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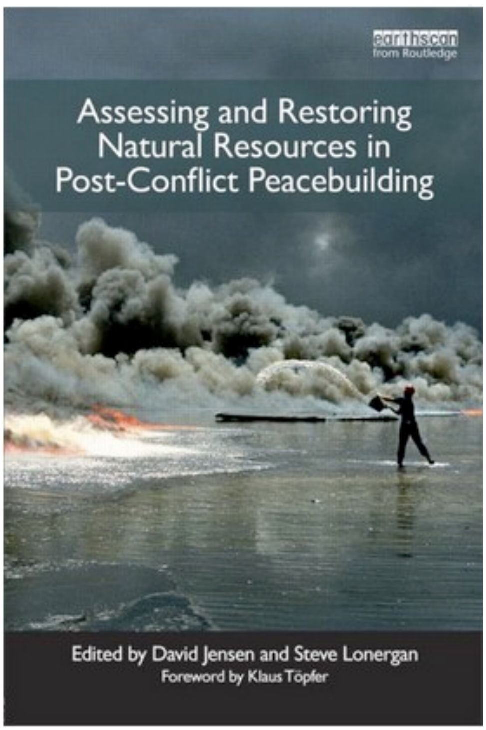

Remediation of polluted sites in the Balkans, Iraq, and Sierra Leone

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Countries emerging from conflict face myriad complex challenges, including restoring peace and security, rebuilding infrastructure and the economy, and providing for the basic needs of their people. The natural environment is often harshly affected during conflicts, and restoring and rehabilitating ecosystems to ensure long-term sustainability is an additional challenge that post-conflict societies must address. In many instances, contamination of soil and groundwater by chemicals and other substances; dispersion of hazardous waste from fires, looting, bombings, and oil spills; and accumulation of municipal waste and hazardous health-care waste pose significant risks to human health and the environment and urgently require remediation.

This chapter takes an in-depth look at cleanup activities the United Nations Environment Programme (UNEP) has undertaken in the Balkans (2000–2004), Iraq (2004–2006), and Sierra Leone (2009–2011). It provides an overview of the findings and recommendations from the environmental site assessments UNEP conducted following the cessation of hostilities, and it details the objectives and achievements of cleanup projects that were implemented. Drawing on the successes and failures of the cleanup activities in these three situations, the chapter concludes with some general lessons for remediation of polluted sites in post-conflict situations.

THE BALKANS, 2000–2004

Following the suspension of NATO air strikes in June 1999, UNEP and the United Nations Centre for Human Settlements (UNCHS)[1] initiated a neutral, independent,

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[1] UNCHS is currently known as the United Nations Human Settlements Programme, or UN-HABITAT.

scientific assessment of the environmental effects of the conflict in what was then the Federal Republic of Yugoslavia (UNEP 2004a).

In order to conduct the assessment and field missions, UNEP and UNCHS established the Balkans Task Force, which comprised more than sixty international experts from six UN agencies, nineteen countries, and twenty-six scientific institutions and nongovernmental organizations (NGOs). The task force also included ten national experts who served as local advisors for the team.

UNEP's post-conflict environmental assessment

Between July and October 1999, UNEP and UNCHS conducted four expert missions in the region, visiting a range of sites, including Pancevo, Novi Sad, Kragujevac, Bor, Pristina, Nis, Novi Beograd (a municipality of Belgrade), Kraljevo, the Iron Gate Reservoir on the Danube River (near the Romanian border), Lepenica River (which runs through Kragujevac), and Morava River (UNEP 2004a).

Following extensive fieldwork in the conflict-affected areas, in October 1999 UNEP and UNCHS published a report titled *The Kosovo Conflict: Consequences for the Environment and Human Settlements*, which concluded that the Kosovo conflict had not caused an environmental catastrophe affecting either the Balkans region as a whole or the territory of the Federal Republic of Yugoslavia (UNEP and UNCHS 1999). However, the report did find that the conflict had more localized effects on the environment, which in some cases were linked to the region's long-term legacy of poor environmental management. Furthermore, in its report UNEP identified four hot spots—in Pancevo, Novi Sad, Kragujevac and Bor—that presented serious risks to the environment and human health, and thus required urgent cleanup action (see figure 1).

Following the publication of the post-conflict assessment, UNEP conducted a feasibility study to define in more detail the scientific and financial requirements of the hot spot cleanup measures. Finalized in April 2000, the feasibility study identified twenty-seven cleanup projects for the four sites, with an estimated combined cost of US$20 million (UNEP 2004a). Donors from ten different countries contributed a total of US$12.5 million for the most critical cleanup projects. These countries were Denmark, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden, and Switzerland.

UNEP's cleanup program

In November 2000, UNEP partnered with the United Nations Office for Project Services to begin implementation of the cleanup program (UNEP 2004b). Partnerships with local and national stakeholders, as well as corresponding coordination mechanisms, were also developed and maintained throughout the program in order to ensure local ownership and cost-effective implementation of cleanup objectives.

Figure 1. UNEP environmental hot spot cleanup sites in Serbia
Source: UNEP (2004).

Pancevo petrochemical plant (HIP Petrohemija)

UNEP's post-conflict assessment and subsequent feasibility report demonstrated that Pancevo, with fourteen priority projects, had the greatest remediation needs of the four hot spots; therefore, a larger portion of program resources were allocated to Pancevo, and specifically to its industrial complex, than to efforts elsewhere. Cleanup efforts were first undertaken at Pancevo's petro-chemical plant (HIP Petrohemija) and focused primarily on remediation of soil and groundwater contamination and rehabilitation of wastewater treatment facilities (UNEP 2004b).

Ethylene dichloride contamination. The NATO bombings of April 1999 damaged tanks holding ethylene dichloride (EDC), resulting in roughly 2,100 metric tons of EDC being released, an estimated 50 percent of which is believed to have infiltrated the soil. The International Agency for Research on Cancer has classified EDC as a possible human carcinogen (U.S. EPA 2006). Site investigations conducted in May 2000 indicated the presence of an EDC free-phase pool in the backfilled sand at the top of the clay layer where the damaged EDC storage tanks were located.[2] EDC concentrations detected in groundwater samples collected from the shallow aquifer were an estimated 5.6 grams per liter (g/L) (UNEP 2004b). In comparison, Dutch environmental-quality objectives for groundwater require remediation if EDC concentrations are above 400 milligrams per liter (mg/L).

