Crime, Law & Social Change **33:** 313–328, 2000.

The environmental legacy of Saddam Husayn: The archaeology of totalitarianism in modern Iraq

ALEXANDER H. JOFFE
Department of Archaeology, Boston University, Boston University, Boston, MA 02215, USA

Abstract. The environmental security risk which Iraq poses to itself and its neighbors is considerable. Iraq's enormous investments in military industries, including weapons of mass destruction, well-documented practice of environmental warfare, and extensive aggression against internal ethnic minorities and neighbors, have created long-term ecological problems which have degraded the air, water, and soil, negatively effected public health, and intentionally displaced populations. These and many other problems will confront any successor regime and the international community. Some of the environmental problems and their causes are reviewed here. It is suggested that detailed study and planning should begin immediately to catalog and address the environmental legacy.

Introduction

Totalitarian regimes treat their environments with almost the same brutality as they treat their people. The case of the former Soviet Union has shown that the environmental legacy of violence and disregard persists long after the regime, or even the political system, disappears. When the fascist Ba'ath regime of Saddam Husayn finally disappears, no matter by what means, Iraqi society will still be faced with the results of decades of environmental destruction. The regime launched two major wars and scores of minor conflicts, carried environmental warfare against neighboring states and its own populace to new heights, and transformed its industrial base to serve its hegemonic ambitions. Iraq's enormous investments in military industries, especially those involved in weapons of mass destruction (WMD), have contributed to not only the progressive impoverishment of the vast majority of the population, but environmental degradation that will be felt for decades, if not centuries, to come.

The environmental security aspects of the Iraqi situation have been almost wholly ignored by both the West and by the Iraqi opposition. This is understandable to the extent that resistance to and removal of the regime remains the paramount concern. But it is argued here that it is critical to begin assessing the consequences of Ba'athist rule with an eye to making concrete plans for addressing possibly dire ecological problems, as a means of focusing the

often fractious and disparate Iraqi opposition on fundamental concerns, and to mitigate the environmental security threat Iraq poses to its itself and its neighbors.

The scope of the problem

The effect of Saddam Husayn and Ba'athist rule on Iraq has been all-pervasive. The application of mass terror by a tiny, paranoid, and ultimately tribally based regime, is well-documented, as are the international consequences of persistent aggression and miscalculation.[1] In environmental terms the effect has been no less profound, although it has received far less attention. Three basic areas of environmental consequences directly related to the regime's policies maybe outlined:

1. Military infrastructure, including industries, especially weapons of mass destruction, and bases.
2. Environmental warfare, against Iran, Kuwait, and the *Ma'dan* (Marsh Arabs).
3. Battlezones, with unexploded munitions, toxic residues, and other damage.

When these three areas are systematically broken down, with some accounting of their geographic and temporal extent, the nature and quantities of materials involved, and their impact on the health and economy of Iraq, the magnitude of the problem may be glimpsed. Hundreds of facilities, hundreds of buildings, covering hundreds of square kilometers, were used for WMD production alone. How were materials handled? Where were toxic wastes dumped? Thousands of square kilometers were intentionally modified by environmental warfare, specifically the creation of canals against Iran, the intentional release and burning of oil in Kuwait, and the draining of marshes in southern Iraq. Many tens of thousands of square kilometers became battlezones during the 1980–1988 Iran-Iraq war, and the 1990–1991 Gulf War, using some of the most lethal conventional and unconventional weapons and materials known. How will these areas be located, much less remediated? Some of the most easily recognized problems, such as depleted uranium (DU), minefields, and unexploded ordinance (UXO), and the effects of intentionally released oil, are still poorly understood. The problem is even greater when the extent and industrial ecology of WMD production is considered. To these must be added the impact of Iraq's vast petrochemical industry, and almost complete lack of environmental protection regulations or ethos.

Military industries produce some of the most toxic primary and secondary materials on earth. In the United States the true costs and consequences of the Cold War military-industrial complex are now becoming understood. Massive

resources are being dedicated to cleaning up facilities that stretch across the entire country, as well as overseas, and the health consequences of these industries are finally being acknowledged. Even decommissioning conventional bases has presented severe environmental problems.[2] In the states of the former Soviet Union, still beset by mentalities of secrecy, these problems are less acknowledged, and less frequently addressed.[3] Conversion of those industries remains a serious problem, in addition to preventing the leakage of personnel and materials.[4]

