites.[36] These chemicals may pose a threat to any habitants nearby. While dismantling Iraq's nuclear, biological and chemical capabilities is required by U.N. Security Council Resolution 687, cleanup of such contaminated sites can be extremely expensive and is probably not a priority for Iraq at this point in time.[36] As a result, persistent chemicals may have time to spread in the environment, contaminating both humans and animals. In addition, it has been reported that an Iraqi nuclear reactor was bombed by Coalition forces, and it is possible that radioactivity has been, or is being, released.[4] If such a situation is a reality, then we may expect further casualties for many years to come.

Call for International Policy

Death and destruction are inherent elements of war, however, non-strategic, non-essential destruction of the environment is not an acceptable action by any party in any situation. Iraq has not been the first country to use a "scorched Earth" policy. In fact, in the United States, "scorched Earth" policies were used by Union generals against southern cities, and by Confederate generals against Pennsylvania towns during the Civil War.[21,37] The problem, however, has become most dire in the twentieth century due to technological developments. While one could argue that an unwritten rule has never been sufficient and a firm policy against "scorched Earth" should have been made long ago, it has been only during the twentieth century that such a stringent policy has become absolutely essential for global security. Prior to the twentieth century, human-induced violent destruction has been limited to local areas of unrest. Today, the actions of one party against the Earth can potentially be felt globally. When the Earth becomes violently damaged by one party,

we all now pay, whether it is through loss of life, health, or the burden of remediation costs. The United Nations must develop a policy which makes "environmental terrorism" an international crime with severe penalties which will be upheld and supported by all Organization members. The wording of such a policy must be straightforward and understood by all parties, such as with the existing policy for treatment of prisoners of war (POWs).

In a sense, during the Gulf War the Earth was lucky. Many worse scenarios can be imagined than the present reality It should be obvious, however, that we cannot depend solely on the technology of our defenses to protect the Earth. The governments of the world must mutually agree to spare the environment as far as is possible in future confrontations and in the future development of weapons and war strategies, with an understanding of internationally enforced penalties for failure to oblige.

REFERENCES

1. Radwan, S. 1991. Gulf oil spill. *Nature.* 350.465.
2. Washington Post. 1991. Gulf oil spill cleanup can be handled in time. *The Express.* Easton, PA. March 1.
3. Raloff, J. and Monastersky, R. 1991. Gulf oil threatens ecology, maybe climate. *Sci. News.* 139:71-73.
4. Shenon, P 1991. Huge slick still a threat to Saudi water plants. *NY Times.* January 28.
5. Washington Post. 1991. Oil may be used as military weapon. *The Express.* Easton, PA. January 27.
6. Annon. 1991. Persian Gulf falls victim to war. *Chemecology.* 20(2):4-5.
7. Pearce, F. 1991. Wildlife choked by world's worst oil slick. *New Sci.* February 2:24.
8. Ford, P. 1991. Vital Saudi water plant prepares for oil slick. *Chr. Sci. Mon.* February 1:2
9. Miller, E.W. 1991. The Valdex Oil Spill: environmental, economic and social impacts. In:*Natural and Technological Disasters.* eds. S.K. Majumdar, *et al.*, The Pennsylvania Academy of Science, Easton, PA. pp. 322-328
10. Schmitt, E. 1991. Fouled region is casualty of war. *NY Times.* March 1.
11. Nayar, K. 1991. Effects of Monsoon Discounted. *India Abroad.* March 8.
12. Holusha, J. 1991. U.S. companies join bid to minimize Gulf oil spill. *NY Times.* January 29.
13. Schneider, K. 1991. Saudis seek U.S. help with oil spill. *NY Times.* January 27.
14. Warner, F. 1991. The environmental consequences of the Gulf War. *Environment.* 33(5):7-9
15. Nybakken, J.W. 1982. *Marine Biology, an ecological approach.* Harper and Row. New York. 446 p.
16. Carefoot, T.H. 1977. *Pacific Seashores: a guide to intertidal ecology.* University of Washington Press. Seattle. 208 p.
17. Goodman, E. 1991. Deliberate oil spill in Persian Gulf is a crime against

humanity. *The Express*. Easton, PA. February 1.
18. Elmer-Dewitt, P. 1991. A man-made hell on Earth. *Time*. March 18.
19. Hoffman, H. 1991. Taking stock of Saddam's fiery legacy in Kuwait. *Science*. 253:971.
20. Limaye, S. *et al.* 1991. Satellite observations of smoke from oil fires in Kuwait. *Science*. 252:1536-1539.
21. Emerson, S. 1991. When Earth takes a hit. *Int. Wildlife*. 21(4):38-41.
22. Zuckerman, M. 1991. When it's dark at high noon. *US News & World Rept.* April 1.
23. Lorch, D. 1991. Burning wells turn Kuwait into land of oily blackness. *NY Times*. March 6.
24. Edmonds, P. 1991. Burning oil could be environmental disaster. *The Express*. Easton, PA. January 23.
25. Wald, M. 1991. Damage to Kuwait oil production requires a close and expert look. *NY Times*. February 23.
26. Browning, K. *et al.* 1991. Environmental effects from burning oil wells in Kuwait. *Nature*. 351:363-367.
27. Irby, R. and J. Snow. 1991. The scientific team in Kuwait. *UCAR Newsletter*. 15(3):3-5.
28. Leerhsen, C. *et al.* 1991. Hellfighters to the rescue. *News Week*. March 25.
29. Molholt, B. and R. Nilsson. 1991. Inhalation carcinogenesis by metals. In: *Air Pollution: Environmental Issues and Health Effects*. Eds. S.K. Majumdar, E.W. Miller and J.J. Cahir. The Pennsylvania Academy of Science. Easton, PA. pp. 379-395.
30. Green, M. 1991. Health experts arrive in Kuwait. *USA Today*. March 15.
31. Seitz, R. 1991. Black skies or pale fire? *Nature*. March 21.
32. Ibrahim, Y. 1991. Another war begins as burning oil wells threaten a region's ecology. *NY Times*. March 16.
33. Schneider, S. 1991. Smoke Alarm. *World Monitor*. March: 50-51.
34. Tyson, R. 1991. Soot from Kuwait fires settles on Hawaii. *USA Today*. May 1.
35. Holden, C. 1991. Kuwait's unjust deserts: damage to its desert. *Science*. 251:1175.
36. Associated Press. 1991. Chemical arms pose problem. *The Express*. Easton, PA. June 9.
37. Jacobs, M. 1864. *The Rebel Invasion of Maryland and Pennsylvania*. J. Lippincot and Co. pp. 9-11.

EPILOGUE

By the first week of November 1991, all oil well fires in Kuwait had been extinguished. This accomplishment was achieved much sooner than expected, due in large part to the intense efforts of some 28 teams assembled to fight the fires (Wald, 1991).

Wald, M.L. 1991. Amid ceremony and ingenuity, Kuwait's oil-well fires are declared out. *NY Times*. November 7.