The aim of UNEP's project at the Pancevo petrochemical plant was to reduce the level of EDC contamination in groundwater and the soil in order to decrease the health risks for factory workers and to protect groundwater resources and the Danube River (UNEP 2004b). Following detailed site investigations and a preliminary human health and environmental risk assessment, it was determined that the remedial target for the EDC cleanup should be the removal of the free-phase EDC and a reduction of the dissolved phase to 1.0 g/L.[3]

Working in close collaboration with HIP Petrohemija and Czech partners, UNEP launched the EDC remediation project in June 2001. Between January and July 2002, comprehensive subsurface characterization works and pilot tests (pump-and-treat remediation and steam-enhanced extraction tests) were performed so workers could select the best available technology for soil and groundwater remediation at the vinyl chloride monomer (VCM) plant. The tests indicated that the VCM plant's treatment facilities could treat fluids containing chlorinated hydrocarbons that resulted from groundwater remediation. The cleanup project upgraded the capacity of these facilities from 3.5 cubic meters per hour (m^3/h) to 5.5 m^3/h by August 2002, and to 8.0 m^3/h by late November 2003 (UNEP 2004b).

Following project investigations and data evaluation, a general design for the cleanup of the upper aquifer was prepared. By January 2004, the interim remedial system, which focused on the shallow aquifer, had recovered over 400 metric tons of EDC, including approximately 93 metric tons of free-phase EDC and 316 metric tons of pure EDC recovered through the treatment of contaminated groundwater.

In order to ensure continued risk reduction, an upgraded full-scale system was commissioned and transferred from the cleanup program to the site owner in April 2004.

Wastewater treatment facility. Although the wastewater treatment facility at Pancevo's petrochemical plant was not directly targeted during the 1999 NATO bombing, damage to the oil refinery and the VCM and chloro-alkali plants led to the discharge of roughly 170,000 m^3 of raw materials, petrochemical products, and firefighting water (UNEP 2004b). This flow overloaded the wastewater treatment

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2 The term *free-phase pool* refers to a collection of a liquid toxin that is freestanding, that is, not dissolved in another medium.

3 The term *dissolved phase* refers to a toxin that is dissolved in an aqueous medium, usually groundwater.

facility's capacity, clogged the units with contaminated sludge, damaged the processing equipment, and cracked or otherwise damaged concrete retaining structures.

The aim of UNEP's cleanup efforts at the wastewater treatment facility was to rehabilitate the treatment plant in order to protect the Danube River system and downstream water supplies. The project began in 2001 in collaboration with HIP Petrohemija. By June 2004, the process equipment had been replaced, the trickling filter and pH regulating facilities repaired, and the activated sludge rehabilitated (UNEP 2004b). The facility's hydraulic and treatment capacity were restored and significantly improved in comparison to pre-conflict levels, and the pollutant-loading into the Danube River and its associated risks to downstream water supplies were reduced.

In April 2004, the project was handed over to the site owner, who was required to provide regular reports to national authorities and provincial environmental authorities on the operation of the rehabilitated facilities.

Pancevo oil refinery (NIS-RNP)

Between April and June 1999, the Pancevo oil refinery (NIS-RNP) was the site of heavy NATO aerial strikes. As a result, an estimated 80,000 metric tons of oil products and crude oil burned, and an additional 5,000 metric tons of oil and oil products leaked into the soil and sewer system, releasing sulphur dioxide and other noxious gases (UNEP 2004b). The bombings further damaged the refinery's sewer system and wastewater pretreatment unit.

Construction of a concrete basin for oil sludge. In addition to destroying some of the refinery's production and storage facilities, the bombings caused large quantities of oil to spill into the ground, the sewer network, and the refinery's wastewater pretreatment facilities, and finally to flow into the Danube River. Because storage facilities were not sufficient, the spilled oil and oil products could not be removed and disposed of safely.

UNEP's cleanup project aimed to provide safe temporary storage for oily wastes that were removed during rehabilitation of the sewer pipeline and the pretreatment unit, as well as to provide temporary storage for other oil wastes from the refinery. By April 2003, working in close collaboration with NIS-RNP, UNEP completed the cleanup works (UNEP 2004b). The project successfully provided 1,700 m^3 of temporary storage capacity for the cleanup operations at the refinery, thereby making possible remediation in the pretreatment facilities and sewage system.

Cleaning and repair of sewer pipelines and oil separators. Throughout the conflict, large amounts of oil, debris, and other materials clogged and partly damaged the sewer pipes, oil separators, and discharge pipelines. Following the conflict, the refinery's wastewater was being discharged directly into a wastewater canal and the Danube River without final treatment at the HIP Petrohemija's integrated wastewater treatment plant.

Overall, this UNEP cleanup activity aimed to protect the Danube River system (UNEP 2004b). More specifically, it would reestablish the NIS-RNP wastewater pretreatment facilities, ensure that wastewater from the refinery met the input specifications for final wastewater treatment at HIP Petrohemija's wastewater treatment plant, enable transport of pretreated wastewater from NIS-RNP to that plant, assess the refinery's sewer networks, and outline a strategy for rehabilitation and priority repairs.

Working with the NIS-RNP, UNEP began its rehabilitation activities in December 2001. The wastewater pretreatment facilities were successfully repaired and upgraded, including repairs to the oil separators' structures. By April 2004, the wastewater pipeline between the refinery and the petrochemical plant had been repaired, so pretreated wastewater could be transported from the refinery to the wastewater treatment plant before it was discharged into the wastewater canal (UNEP 2004b).

As part of its efforts to assist the refinery in defining its rehabilitation strategy and prioritizing its work, UNEP partially cleaned the refinery's sewer network, performed a geodetic survey, and completed design preparation. When it handed the project over to the site owner in April 2004, it delivered a study on technical solutions for rehabilitation of the refinery's sewage system and for the proper management of wastewater.

Pancevo fertilizer factory (HIP Azotara)

During the 1999 Kosovo conflict, the Pancevo fertilizer factory (HIP Azotara) was struck by a NATO aerial attack. The nitrogen-phosphorus-potassium plant and the fuel-oil tanks were destroyed, and the ammonia plant was damaged. As a result, significant quantities of hazardous substances flowed into the wastewater canal and poured into the Danube River. In an effort to avoid potential health risks for the workers and the surrounding population, the site managers released approximately 250 metric tons of ammonia into the wastewater canal and the Danube.

Investigations conducted by UNEP in 1999 and 2000 confirmed that high concentrations of pollution originating from industrial wastewaters had contaminated the canal. Specifically, EDC concentrations in the sediment's top layer varied from 130 milligrams per kilogram (mg/kg) to 300,000 mg/kg, indicating the presence of free-phase EDC in some of the canal's bottom layers (UNEP 2004b). Additionally, significant concentrations of mercury (from 1.4 to 40 mg/kg) and petroleum hydrocarbons (from 5,000 mg/kg to 32,000 mg/kg) were found in the canal sediment. High concentrations of these pollutants were also discovered in deeper layers of the sediment, indicating chronic pollution of the canal. Finally, a considerable amount of polyvinylchloride dust was later identified in the canal sediment. It was determined that there was an urgent need to protect downstream drinking-water resources and prevent the discharge of dissolved and sediment-associated pollutants into the Danube River system.