The Iraqi situation is and will be similar to that of the former Soviet Union. One of the few advantages which any future Iraqi leadership possesses is the documentation assembled by the IAEA and UNSCOM on the most toxic industries, those involved in weapons of mass destruction. In addition to conducting baseline surveys of all industrial facilities, UNSCOM and IAEA inspections gathered information about waste handling and disposal to assess the materials balance of WMD production, but these data do not figure prominently in their public reports. The data are not generally available to researchers, and since they were gathered with the assent of the current regime, they cannot be utilized by the Iraqi opposition for environmental planning. Whether a successor regime could reclaim, or ideally open these data for study, is an unaddressed legal question.[5] Much less information is available on other military industries, the impact of the vast military infrastructure, environmental warfare, and battlezones. Much relevant data may reside within the intelligence files of Western governments, and of course Iraq itself, but it seems unlikely that parties on either side of the equation will relinquish information for environmental purposes. Any future Iraqi regime concerned about its people will have to contend with an environmental problem of unknown magnitude. The environmental epidemiology of the problem is presently unknown, but allegations by Iraq that specific Western munitions, such as depleted uranium, have contributed to increased infant mortality and birth defects raise the possibility that the effects are already being felt.[6]

A review of the problem

Ample open source literature exists to at least systematically review the range of problems and consequences facing Iraq. All industrial processes are complex chains of resource extraction and transformation, the movement and consumption of finished products, and the disposal of both finished products and by-products. An approach to the industrial ecology of weapons production must account for all stages in the lifecycle of materials. In the wake of the Cold War it has been learned that dismantling weapons systems is far from the final step in the lifecycle of components and materials. It is also clear

that in the context of disarmament, severe environmental consequences must be anticipated.[7] The case of Iraq disarmament has come haphazardly in the aftermath of the Gulf War and the application of sanctions. After any number of "full, final, and complete disclosures," by Iraq, and almost a decade of UNSCOM and IAEA inspections and monitoring, Iraq's military industries remain formidable. A selected number of problems are discussed below.

Military industries: WMD

The industrial processes involved in WMD production are well-understood. In addition to the actual weapons systems, extensive waste and by-products are generated, which must be either recycled or disposed. How Iraq handled these wastes is unknown. To these formidable unknowns must be added the results of warfare. Many WMD sites were destroyed by aerial bombing during the Gulf War, others were unilaterally destroyed by Iraq, and still more were dismantled or destroyed by UNSCOM. A significant portion of Iraq's petrochemical industry came under attack, both during the Iran-Iraq War, and the Gulf War. The cumulative environmental impact of all these activities is unclear, although it is probable that the destruction of chemical warfare storage facilities during and after the Gulf War has contributed to health problems among coalition forces.[8] A variety of monitoring systems were established in connection with UNSCOM surveys and IAEA safeguards, and Iraq itself conducted limited radiological and chemical monitoring.[9]

Contaminants from nuclear weapons manufacture are included in Table 1.

Just production of the high explosives (HE) used in nuclear weapons creates some amount of waste material, from HE residues mopped up after milling, to developer and fixer solutions used in radiographic analysis of charges.[11]

In addition to the numerous programs to create nuclear weapons, what is publicly known of Iraq's handling of nuclear materials is not reassuring. The IAEA removed existing research reactor fuel from Iraq. The fuel, for example, from the Soviet IRT reactor at the Al Tuwaitha nuclear research center was recovered from a fuel pond, and from an emergency storage site called "location B", which "consisted of pits in a farmland area a few miles from the Al Tuwaitha Nuclear Centre. The irradiated fuel at location B was stored under normally unacceptable conditions and presented severe preparation problems for safe transport. Radiation levels were unusual and because of the lack of water treatment and suitable containers, corrosion problems could not be avoided."[12] The over 400 tons of materials, including yellowcake, had been "moved to secret locations or buried in desert areas," before being located, collected, and sealed by the IAEA.[13] These various locations are not

Table 1. [10]

Inorganic contaminants:
Radionuclides:
Americium-241
Cesium-134, 137
Cobalt-60
Plutonium-238, 239
Radium-224, 226
Strontium-90
Technetium-99
Thorium-228, 232
Uranium-234, 238
Metals:
Chromium
Copper
Lead
Mercury
Nickel
Other:
Cyanide
Organic contaminants:
Benzene
Chlorinated hydrocarbons
Methylethyl ketone, cyclohexanone, acetone
Polychlorinated biphenyls, select polycyclic aromatic hydrocarbons
Teraphenylboron
Toluene
Tributylphosphate
Organic facilitators:
Aliphatic acids
Aromatic acids
Chelating agents
Solvents, diluents, chelate radiolysis fragments
Mixtures of Contaminants:
Radionuclides and metal ions
Radionuclides, metals, and organic acids
Radionuclides, metals, and natural organic agents
Radionuclides and synthetic chelating agents
Radionucldes, metal ions, and organophosphates
Radionuclides, metal ions, and petroleum hydrocarbons
Radionuclides, chlorinated solvents, and petroleum hydrocarbons
Petroleum hydrocarbons and polychlorinated biphenyls
Complex solvent mixtures
Complex solvent and petroleum mixtures

publicly identified, and whether they were located with a global positioning system (GPS) is unknown.

Iraq undertook a variety of engineering projects to construct nuclear facilities. At least 10 major sites were involved. The Al-Tuwaitha Nuclear Research Center, 18 kilometers SSE of Baghdad was the main site, and included several research reactors, plutonium separation and waste processing, uranium metallurgy, and uranium enrichment facilities, as well as the Osiraq (Tammuz-1) reactor, destroyed in 1981. The Al Atheer Center, located 68 kilometers SW of Baghdad, did uranium casting and metallurgy, core assembly, and explosive lens assembly and testing.[14] Any number of contaminants listed in Table 1 can be reasonably expected to be present in and around these and other facilities. Given that Iraq tried to disguise a number of nuclear facilities as non-weapon related, to the point of constructing false concrete walls to cover equipment, suggests that the geography of nuclear manufacturing and waste is pervasive.

Chemical weapons (CW) production is an equally toxic, and far more voluminous, industry. Iraq initiated its CW program in the 1970's and employed weapons against Iran and Kurds during the 1980's.[15] The physical extent of CW production is especially impressive. The primary CW site, Muthanna State Establishment, 120 kilometers NW of Baghdad, ranges over 25 square kilometers. Iraq claims to have produced over 200,000 filled and unfilled special munitions, of which some 127,000 remained in 1991. UNSCOM undertook a tremendous program to account for these, and destroyed some 40,000 munitions.[16] Almost 4000 tons of bulk CW were declared by Iraq, which claimed further that 80% had been consumed during the Iran-Iraq war. UNSCOM destroyed 411 tons of CW at a facility constructed at the Muthanna State Establishment, along with 3000 tons of precursor chemicals and large quantities of production equipment.[17]

In the cases of munitions, bulk CW, and precursor chemical, significant quantities of material remain unaccounted for. In addition, Iraq claims to have unilaterally destroyed or "discarded" large quantities of materials, including almost 30,000 munitions, 130 tons of non-weaponized CW, and 242 tons of precursors. In addition, 1.5 tons of VX was discarded unilaterally by dumping on the ground.[18] While much of this could not be confirmed by UNSCOM the quantities involved could create a significant environmental threat. Similar concerns relate to dual-use facilities involved in CW and the equally numerous, if quantitatively less voluminous, biological weapons (BW) programs. While the high concentrations of salt and lime in the soils of Iraq, coupled with the arid climate, would serve to neutralize and evaporate some residues, experience in Asia and Europe has shown that long-term environmental damage and health effects should be expected.[19] On-going problems

should be expected from weapons which remain hidden by Iraq, including leakage during storage and transport. The problem of the long-term effect of low exposures to CW agents is one which UNSCOM was concerned.[20] The long-term effect on Iraqis is unknown.

It must also be noted that a portion of Iraq's unconventional warfare capability was destroyed during the Gulf War. Already in 1991 reports began to circulate that stockpiled weapons and production facilities were responsible for casualties among Iraqis. Since the war extensive studies have been conducted which demonstrate that coalition troops were accidentally exposed to CW and possibly BW through the destruction of storage and production facilities, and intentional release.[21] These exposures are among prime suspects for Gulf War Syndrome.

Military industries: Delivery systems

Less well-known than the extensive toxic materials created by WMD production are those involved in delivery systems. The manufacturing of any weapon creates waste from refining, curing, casting, and milling metals, acids and solvents, and the like. Along with conventional military (and other) industries, these wastes will have to be addressed in the future. For the moment, however, one especially toxic aspect of delivery systems may be highlighted, missile propellant.

Prior to the Gulf War Iraq had a force of over 800 SCUD missiles and variants, and was developing longer-range versions. Over 500 of these were expended against Iran, while almost 100 were fired during the Gulf War. Iraq claims to have unilaterally destroyed 83 missiles, and UNSCOM supervised the destruction of 48. Discrepancies remain in accounting for missiles, missile assemblies, launchers, and propellants, leading most observers to suspect that Iraq is concealing a force of up to several dozen missiles. The SCUD typically carries a 1000 kilogram warhead and 4500 kilograms of liquid propellant. In addition there are several thousand short range surface to surface and surface to air missiles.[22]

Inhibited red fuming nitric acid (IRFNA) is used as an oxidizer by Scud, SA-2, Silkworm, and Kyle missiles. In a SCUD launch some 3500 kilograms of IRFNA are present, and approximately 150 kilograms remain after engine shutoff. If the SCUD breaks up or is intercepted below 3000 meters the IRFNA could be expected to produce skin, eye, and respiratory effects on the ground, dispersing in an area up to two kilometers in length[23] IRFNA has been suspected of contributing to Gulf War Syndrome and has been studied by the Department of Defense and the CIA, along with a large literature devoted to rocket propellants generally.