Phase one of the project involved preparing technical documentation and designing an environmentally acceptable remediation strategy. Working in close collaboration with Serbian environmental authorities and local stakeholders, UNEP completed the predesign investigation work in 2001 (UNEP 2004b). Findings from the investigations confirmed that the canal contained 41,000 m^3 of sediment that had significant concentrations of mercury and mineral oils. Further investigations in 2002 and 2003 revealed that EDC concentrations in the sediment had been reduced to almost negligible values, while roughly 550 metric tons of mineral oils and 260 kg of mercury were estimated to still be present in the canal.

In 2003, preliminary environmental impact assessments and general designs were developed for two remedial options: dredging the sediment and depositing it in a new landfill, and dredging and dewatering the sediment and treating it with thermal desorption (UNEP 2004b). By April 2004, a review of the preliminary environmental impact assessment and a general design for the thermal desorption option were completed. National environmental authorities and relevant stakeholders in Pancevo expressed their commitment to technical preconditions for sustainable remediation measures, and a potential donor was identified for remediation of the pollution in the canal.

Overall, UNEP's cleanup program allowed for seven out of the fourteen feasibility study projects for the Pancevo industrial complex to move forward. Although UNEP's remediation efforts in Pancevo led to a considerable reduction in the extent and magnitude of conflict-related environmental problems, chronic environmental problems such as industrial air pollution and improper waste management remain. They require continued investment and improvements to management practices.

Novi Sad oil refinery (NIS-RNS)

During the 1999 Kosovo conflict, the Novi Sad oil refinery (NIS-RNS), which was constructed on backfilled sand, was the target of several aerial strikes. As a result, several storage tanks and pipelines at the refinery were damaged, and over 70,000 metric tons of crude oil and oil products burned or leaked into the wastewater collection system and the ground, causing severe contamination of the soil and groundwater (UNEP 2004b). Visual inspection and analysis of groundwater samples indicated the presence of free-phase oil in the groundwater table. UNEP's post-conflict environmental assessment identified the potential risk to drinking-water wells downstream from the refinery as a key environmental concern. The site has also been a source of long-term and ongoing pollution, which has exacerbated the risks posed to human health and the environment.

Taking into account UNEP's feasibility study, as well as budget constraints, the Novi Sad cleanup program concentrated on protecting the Ratno Ostrvo drinking-water wells in the area between the Novi Sad oil refinery and the Danube

River, comprehensively monitoring the area's groundwater resources, and initiating efforts to address the contamination source zone within the oil refinery.

Remediation of free-phase oil in groundwater. Working in close collaboration with the Novi Sad oil refinery, UNEP delineated areas within the refinery compound where free-phase oil was present in the groundwater table. After reviewing various remediation alternatives, UNEP conducted pilot studies of techniques in order to select the most appropriate one for risk remediation. By January 2004, roughly 4.5 metric tons of free-phase oil had been recovered (UNEP 2004b). By February 2004, the mobile abstraction and separation unit was handed over to NIS-RNS, which was then responsible for the continued operation of the unit and for submitting regular progress reports to various national and provincial environmental authorities.

Although the remediation project achieved its objectives, it provided only a limited solution to the refinery's historic and more recent pollution problems.

Construction of a hydraulic barrier at the eastern refinery border. Not only had the conflict caused oil spillage, the Novi Sad oil refinery had historically been an ongoing source of pollution, so the entire refinery area was considered a potential source from which contamination could migrate. Since the Ratno Ostrvo drinking-water wells were located near the refinery, immediate measures for protecting the wells from groundwater contamination were considered the highest priority during remediation.

UNEP, together with Novi Sad Waterworks, began the construction of a hydraulic barrier between the refinery and the drinking-water wells in summer 2001 (UNEP 2004b). By April 2002, the project was handed over to the Novi Sad authorities. Although the project achieved its preventive objectives, additional measures were identified for addressing contamination sources at the refinery in the long term.

Groundwater monitoring. Close monitoring of the groundwater sources, both inside and outside the refinery area, was required in order to provide early warning of contaminant migration in the region. Starting in November 2000, UNEP worked in close collaboration with Novi Sad Waterworks, the Novi Sad oil refinery, the Novi Sad Institute of Chemistry, and the Swiss Agency for Development and Cooperation to monitor groundwater quality in the area and has determined the extent of groundwater pollution from spills at the oil refinery. This program modeled the velocity and preferential pathways of contaminant migration from the source zone, and the results confirmed the long-term risk to the drinking-water wells. The data made possible early warning of pollutant migration from the refinery and provided the basis for determining when to start up the hydraulic barrier operation. The monitoring program did not identify any immediate threat to the quality of groundwater abstracted from the water-supply wells in Ratno Ostrvo (UNEP 2004b).

In February 2004 the program was handed over to NIS-RNS and the Novi Sad Waterworks. Following this handover, the oil refinery site owner and the Novi Sad Waterworks were responsible for reporting monitoring results to the national and provincial environmental authorities.

Repair of the sewage collector outside the refinery. An approximately two-kilometer-long buried concrete collector conveys wastewater from NIS-RNS across the Ratno Ostrvo water-well area to the Danube. The collector and the wells are operated and maintained by Novi Sad Waterworks. The 1999 NATO bombing may have further damaged the collector, which was reportedly in bad condition prior to the conflict. Severe leakage from the damaged collector has been polluting groundwater and threatening nearby drinking-water wells.

UNEP's objective was to assess and repair the wastewater collector in order to prevent wastewater from leaking into the groundwater and polluting nearby drinking-water wells. Working in close collaboration with the Novi Sad Waterworks, UNEP completed the project in September 2003. Workers sealed the collector's cracked and leaking parts, preventing further pollution. The project was handed over to Novi Sad Waterworks and the municipality of Novi Sad in February 2004 (UNEP 2004b).

Overall, UNEP's remediation efforts in Novi Sad enabled three of the seven priority projects identified in the feasibility study to be fully addressed. Throughout the process, UNEP encouraged national and international stakeholders to provide additional inputs to risk-reduction efforts.

Kragujevac industrial complex

In April 1999 Kragujevac's Zastava industrial complex—including a power station, car assembly line, paint shop, computer center, and truck line—was heavily damaged by NATO bombings, and some areas of the facility were completely destroyed. The most significant risk identified at this site was the high concentrations of polychlorinated biphenyls (PCBs) and dioxins detected on the Zastava Automobili paint-hall floor and in nearby wastewater pits, PCBs within the Zastava Energetika power plant's transformer station, and sediments in the Lepenica River. The assessment further revealed that an estimated 2,150 kg of PCB-containing oil had leaked from damaged transformers.

UNEP's feasibility study identified five priority projects for the Zastava industrial complex. Cleanup efforts concentrated on remediation of PCB contamination of the concrete floor at the paint hall, cleaning of the wastewater pits and decontamination of wastewater in the paint hall, remediation of PCB contamination at the transformer station, and transportation and treatment abroad of hazardous waste generated by the Kragujevac remediation projects (UNEP 2004b).