A number of Iraqi industrial sites were connected with missile and propellant production. Liquid fuel engine development was undertaken at the Taji site, 30 kilometers N of Baghdad, while the Al Rafah site, 60 kilometers W of Baghdad had a static engine test facility. The production of propellant and oxidizer is presumed to have taken place, but this is an area where Iraq has refused to fully disclose its activities.[24] Nitric acid production also takes place at other facilities, at least one of which vents directly into the atmosphere without any scrubbers or other environmental safeguards.[25]

The potential exposure of coalition troops and other personnel during the Gulf War is bad enough, but extensive exposure of persons within Iraq is certain. The loading and unloading of propellants, both operationally, and during maintenance and training, creates spills which contaminate soil and ground water. Atmospheric pollution is created during fueling and firing, and falling debris contains amounts of unused fuel and other combustion products. This is in addition to propellant production, storage and transportation, and the storage and transport of missiles and launchers. The cumulative effect of almost 800 SCUD launches, thousands of shorter range SAM and other missile launches and landings, and twenty years of operations (and fuel production) has not been assessed. Parallel evidence from Russia has shown extensive environmental damage from military and civilian rocket fuels. The contamination of soil, groundwater, air, flora, and fauna are increasingly well-documented, as are the health consequences.[26]

Military infrastructure

The degree to which Iraq is a country which has been physically remade by its military is not generally recognized. The number of installations is vast, as seen by the number which were targeted during the Gulf War. Over 40,000 strikes were conducted against 1200 military installations known prior to the start of the Gulf War, a number grew to 2693 by 1992. The number of buildings, bunkers, barracks, and hangers, and the like, which comprise these installations is unknown.

The problems associated with active military bases and, as they are called in American parlance “formerly used defense sites” (FUDS), have become better understood in the last few years, particularly in the wake of base realignments and closure (BRAC). The three broad categories of projects eligible for cleanup are hazardous, toxic, and radioactive waste (including above and below ground storage tanks and drums, transformers, landfills, soil and groundwater), building demolition and/or debris removal, and ordnance and explosive waste. Within the continental United States over 8700 military installations and ranges are scheduled for cleanup.[28] The problem of military

Table 2. [27]

Known Iraq installations categories			
	2 Aug 90	16 Jan 91	Post War 1992
Airfields	122	128	122
NBC-associated	40	60	86
C3	201	604	692
Military leadership & support	126	213	270
Naval	46	53	53
Strategic air defense	493	674	988
SAM-associated	214	285	328
Scud-associated	24	121	154

installations is further complicated by the inclusion of millions of acres of test ranges, containing UXO, heavy metals, and other contaminants, those used for unconventional munitions such CW and depleted uranium and practices of open air burning of munitions and propellants (Table 2).

Data regarding Iraqi military installations, waste disposal and weapons handling practices are virtually nonexistent. Given the number of military installations located within and around highly populated areas, especially Baghdad, the health consequences of contaminants is likely to be significant. Furthermore, the extensive movements of the military around Iraq, during both wartime and peacetime operations, makes the geography of contamination potentially vast. Just the potential groundwater contamination resulting from fueling military vehicles is vast. Even under the best of circumstances Iraq is unlikely to design and implement as comprehensive an environmental protection strategy as the United States or Western European countries. But the sheer number of installations makes identifying and prioritizing the most hazardous an important goal for a successor regime. This is in addition to the global problem of “brownfields”, or contaminated industrial sites.[29]

Environmental warfare

Iraq has been a pioneer in environmental warfare, both against its own populace and foreign powers. During the Iran-Iraq war large canals were constructed to defend the border east of Basra, which were then inundated. The first such moat, the Jasim Canal, was almost three meters deep, 1.2 kilometers wide, and 29 kilometers long. Later in that war both Iraq and Iran constructed canals as defenses.[30] After the Gulf War the reverse strategy was employed against Iraqi citizens. The primary populace of the southern marshes are Shia *Ma’dan* (Marsh Arabs), long regarded by the Saddam regime as an untrustworthy element. In the aftermath of the Gulf War the regime constructed

a series of huge barrages (the "Third River project") which have diverted water from the Al Amarah and Hawr al Hammar marshes, reducing them in area by up to 90 percent.[31] Mechanized units have pursued and killed the residents, toxic and incendiary chemicals have allegedly been used, and tens of thousand refugees have fled east into Iran. The wetlands were habitat to numerous animal species as well. Overall the marsh destruction may have irreversible environmental and social consequences.

A number of Iranian refineries and oil welk were destroyed during by Iraqis during their 1980–1988 war, as well as attacks conducted by both sides during the "Tanker War" phase of that conflict. Some of the resulting well fires were not extinguished until the early 1990's.[32] Late in the Gulf War some 788 Kuwaiti oil wells were destroyed by retreating Iraqis, over 600 in flames and the rest left gushing or otherwise damaged. Over 50 million metric tons of oil was burned, introducing almost 130 tons of carbon dioxide and eight million metric tons of elemental carbon into the atmosphere. Between two and four million barrels of oil were introduced into the marine environment, while some 20 to 50 million barrels were contained in oil lakes. A large literature addresses the variety of environmental consequences to land, water, marine life, climate, and health. While the overall short-term impact was great, the long-term impact on the marine environment appears less catastrophic. The terrestrial and health impacts remain unknown.[33]

Battlezones

The effect of conventional and unconventional warfare on the environment has become a topic of research only in recent years. The vast expanses of minefields and large quantities of UXO, from the Iran-Iraq war, Gulf War, and Kurdish conflicts, remain outstanding problems whose geography remains poorly known. It has been estimated that 40,000 square kilometers of Kuwait, Saudi Arabia, and Iraq were directly effected by land operations during the Gulf War, with over 5,000 destroyed Iraqi tanks and armored vehicles, one million mines, over 200,000 tons of munitions, and four million tons of human wastes.[34] The areas affected and quantities of contaminants from the eight year Iran-Iraq war are far larger.

All munitions leave some residues, but one type has attracted particular attention. The highly controversial problem of depleted uranium has been repeatedly discussed but no consensus on health consequences has been reached. Depleted uranium (DU) is a byproduct of enrichment for fuel and weapons-grade uranium and contains less than 0.2% U235 and over 99% U238. It is 1.7 times the density of lead, one of the properties which encouraged the defense establishments of many countries to incorporate the material into both armor

and munitions. DU is also pyrophoric, and when burned has a tendency to aerosolize and may travel distances up to tens of kilometers from the release point. When a DU round strikes a target it is typically burned, oxidized, or fragmented, and human contamination can occur through inhalation, ingestion, or embedding. Radiological exposure is one obvious concern, although there is considerable disagreement about dosages, and it should be recalled that DU is also a toxic heavy metal.[35]

Over 300 tons of DU munitions were fired during the Gulf War throughout the Kuwait Theater of Operations. Coalition troops and Iraqis were exposed to DU in various forms, and DU has emerged as another possible contributor to Gulf War Syndrome. Controversy reemerged during the Balkan crisis when NATO apparently employed DU against Serbian armor. With a half life of 4.5 billion years, DU will be present in the environment of Southwest Asia, and anywhere else it is employed, for some time to come.

Finally, the impact of mechanized conflict on ecosystems should be mentioned. Vast areas within Iraq and its neighboring countries have been degraded by mechanized warfare in the past two decades. While dunes can be expected to restore themselves, desert pavements of small pebbles form over extremely long periods and are easily destroyed by vehcile tracks. Once pavements are disrupted, underlying soils are quickly eroded. Among the biological results of military operations in arid and semi-arid environments are disruption of floral and faunal communities, making them more susceptible to invasion by exotic species, and soil compaction, increased erosion, delivery of sediments to streams, and distribution of airborne particulate. Restoration of plant cover and biomass have been estimated to take 50–300 years, while complete ecosystem recovery perhaps as much as 3000 years.[36]

Conclusions

One UNSCOM specialist in chemical weapons described Iraq as a giant toxic waste dump, on par with the United States in the 1940's or Ireland in the 1960's.[37] This preliminary exercise in industrial archaeology certainly confirms that view. A separate study could be made of why certain environments tend to produce particular types of political institutions, which then proceed to abuse humans and the landscape in broad ways. Indeed, the study of ancient Iraq has been at the forefront of archaeological and anthropological discussions of cultural ecology, the evolution of states and civilizations, and environmental consequences of complex societies.[38] The combination of industrialization, petrochemical wealth, and Stalin-inspired totalitarian dictatorship has been of grave consequence to Iraq, and the world. This particular relationship of environment, resources, economy, and culture is far

from academic. The case of Iraq has increasing relevance not only locally, but as an example of how the international community responds to escalating security problems such as transborder pollution, resource depletion, and migration, and the intentional destruction of environments to create ethnic and state conflict.[39] Broadening the concept of "international security" to include environmental and human rights issues is a necessary first step, with accompanying legal, diplomatic, and institutional innovations.[40]

How will a successor regime respond to the kinds of problems outlined above? It is probably too much to expect a Western-level of concern or reaction, particularly given the tremendous problems in other sectors, such as the restoration of infrastructure, education, health, and civil society, much less the problem of justice and accountability. A successor regime could plead poverty, since billions were systematically diverted by Saddam and his circle for military projects and their own enrichment. But the oil revenues which brought Iraq to the edge of nuclear capability could, at least in theory, help clean-up that and other legacies. Given that the West has exacerbated the problem, by selling all manner of weapons to Iraq and by the direct consequences of the Gulf War, there is an obligation to investigate the problem and help remedy the situation. A necessary step is obviously removing Saddam Husayn and his regime from power. The planning for this, however, must go well beyond the seemingly intractable first steps. Planning for the future of Iraq will require identifying in detail the types of environmental hazards outlined above, and strategies for remediation and restoration.