Remediation of PCB contamination of paint-hall floor. Due to the bombings, an estimated 2,150 kg of PCB-containing oil leaked out of two paint-hall transformers and flowed onto the concrete floor and toward nearby wastewater pits. Analyses of samples taken during UNEP's assessment missions in 1999 and 2000 revealed high levels of PCBs, dioxins, and furans in the debris on the floor. Further analysis by UNEP in 2001 confirmed that PCBs had penetrated approximately 150 square meters (m^2) of the paint hall's concrete floor to a depth of roughly 25 centimeters, thereby contaminating the soil below the floor in some places. An estimated 30,000 mg/kg of PCBs were found in the top layers of concrete near the former transformers, while elsewhere in the paint hall the concentrations were less than 50 mg/kg (UNEP 2004b). Roughly 400 m^2 of less contaminated concrete were identified in the remainder of the paint hall and in the area toward the new basic paint pit. Very low concentrations of dioxins and furans were found in the concrete, so PCBs were the primary concern for the cleanup project.

The main risk from the PCB contamination was exposure of the paint-hall workers. As a result, UNEP's cleanup project aimed to reduce health risks for factory workers, to prevent any further cross-contamination, and to pack and store waste properly to allow for future transportation.

Working in close collaboration with the Zastava car factory and the University of Kragujevac's Institute of Chemistry, UNEP started implementation of the project in December 2001. Contaminated layers of concrete and soil were removed and packaged, and decontamination of these layers was verified. When the project reached its target of reducing PCB concentrations in the remaining soil to less than 50 mg/kg, the soil was covered with concrete, and antistatic epoxy resin was placed over the concrete. The cleanup efforts also included removing damaged transformers and debris created by the conflict. In all, an estimated 135 metric tons of hazardous waste resulting from remedial activities were characterized, properly packed, labeled, temporarily stored, and later transported and incinerated abroad (UNEP 2004b). The cleanup activities were completed in August 2002, allowing for the reuse of the affected part of the paint hall.

Cleaning of wastewater pits and decontamination of wastewater. PCBs leaking from the two transformers damaged by the bombing reached the open wastewater pits in the Zastava paint hall and mixed with water, paint sludge, and debris. Since oils containing PCBs are denser than water and not very soluble, they were mainly confined to the sediment at the bottom of the pits. In all, an estimated 6,000 m^3 of PCB-contaminated wastewater was found to be in the pits (UNEP 2004b).

The cleanup project aimed to reduce health risks to factory workers; prevent further cross-contamination; protect water resources from further contamination, particularly through uncontrolled sewage discharges into the Zdraljica River and Lepenica River; and properly pack the cleanup waste to allow for transportation at a later date.

Working in close collaboration with the Zastava car factory and the University of Kragujevac's Institute of Chemistry, UNEP began implementation of the project in August 2001. An estimated 6,000 m^3 of PCB-contaminated wastewater, with a maximum concentration of 0.7 mg/L, was removed from the pits and treated using a remediation method elaborated by national experts and reviewed by international experts.

Once the wastewater was purified, its PCB content was less than 0.0005 mg/L. In all, 120 metric tons of contaminated debris and bottom sediment were removed. An additional ten metric tons of equipment from the pits were dismantled, decontaminated, and disposed of. The resulting hazardous waste was characterized, properly packed, labeled, and later transported and incinerated abroad. Following verification of the decontamination work, the cleanup project was completed in April 2002 (UNEP 2004b). The project not only ensured that workers were protected by an improved environment, it also allowed for reuse of the wastewater pits.

Remediation of PCB contamination at transformer station. The 1999 NATO bombings damaged a transformer at the substation near Zastava Energetika headquarters, causing PCB-containing oil to leak. UNEP assessment missions in 1999 and 2000 revealed high concentrations of PCBs, dioxins, and furans in the concrete and a nearby rainwater gully. The contaminated concrete area was estimated to be 150 to 200 m^2.

UNEP's cleanup project aimed to reduce the health risks to factory workers by removing the damaged transformer and cleaning up the site, as well as allowing for reuse of the transformer station, which supplies the factory and provides heating to the municipality.

Working together with Zastava Energetika and the University of Kragujevac's Institute of Chemistry, UNEP began remedial activities in September 2002 (UNEP 2004b). The transformer was removed and temporarily stored at an access-restricted site designated specifically for used PCB equipment. Once the contaminated concrete and soil layers from the transformer pit and adjacent concrete surface were removed and replaced, the old transformer was replaced by one that does not use oil containing PCBs. In total, an estimated 50 metric tons of hazardous waste was characterized, properly packed, labeled, and later transported and incinerated abroad.

The remedial project not only protected workers and improved the environment, it also allowed for reuse of the transformer station.

Transportation and treatment of hazardous wastes from remediation projects. The primary objective of this activity was to treat and finally dispose of roughly 150 metric tons of hazardous waste resulting from all UNEP cleanup projects in Kragujevac, in accordance with environmentally sound management requirements, thereby eliminating risks arising from the waste's storage on factory premises.

By October 2003, UNEP, working in collaboration with Zastava factory officials and national authorities, and in accordance with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, had successfully transported and treated the hazardous waste resulting from its cleanup efforts in Kragujevac (UNEP 2004b).

Overall, UNEP's remediation efforts in the Zastava complex enabled the completion of four of the five priority projects identified in the feasibility study. National environmental authorities implemented the fifth project, regarding the monitoring of the Lepenica River. Local and national stakeholders played a critical role in ensuring the successful implementation of all activities.

Due to the successful implementation of all priority projects, a joint final-assessment mission conducted by UNEP and national authorities concluded that the designation "environmental hot spot" no longer applied to Kragujevac (UNEP 2004a).

Bor

NATO bombings in May 1999 struck the RTB Bor mining and smelting complex, damaging the transformer station that provided the site with electricity. UNEP's subsequent assessment of the complex revealed localized PCB contamination at the destroyed transformer station. Furthermore, the assessment raised concerns regarding severe and chronic air pollution that resulted from the plant's long-term operations.

Bearing in mind both the wider environmental problems in the Bor region and the post-conflict environmental assessment, cleanup activities at Bor focused on assessing and reducing remaining PCB-related risks at the transformer station and the dump site, and strengthening the overall environmental management capacity of local stakeholders (UNEP 2004b).

UNEP assessment missions in 1999 and 2000 obtained soil and sand samples at the transformer station that revealed PCB values ranging from 3.35 to 682 mg/kg of soil as based on dry matter. During that same period, local stakeholders took the initiative to move PCB-contaminated debris and material, including approximately 120 capacitors, from the destroyed transformer station to the RTB Bor dump site. UNEP's remedial activities aimed to identify and reduce the potential health risks to workers from PCB contamination, and to enable redevelopment of the transformer station area. A UNEP risk assessment conducted in September 2001 concluded that no further remedial activities were needed at the transformer station site. In 2002–2003, a new transformer station was erected at the same site with Norwegian funding.