But finding the political will and cultural determination to address these problems could serve an important function beyond the obvious. The Iraqi opposition is fractious and divided, with numerous groups representing the gamut of political, religious, and ethnic interests. One thing they all have in common are the daunting environmental problems outlined above. A series of technical studies and plans for saving the Iraqi environment could serve as a minor catalyst to political unity. The studies proposed here should be coupled with those which address the equally pressing problems of how to dismantle the intelligence and security apparatus,[41] reform the military and justice systems, rebuild the infrastructure and economy, and not least of all, justice and historical accountability.[42] A technocratic group with the best set of plans could eventually rise above long-standing political and cultural divisions, and perhaps even help inspire Iraqis within the country to risk their lives and rise up against Saddam. If that happens, we can only hope that the West will not betray Iraq again, either by failing to support an uprising, or by letting Iraq fall back into the hands of Saddam's henchmen.

An open source approach to reconstructing the military and industrial ecology of totalitarian Iraq is a logical and pressing priority. This could be ac-

complished using published UNSCOM and IAEA documents, commercially available from firms such as Jane's, and specialized databases assembled by institutions such as the Wisconsin Project and the Center for Non-Proliferation Studies, and categorizing industrial and military industries according to formats such as the Militarily Critical Technologies List (MCTL) and the North American Industrial Classification System (NAICS)[43] Saddam and his regime will not be around forever. When they go, however they go, will anyone be ready?

Notes

1. Baram, 1997; Darwisha, 1999.
2. See the materials at http: //www.denix.osd.mil/denix.
3. Tsvang 1997, Peterson 1993.
4. De Andreis and Francesco Calogero, 1995; Rimmington, 1996; Smithson, 1999; Bozheyeva et al., 1999.
5. Charles Duelfer, telephone conversation, 28 February 2000.
6. UNICEF, 1999.
7. Graedel, 2000; Wolfson, 1995; O.T.A., 1991; O.T.A., 1993.
8. See the various documents collected at http: //www.gulflink.osd.mil. See also Tucker, 1997.
9. Donohue et al., 1994.
   It is interesting to note that Iraqi scientists have published a number of environmental analyses in international journals. Some of these were connected to the Chernobyl accident and others to the proposed siting of a nuclear power reactor. See Sabri et al., 1993a, b; Marouf, 1992; Marouf et al., 1995.
10. Adapted from *Complex Cleanup*, Table 2-1.
11. Jardine and McGee, 1995.
12. IAEA Inspections and Iraq's Nuclear Capabilities, April 1992.
13. IAEA, April 1992.
14. UNSCOM, *Major Sites Associated with Iraq's Past WMD Programs*.
15. See the summary of Iraqi CW and BW use in U.S. Government White Paper, February 13, 1998, *Iraq Weapons of Mass Destruction Programs*.
16. UNSCOM Report to the Security Council, 25 January 1999, Annex B, Status of the Verification of Iraq's Chemical Weapons Programme, paragraphs 8–11.
17. UNSCOM, Annex B, paragraph 12–16.
18. UNSCOM, Annex B, paragraph 16.
19. Cf. Deng and Evans, 1997; Pitten et al., 1999; Rathmell, 1995.
20. Duelfer, 20 February 2000.
21. E.g., Defense Intelligence Agency, IIR 2 201 0779 91/Soldiers Killed with Biological Warfare, a translation of an article from the Egyptian newspaper Al-Hakika. http: //www.gulflink.osd.mil/declassdocs/dia/19961031/961031_950719_22010779_91a.html. See also note 8.
22. Cordesman, 1999a, b. See also UNSCOM Report to the Security Council, 25 January 1999, Annex A, Missile Monitoring System, Paragraph 82.

23. Department of Defense Information Paper, August 13, 1999, Inhibited Red Fuming Nitric Acid. Available at http: //www.gullflink.osd.mil/irfna/.
24. Cordesman, *War of Sanctions*, p. 504.
25. Personal communication, UNSCOM inspector, 20 February 2000.
26. Wolfson and Tsvang, 1995. Some of the damage in Russia was a result of using unsymmetrical dimethylhydrazine as fuel. Iraq unsuccessully attempted to import unsymmetrical dimethylhydrazine and primarily used kerosene as liquid missile fuel.
27. Adapted from Office of the Secretary of the Air Force, *Gulf War Air Power Survey*, volume V, pp. 218–219.
28. See http: //www.sac.usace.army.mil/pm/derp_htm and the information available through http: //www.dtic.mil/envirodod/.
29. O.T.A., 1995.
30. Hiro, 1991. See also the resources at http: //edcwww.cr.usgs.gov/earthshots/slow/Iraq/Iraq.
31. C.I.A., 1994; Munro and H. Touron, 1997.
32. Sayers, 1991.
33. Literathy, 1993.
34. Khuraibet, 1999; Sadiq and J.C. McCain, 1993.
35. See the resources at http://www.gulflink.osd.mil/du_index.htm,
    http: //www.ngwrc.org/Dulink/du_link.htm,
    http: //www.miltoxproj.org/DU/DU_Titlepage/DU_Titlepage.htm,
    http: //www.psr.org/duissuebrief.html. C.D.I., 1999.
36. Alsdirawi, 1994; El-Baz, 1994; Al-Ajmi and R. Misak, 1995; Lovich and D. Bainbridge, 1999.
37. Telephone communication, UNSCOM inspector, 20 February 2000.
38. Adams, 1994. See Westling (ed.), 1988.
39. E.g., Kahl, 1998.
40. Del Rosso, 1995; Florini and Simmons, 1998.
41. Joffe, 1999.
42. Joffe, 2000.
43. For MCTL see http: //www.dtic.mil/mctl/.
    For NAICS see http: //www.census.gov/epcd/www/naics.

References

Adams, Robert M., "Ancient Sumer, Modern Iraq," *Scientific American* 1994 (271), 112.

Al-Ajmi, Dhari and R. Misak, "Impact of the Gulf War on the Desert Ecosystem in Kuwait," in E. Watkins (ed.), *The Middle Eastern Environment: Selected Papers of the 1995 Conference of the British Society for Middle Eastern Studies* (Cambridge, England: St. Malo Press, 1995).

Alsdirawi, Fozia, "The Impact of the Gulf War on the Desert Ecosystem," in F. el-Baz and R.M. Makharita (eds.), *The Gulf War and the Environment* (Lausanne: Gordon and Breach, 1994).

Baram, Amatzia, "Neo-Tribalism in Iraq: Saddam Hussein's Tribal Policies, 1991–96," *International Journal of Middle East Studies* 1997 (29:1), 1–31.

Bozheyeva, Gulbarshyn, Y. Kunakbayev and Dastan Yeleukenov, *Former Soviet Biological Weapons Facilities in Kazakhstan: Past, Present, and Future* (Monterey: Center for Nonproliferation Studies, 1999).

Center for Defense Information, "Depleted Uranium – A Necessary Evil?," *The Defense Monitor* 1999 (28), 1–4.

Central Intelligence Agency, *Destruction of Iraq's Southern Marshes* (Washington, D.C.: Government Printing Office, 1994).

Cordesman, Anthony H., *Iraq and the War of Sanctions, Conventional Threats and Weapons of Mass Destruction* (Westport, CT: Praeger, 1999).

Cordesman, Anthony H., *Weapons of Mass Destruction in the Middle East, Regional Trends, National Capabilities, Delivery Options, and Weapons Effects* (Washington, D.C.: Center for Strategic and International Studies, 1999).

Dawisha, A., " 'Identity' and Political Survival in Saddam's Iraq," *Middle East Journal* 1999 (53:4), 553–567.

De Andreis, Marco and F. Calogero, *The Soviet Nuclear Weapons Legacy* (Oxford: Oxford University Press, 1995).

Del Rosso, Stephen J., "The Insecure State: Reflections on 'the State' and 'Security' in a Changing World," *Daedalus* 1995 (124:2), 175–207.

Deng, Hongmei and P.O.M. Evans, "Social and Environmental Aspects of Abandoned Chemical Weapons in China," *The Nonproliferation Review* 1997 (4:3), 101–108.

Donohue, D., S. Deron, et al., "Environmental Monitoring and Safeguards: Reinforcing Analytical Capabilities," *IAEA Bulletin* 1994 (36:3), 20–23.

El-Baz, Farouk, "Gulf War Disruption of the Desert Surface of Kuwait," in F. El-Baz and R.M. Makharita (eds.), *The Gulf War and the Environment* (Lausanne: Gordon and Breach, 1994).

Florini, Ann M. and P.J. Simmons, *The New Security Thinking: A Review of the North American Literature* (New York: Rockefeller Brothers Fund, 1998).

Graedel, Thomas, "The Evolution of Industrial Ecology," *Environmental Science & Technology* 2000, January 1, 2000, 28a–31a.

Hiro, Dilip, *The Longest War, the Iran-Iraq Military Conflict* (New York: Routledge, 1991).

Jardine, L.J. and J.T. McGee, *Secondary Wastes and High Explosive Residues Generated during Production of Main High Explosive Charges for Nuclear Weapons* (Livermore, CA: Lawrence Livermore National Laboratory, 1995).

Joffe, Alexander H., "After Saddam is Gone", *Middle East Quarterly*, 2000 (7:2), 33–41.