UNEP's risk assessment of the RTB Bor dump site, which was finalized in February 2003, revealed that there were no immediate risks to groundwater resources from PCB contamination, but recommended that measures be taken to protect workers' health and to reduce risks at the site (UNEP 2004b). In December 2003, approximately 150 PCB-containing capacitors, which had been removed from the damaged transformer station and stored near the RTB Bor dump site, were removed, packed, and transported abroad for final treatment.

UNEP's remediation activities provided support for enhancing local capacity in the fields of environmental planning and monitoring, particularly the monitoring of air pollution. UNEP further assisted in enhancing local environmental planning capabilities by supporting the formulation of the first Local Environmental Action Plan for Bor.

IRAQ, 2004–2006

UNEP has been actively working in Iraq since the end of the 1990–1991 Gulf War. Following the end of those hostilities, UNEP undertook field assessments in Iraq, Kuwait, and Saudi Arabia to identify the environmental consequences of the conflict, including the effects of the intentional destruction of over 700 oil wells (UNEP 2003). Although major risks to human health and livelihoods were identified by the UNEP reports, the political situation prevented sustained cleanup efforts.

In 2001 UNEP extended its work in Iraq by monitoring and assessing the degradation and demise of the Mesopotamian Marshlands. This study found that the geographical area of the marshlands had declined by 90 percent due to a combination of dams, intentional diversion, and mismanagement of water resources.[4]

In February 2003, as coalition forces planned their second invasion of Iraq, UNEP initiated a desk-based environmental surveillance program to monitor the conflict as it occurred. UNEP's work resulted in the publication of the *Desk Study on the Environment in Iraq* in April 2003 (UNEP 2003). Two key needs were identified in the desk study and subsequent progress report: first, the need for an environmental assessment of selected contaminated sites; and second, the need to build and strengthen the environmental governance capacity of the Iraqi administration and provide specific training to experts from the Ministry of Environment in several key areas (UNEP 2003, 2005).

Following completion of the desk study and a subsequent post-conflict needs assessment conducted between June and October 2003, UNEP, in consultation with the Iraqi Ministry of Environment, helped develop a project titled Strengthening Environmental Governance in Iraq through Environmental Assessment and Capacity Building (UNEP 2005). The program included a comprehensive package of activities for building the Ministry of Environment's capacity to conduct assessments of contaminated sites, develop sound environmental policies, and monitor environmental quality. It was divided into five components: assessment of contaminated sites; capacity building in technical and policy areas; institutional capacity assessment; improvement of infrastructure and equipment; and monitoring of the Mesopotamian marshlands. Funded by the government of Japan, the project activities were carried out from July 2004 to December 2005, with training activities conducted in Jordan, Switzerland, and the United Kingdom.

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[4] For a more detailed discussion, see Steve Lonergan, "Ecological Restoration and Peacebuilding: The Case of the Iraqi Marshes," in this book.

Although capacity building and institutional capacity assessment were crucial components of the program, this chapter focuses primarily on the assessment and cleanup of contaminated sites.

Environmental site assessments

Regarding the assessment and cleanup of contaminated sites, the UNEP program had two key objectives. In the short term, it would identify and remediate the environmental hot spots that posed the most immediate risks to human health and the environment. In the long term, it would build institutional capacity, knowledge, and expertise within the Ministry of Environment for the establishment of a national site assessment program, remediation activities, and improvements in hazardous waste management (UNEP 2005).

Traditionally, UNEP's methodology for conducting hot spot assessments has been to assemble a team of international experts who partner with local institutions and government scientists to conduct field sampling. UNEP then divides the samples into a number of batches, which UNEP analyzes independently, using internationally accredited laboratories, while national counterparts conduct the analyses in parallel. This approach maximizes transparency and ensures that the findings are informed by sound science. It also facilitates capacity building at the local level and local ownership of issues arising from assessments.

However, such an approach was not feasible in the context of a deteriorating security situation in Iraq, particularly following the bombing of the Canal Hotel in Baghdad in August 2003 and the subsequent withdrawal of UN staff members. As a result, UNEP adopted an alternative approach that focused on building a team of national experts to conduct environmental site assessments (ESAs) at each hot spot according to UNEP standards and on the basis of UNEP training and quality-control procedures.[5] UNEP independently analyzed the resulting field samples at internationally accredited laboratories. The national team was primarily from the Ministry of Environment and was provided with UNEP training in neighboring countries, including Bahrain, Egypt, Jordan, and Syria (UNEP 2005).

Site selection for priority assessment was led by the Ministry of Environment, with UNEP acting in an advisory role. UNEP's previous environmental assessments had provided information on a number of sites, and this was complemented by secondary data. UNEP compiled an initial list of over fifty sites, mainly in industrialized regions surrounding Baghdad, all of which were damaged or in environmentally poor condition due to fires, looting, armed conflict, or poor operating practices. This list was presented to the Ministry of Environment for review and discussion, and the source-pathway-receptor model was used to identify the sites with the most acute risks. The top five sites, selected on the basis of security and access considerations, were Qadissiya, Suwaira, Khan Dhari,

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5 UNEP has developed environmental site assessment as an approach for post-conflict countries, based on international best practices in environmental assessment.

Figure 2. Priority assessment sites in Iraq
Source: UNEP (2005).

Mishraq, and Quireej (UNEP 2005; see figure 2). Cleanup operations would be conducted on a pilot basis for training purposes at the sites with the greatest immediate environmental risks to human health.

Qadissiya metal-plating facility

Constructed in the 1980s and located on the urban fringes approximately thirty kilometers south of Baghdad, the Qadissiya military industrial site operated continuously until March 2003. During the conflict in 2003, it suffered damage from ground conflict as well as air strikes. The unsecured site had previously contained a complex of metal-plating and machining units, all of which were partially or completely demolished. Particularly, the site contained pure sodium cyanide, a toxin with a lethal dose of less than one gram by ingestion (UNEP 2007). Following the conflict, the site was repeatedly looted, and piles of cyanide were deposited on open ground. Photographic and laboratory evidence revealed a significant volume of highly hazardous waste dispersed across the site. Chemical analysis of the waste piles indicated that the principal contaminants were heavy metals—specifically lead, nickel, copper, and antimony.

UNEP's ESA found that the Qadissiya facility represented a severe danger to human health, the principal risk arising from direct contact with hazardous waste by site trespassers, particularly children. Dispersed piles of sodium cyanide pellets were found to pose the greatest hazard. Uncontrolled demolition potentially increased the volume of hazardous waste, much of which could have been covered by or mixed in with demolition rubble (UNEP 2007). The ESA noted that if no corrective action was taken, high levels of hazard from chemical waste would continue for up to a decade.

Suwaira pesticides warehouse complex

Located approximately fifty kilometers southeast of Baghdad, less than two kilometers north of the Tigris River, and three kilometers north of the town of Suwaira, the Suwaira warehouse facility was used to store, mix, and dispatch a range of pesticides over a thirty-year operating period (UNEP 2007). Empty imported pesticide containers were washed and reused for the local sale of pesticides, and some damaged drums were dumped on site. The warehouse complex held a large quantity of obsolete and highly toxic methyl mercury pesticide.

The Suwaira warehouse facility operated normally until March 2003, when it was looted and the majority of the pesticides, as well as containers at the site, were stolen. The buildings on the site suffered only limited damage, but looters smashed containers and spread pesticides throughout the building and in parts of the compound in the process of stealing material. As of July 2005, the facility was secure but idle, and no cleanup had been carried out. The warehouses contained roughly 100 m^3 of waste pesticides, and at least three of the warehouses were considered unsafe to use or even enter until they could be decontaminated. Still, UNEP's ESA found that the site represented only a low priority to human health because security conditions prevented access to the contaminated warehouses.

Khan Dhari petrochemicals warehouse site

Located thirty-five kilometers west of Baghdad near the town of Abu Ghraib, the Khan Dhari petrochemicals warehouse site was administered by the Midland (Al-Doura) Refinery Company. The site contained a complex of eighteen warehouses and two support buildings (UNEP 2005).

The Khan Dhari warehouse operated normally until March 2003. Immediately following the 2003 conflict, the site was looted for machinery, empty drums, fittings, and chemicals, and looters poured the contents of containers full of chemicals onto the ground. According to site staff, 6,000 empty barrels contaminated with chemicals were stolen from the warehouse complex. Looters also started a fire that destroyed four warehouses, as well as the chemicals stored indoors and in the adjacent yard. Photographic and laboratory evidence revealed a significant volume of hazardous waste, mostly from fire-damaged drums, spilled heavy liquids, and burnt residues that were dispersed across the site.

UNEP's ESA found that the Khan Dhari site represented only a low risk to human health, primarily because of the site controls that were in place. In the absence of remedial action, however, large parts of the site represented a moderate risk to the health of site workers and were therefore deemed unfit for normal use. The principal threat arose from direct contact with and inhalation of lead dust and oxidized organic chemicals.

Mishraq sulphur mining complex

Located fifty kilometers south of Mosul, the Mishraq sulphur mining and processing complex was in operation from 1972 to early 2003. In March 2003, production ceased, and between April and July 2003 the site was comprehensively looted (UNEP 2005).

In June 2003, a fire set by looters burned continuously for almost a month. Reports indicate that the volume of sulphur burned ranged between 300,000 and 400,000 metric tons. Twenty-five villages and three towns were affected, with at least two deaths and many hospital reports of respiratory problems. A large part of the local population evacuated their villages at the time of the fires. There were also reports of extensive damage to wheat crops in the surrounding areas, most likely due to acute acid burns to the exposed plants, which resulted in stunted growth and plant death. As of July 2005, the entire site was shut down and secured, and it was lying idle and semiderelict.

UNEP's ESA found that the Mishraq site represented a low risk to human health and the environment, and that the primary risk was related to acidic surface-water ponds. Maintenance of site security could minimize this hazard, but failure to engage in corrective action would result in high levels of hazard from chemical waste for decades. Following the June 2003 sulphur fire, initial investigations indicated that the short-term damage to vegetation was severe close to the plant, but damage to the environment as a result of the fire was not widespread or long-term. Rainwater ponds, drainage ponds, and gullies close to the sulphur-processing and acid plants were found to contain hazardous levels of acid. Runoff from these areas could affect local river quality.

Quireej military scrapyard site

Located roughly fifteen kilometers south of Baghdad, the Quireej military scrapyard was primarily vacant land prior to 2003 (UNEP 2005). Between 2003 and 2004, it was used as a storage site and active scrap-recovery facility for damaged and redundant Iraqi military and civilian vehicles and equipment. Uncontrolled dumping and scrapping of vehicles resulted in localized contamination. Today the site is idle.

UNEP's ESA found that the Quireej military scrapyard site represented a moderate risk to human health, primarily to site workers but also to site residents. The primary toxicity risk was found to be to workers who came into direct contact with and inhaled chemicals in the process of transporting, cutting, sorting, and burning the scrap. The mixing of civilian and military scrapping activities was found to be exacerbating the problem.

UNEP's cleanup activities

Following completion of the ESA, which identified the key sites posing acute risks to human health and the environment, UNEP developed a cleanup project for the two sites with the greatest immediate risks. At the Suwaira warehouses the cleanup focused on the collection and containment of toxic pesticide residue, including chlorophenyl mercury and calcium cyanide. The cleanup also involved the design and creation of on-site, secure storage for the hazardous waste that was collected. At the derelict Qadissiya metal-plating facility, cleanup focused on the collection and containment of sodium cyanide, hexavalent chromium salt, and sodium hydroxide. By focusing cleanup efforts on the two sites that posed the most immediate threats to human life, the project further aimed to build the capacity of the Ministry of Environment, of other ministries, and of contractors so these entities could manage hazardous wastes, coordinate and implement cleanup works, and solve similar problems throughout Iraq in the future (UNEP 2007).

Suwaira site

At the Suwaira site, residue from the warehouse was collected in plastic bags and sealed in storage drums that were clearly labeled in Arabic and English to indicate that the contents were "toxic, environmentally hazardous, not to be touched, and flammable" (UNEP 2007, 38). The drums were numbered serially, and samples taken from each drum were cross-referenced with the same serial number. In total, 149 drums were filled. Ninety contained hazardous waste such as soil, dust, and bird guano mixed with chlorophenyl mercury; twenty-seven contained chlorophenyl mercury; thirty-one contained calcium cyanide; and one contained seeds. The drums were stored at the end of the warehouse and enclosed with warning tape (UNEP 2007).

Once the pesticide residue was collected, the Suwaira warehouse was extensively cleaned. The walls, windows, and doors were repaired, and holes were filled. The ceiling and walls were thoroughly scrubbed and washed with water jets. The floor-cleaning process was then repeated for a second time. Thereafter, a special concrete-polishing machine was used to remove stains and discoloration from the surface of the concrete floor. Following this cleaning process, the warehouse was washed with a warm soap solution and a hypochlorite solution, and then cleaned and washed a second time to reach a satisfactory state (UNEP 2007). Manholes in the floor were cleaned, and new covers were installed. Finally, the outside of the warehouse was cleaned and washed.

Qadissiya site

At Qadissiya, UNEP successfully collected, labeled, and stored all identified chemicals in steel barrels. In total, 150 drums of sodium cyanide, 228 drums of hexavalent chromium salt, and 68 drums of sodium hydroxide were collected

(UNEP 2007). Contaminated liquids found inside the plating basins were pumped out, placed into jerrycans, and stored inside the Qadissiya storage facility. A total of 220 jerrycans were filled with a mixture of hexavalent chromium salt and cyanide salt. One hundred bags of asbestos were collected and packed into larger plastic bags, which were then placed inside a third layer of plastic bags. The bags were sewn tight with a special sewing machine and stored. Samples were also taken of all drums, and the bags containing the samples were clearly labeled.