Joffe, Alexander H., "Dismantling Intelligence Agencies," *Crime, Law, and Social Change*, 1999 (32:4), 325–345..

Kahl, Colin H., "Population Growth, Environmental Degradation, and State-Sponsored Violence: The Case of Kenya, 1991–93," *International Security* 1998 (23:2), 80–119.

Khuraibet, Ali M., "Nine Years after the Invasion of Kuwait: the Impacts of Iraqi Left-over Ordnance," *The Environmentalist* 1999 (19), 361–368.

Literathy, P., "Considerations for the Assessment of Environmental Consequences of the 1991 Gulf War," *Marine Pollution Bulletin* 1993 (27), 349–356.

Lovich, Jeffrey E. and D. Bainbridge, "Anthropogenic Degradation of the Southern California Desert Ecosystem and Prospects for Natural Recovery and Restoration," *Environmental Management* 1999 (24), 309–326.

Marouf, B.A., T.A. Al-Khayat and A.K. Mehdi, "Population Exposure Owing to a Borax Accident in the Tammuz 2 Nuclear Reactor," *Environmental Management and Health* 1995 (6:1), 10–13.

Munro, D.T. and H. Turon, "Estimation of Marshland Degradation in Southern Iraq using Multitemporal Landsat TM Images," *International Journal of Remote Sensing* 1997 (18:7), 1597–1606.

Peterson, D.J., *Troubled Lands, The Legacy of Soviet Environmental Destruction* (Boulder: Westview, 1993).

Pitten, F.-A., G. Mueller, et al., "Risk Assessment of a Former Military Base Contaminated with Organoarsenic-based Warfare Agents: Uptake of Arsenic by Terrestrial Plants," *Science of the Total Environment* 1999 (226:2–3), 237–245.

Rathmell, Andrew, "Chemical and Biological Weapons in Iraq: Security and Environmental Implications," in E. Watkins (ed.), *The Middle Eastern Environment: Selected Papers of the 1995 Conference of the British Society for Middle Eastern Studies* (Cambridge, England: St. Malo Press, 1995).

Rimmington, Anthony, "From Military to Industrial Complex? The Conversion of Biological Weapons's Facilities in the Russian Federation," *Contemporary Security Policy* 1996 (17:1), 80–112.

Sabri, A.W., A. Rasheed and T.J. Kassim, "Heavy Metals in the Water, Suspended Solids and Sediment of the River Tigris Impoundment at Samarra," *Water Research* 1993 (27:6), 1099–1103.

Sabri, A.W., T.I. Kassim, K.A. Rasheed and A.A. Al-Lami, "Environmental Studies for the Iraqi Nuclear Power Plant Site Selection," *International Journal of Environmental Studies*, Section A, 1993 (44:2–3), 135–142.

Sadiq, Muhammad and J.C. McCain, *The Gulf War Aftermath. An Environmental Tragedy* (Dordrecht: Kluwer Academic Publishers, 1993).

Sayers, Bob, "Capping Blowouts from Iran's Eight-year War," *World Oil* 1991 (212), 44–48.

Smithson, Amy E., *Toxic Archipelago: Preventing Proliferation from the Former Soviet Chemical and Biological Weapons Complexes* (Washington, D.C.: The Henry L. Stimson Center, 1999).

Tsvang, Roma, "Environmental and Public Health Consequences of Nuclear Weapons Porduction in Russia," *Environmental Policy Review* 1997 (11:2), 17–31.

Tucker, Jonathan B., "Evidence Iraq Used Chemical Weapons during the 1991 Persian Gulf War," *The Nonproliferation Review* 1997 (4:3), 114–122.

U.S. Congress, Office of Technology Assessment, *Complex Cleanup: The Environmental Legacy of Nuclear Weapons Production*, OTA-O-484 (Washington, D.C.: U.S. Government Printing Office, 1991).

U.S. Congress, Office of Technology Assessment, *Hazards Ahead: Managing Cleanup Worker Safety at the Nuclear Weapons Complex*, OTA-BP-O-85 (Washington, D.C.: U.S. Government Printing Office, 1993).

U.S. Congress, Office of Technology Assessment, *State of the States for Brownfrelds: Projects for Cleanup and Reuse of Contaminated Sites* (Washington, D.C.: U.S. Government Printing Office, 1995).

UNICEF, Iraqi Ministry of Health, *Child And Maternal Mortality Survey 1999 – Preliminary Report, Iraq*, July 1999.

Westling, Arthur, (ed.), *Cultural Norms, War and the Environment* (New York: Oxford University Press, 1988).

Wolfson, Ze'ev, "Environmental Impact of Disarmament in Russia," *Environmental Policy Review* 1995 (11:2), 31–35.

Wolfson, Ze'ev and R. Tsvang, "The Impact of Missile and Space Activity on the Environment in Russia," *Environmental Policy Review* 1995 (9:2), 11–22.