A hangar was constructed to store the contaminated soil and concrete that the chemicals had been lying on, as well as all related equipment, which included empty storage containers, drums, chemical wash tanks, and a cyanide salt annealing vessel with solidified chemicals. The hangar, which covered an area of 360 m^2, was constructed with concrete floors, closed walls, and a sealed roof (UNEP 2007).

SIERRA LEONE, 2009–2011

When peace was declared in 2002 after more than a decade of conflict, the small West African nation of Sierra Leone was left to tackle a number of serious environmental problems from the conflict. These included direct impacts, such as the destruction of infrastructure and large-scale displacement of skilled workers; indirect impacts on people's coping strategies; and institutional consequences of the almost entire collapse of governance during the conflict, including basic natural resource management (UNEP 2010).

Recognizing the critical value of the environment and natural resources, the government of Sierra Leone included them as key peace and development priorities, most notably in its *An Agenda for Change: Second Poverty Reduction Strategy* (ROSL 2008). In 2009 it requested that UNEP contribute to the *UN Joint Vision for Sierra Leone*, which outlines UN support for the *Agenda for Change* (UNIPO 2008).

When UNEP began an in-country capacity-building program to improve the governance of natural resources in July 2010, one immediate issue was the cleanup of a cache of toxic chemicals that had been left at an old oil refinery site in Kissy, a densely populated area in the eastern part of the country's capital, Freetown (see figure 3). The chemical in question was tetraethyl lead (TEL), which before 2000 was used around the world as an additive to gasoline to boost its octane rating and prevent engine damage.

TEL can be unstable; it is flammable, explosive, and highly toxic. Lead is a neurotoxin that is volatile in its organic form and is easily absorbed into the body through inhalation, absorption, or ingestion. Once organic lead is converted into inorganic lead, the risk of absorption into the body is reduced considerably (Innospec 2011).

In the mid-1990s operations at Kissy Refinery wound down, and the site was abandoned by its owners as a result of the civil war. The site was left without adequate supervision by trained personnel and was seriously affected during the attacks on Freetown by the Revolutionary United Front (RUF) in the latter part

Figure 3. UNEP cleanup site in Sierra Leone
Source: UNEP (2011).

of the 1990s. During this time a number of empty and partially filled drums were buried in unlined "grave sites" in a manner contrary to accepted standards for the disposal of TEL compound drums (Innospec 2011).

There are also unverified reports that RUF rebels may have tried to empty the TEL drums into the local water source, only to be discouraged by the approximately 300-kilogram weight of the drums. If this did happen, it would constitute a serious attempted war crime.

Site investigations at Kissy Refinery, Freetown

Preliminary investigations by a team of researchers from Sierra Leone's Environment Protection Agency (EPA-SL) and Fourah Bay College triggered an official request to UNEP's regional office for Africa for assistance in the analysis and disposal of the toxic stockpile at Kissy Refinery (UNEP 2009). UNEP's regional office launched a field mission to Freetown in July 2009 to conduct a quantitative assessment of the situation, to advise on proper measures to minimize the risks, to train managers on safety issues, and to draft a comprehensive remediation plan that would address final cleanup of the site.

The assessors found a total of forty-two metal drums of TEL stacked in an open shed on the premises of the refinery. At least two of these drums were showing signs of serious corrosion. Two large mounds of earth purported to be the burial site for another twenty-one drums were also identified. Once the cleanup was initiated, it turned out that there were fifty-one buried drums in varying states of corrosion in four separate burial sites. In total, ninety-three barrels of toxic waste would need to be decontaminated.

Sizable parts of the forty-two-acre refinery comprise a community market garden, where local residents grow fruit, vegetables, and staple crops, most of which are sold to nearby markets. The research team noted that absorption and bioaccumulation of toxic components of liquid fuel and gas by these crops were highly likely, but this required further investigation. The preliminary investigation further highlighted other breaches of environmental standards; for example, caretaking personnel were not being properly protected from the effects of the refinery's chemical fumes (UNEP 2009). UNEP's assessment determined that the significant quantities of TEL at Kissy Refinery posed a severe risk to the health, livelihoods, environment, and security of nearby communities.

Cleanup efforts

Following UNEP's technical assessment, Innospec, a UK-based private contractor and the world's only producer of TEL, submitted a commercial proposal for the final decommissioning and decontamination of TEL drums at Kissy Refinery (Innospec 2011). UNEP provided technical assistance and cofunding for the remediation operation, which was driven and managed by EPA-SL.

The cleanup project began in May 2011 and was originally scheduled to last for twenty-seven days. However, because more buried barrels were discovered after cleanup operations commenced—many of them heavily corroded—the project was extended to fifty-three days.

Innospec imported much of the special equipment required for the project, including a storage and transport vehicle, pumping equipment, and safety gear for the workers. The Innospec project managers hired and trained ten local workers, who began a supervised process of tapping and siphoning the drums to move the liquid into a transport container. The liquid TEL recovered from the site was transported to the United Kingdom for further treatment (Innospec 2011).

The empty drums were then cut open and flame-washed (blasted with an oxy-acetylene torch) to decontaminate any remaining liquid. Some of the oxidized sludge was mixed with cement to create stable concrete blocks that safely lock in the lead content. The burial sites were lined with a membrane layer and back-filled to minimize any further contamination.

There were several challenges involved in carrying out such an operation in a country like Sierra Leone. First, given the low level of development in the country and the lack of an existing chemicals industry, there was very low technical capacity related to chemicals management. Obtaining in-country support in terms of trained personnel and appropriate equipment was very challenging. Second, the safety and security conditions at the refinery were not ideal: hot and humid temperatures posed a risk to the TEL itself and were difficult for workers to withstand while wearing hazmat suits. The operation also needed to be completed before the rainy reason, meaning operations had to be conducted nearly continuously during daylight hours. It was also difficult to secure the site in order to protect the public from potential risks and to prevent equipment theft. Third, Sierra Leone is not a party to the Basel Convention on the transport of hazardous waste. This meant that although it was possible to transport liquid TEL outside of the country because it is considered a chemical product, it was not possible to export any TEL sludge for reprocessing outside of the country because the sludge is considered hazardous waste. This necessitated employment of a domestic solution: in situ containment in concrete.

By the end of June 2011, ninety-three TEL drums had been successfully decontaminated with no incidents, accidents, or contamination to the local workforce, population, or environment. This amounted to almost 12,000 liters, or nineteen metric tons, of TEL (Innospec 2011). Soil samples were taken from the area to provide a preliminary assessment of the extent of any ground contamination. Depending on the results of the soil analysis, further investigation may be required to determine whether a second phase of ground remediation work should be conducted.

LESSONS LEARNED

UNEP's experiences in the cleanup of contaminated sites in the Balkans, Iraq, and Sierra Leone yield several key lessons.

Timing

In order to be effective, post-conflict environmental assessment and cleanup efforts should start as rapidly as possible following the cessation of hostilities. Where potentially severe environmental damage may arise from a conflict, an independent, objective assessment must take place as soon as the security situation allows.

The sooner action is taken, the more effective the outcomes are likely to be in terms of protecting the environment and human health from further risks and effects. Early action is also justified by the fact that cleanup costs often increase with time, especially in the case of contaminants that can migrate through the soil and affect groundwater. It is crucial that sufficient financial resources for a comprehensive cleanup effort are secured as early as possible in order to facilitate a fast start to the program and ensure a sustainable and effective remediation project.

Scope of remediation

It is important for designers of remediation programs to identify the multiple ways in which a specific site has been contaminated. In addition to direct or indirect impacts from the conflict, some level of environmental contamination often predates the conflict. This was the case, for example, at the Pancevo fertilizer factory (HIP Azotara) in Serbia.

When project leaders are setting the scope of a remediation program, they must address three major questions: What causes of contamination, both preexisting and conflict-related, should be addressed during remediation? What overall degree of remediation and restoration should the project achieve (for example, a return to natural conditions or only pre-conflict conditions)? What existing or new sources of pollution may recontaminate the site?

Ideally, cleanup efforts should not focus solely on reversing the conflict's negative effects on the environment, but should kick-start long-term environmental restoration and lay the foundation for environmentally sound site management. Furthermore, cleanup operations should be conducted only where sustainability can be demonstrated. This entails both stopping all other forms of contamination related to the site and preventing new contamination. Sometimes cleanup operations at industrial sites need to go hand in hand with technology upgrades and training in cleaner production methods. In many instances, the availability of funding, the time frame for remediation activities, and the prevailing security situation will influence the overall scope of remediation.

Flexibility in remediation design and contingency planning

A thorough understanding of the local security, political, and socioeconomic context is critical for the design of remediation programs for post-conflict situations. Although it is necessary to draw on existing methods for post-conflict environmental assessment and remediation, strategies must be flexible and adaptable to the particular post-conflict situation and the evolving security situation on the ground. A one-size-fits-all approach or strict adherence to a project framework should be avoided. UNEP's cleanup work in Iraq clearly demonstrated the need for a flexible and adaptive approach when experts had to modify their projects amid a deteriorating security situation and maintain an appropriate balance between security considerations and the quality and cost of remediation.

When designing remediation programs, project leaders should also anticipate that cleanup sites involving abandoned industrial areas may have significant subsurface dump sites. Contingency planning should take this risk into account.

Cleanup operations in Sierra Leone demonstrated the need to adapt to changing conditions when additional drums of TEL were discovered in subsurface dump sites.

Furthermore, project leaders should anticipate additional challenges and costs when conducting remedial work in a context that lacks a strong industrial sector. In Sierra Leone the absence of a well-established industrial sector posed unexpected difficulties in implementation of the remediation project, both in terms of costs and the lack of skilled workers with the requisite background in handling hazardous chemicals.

Although effective cleanup programs should be tailored to fit the specific country context, practitioners should also attempt to achieve remediation that meets the best international standards—rather than local standards—so the country can establish a higher benchmark for future remediation and learn about best practices. In exceptional cases, however, a risk-based analysis may indicate that a lower standard can be used.

Prioritization of sites

In a post-conflict situtation, the number of contaminated sites may outweigh the amount of financing available for cleanup and remediation. It may be necessary to prioritize certain sites and to justify pursuing remediation at those sites rather than at alternative locations. This was the challenge facing UNEP in both Iraq and Serbia.

In situations where cleanup demand exceeds available financing, a transparent decision-making framework should be developed that allows stakeholders to rank and prioritize sites. This process should be informed by technical assessments that use the source-pathway-receptor approach to identify which sites pose the greatest immediate risks. UNEP's assessment in Iraq demonstrated the value of this approach. Although five sites were determined to be potential hot spots, only two of the sites represented immediate risks to human health on the basis of the source-pathway-receptor analysis.

Ideally, the first sites to undergo cleanup should be used as pilot cases to help build the capacity of stakeholders and raise public awareness of potential risks. Early and successful efforts can help build political momentum and public support for additional cleanup operations.

Life cycle approach to hazardous waste

When remediation works are conducted, the complete life cycle of hazardous waste must be taken into account from the outset of project design through collection, storage, transport, treatment, and final disposal. As was the case in Sierra Leone and Iraq, sites containing valuable scrap metal, equipment, or chemicals that can be sold on local markets will need to be secured to discourage theft and looting.

Because many post-conflict countries lack sufficient capacity and expertise to treat and dispose of hazardous waste, the best solutions are often regional.

Neighboring countries with internationally accredited treatment and disposal facilities should be used to the extent possible. Where regional solutions cannot be found, facilities farther away should be sought. When local contractors transport hazardous wastes to local treatment and disposal sites, chain-of-custody systems with appropriate levels of monitoring and enforcement should be used to prevent illegal dumping.

When the transport of hazardous waste crosses international borders, compliance with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is essential. Special efforts may be needed to train port and customs authorities regarding remediation equipment that needs to be imported and exported. Customs delays were experienced in all three cases, in particular during the importation of specialized cleanup equipment.

Public awareness and communication

From the outset, planning should incorporate media strategies and public awareness and consultation measures. This is especially critical when sites represent an immediate health risk and access cannot be easily restricted, as with the sites in Sierra Leone and Iraq.

Awareness campaigns should include basic information on the risks posed by specific contaminated sites and hazardous materials, and on ways to limit public exposure. When key resources such as drinking water have been contaminated, the public must be provided with clear guidance regarding treatment options and alternative sources. All forms of media, including TV, radio, Internet, and print, should be used to disseminate information to the public, and awareness workshops or door-to-door visits should be conducted in communities in the immediate vicinity. However, the timing of media campaigns needs to be carefully planned to avoid creating public panic before safeguards, risk-exposure guidance, or alternative measures are in place.

Proper photographic records of contaminated sites and remediation efforts should be created to help communicate problems and to highlight progress in cleanup efforts. Furthermore, follow-up monitoring should be instituted to track the presence of hazardous materials and ensure that the remediation work has been sufficiently carried out. Ideally this should be taken on as a core responsibility of the host government.

Partnerships

To be successful, any remediation program must include an effective framework for sustained engagement, coordination, and collaboration among site owners, local and national stakeholders and authorities, and international actors, including UN agencies, NGOs, and donors. Such an approach yields four major benefits.

First, it allows for the establishment of more sustainable projects and of solutions that are specific to the local context, thereby increasing acceptance of remediation activities among local residents and site owners. Second, it prevents overlap between projects and helps to identify synergies between related projects. Third, consistent and concerted engagement with local and national counterparts ensures a smoother handover to site owners and local authorities once the remediation project has come to an end. Finally, partnerships and collaboration create the space and interest for long-term, sustained investment in follow-up remediation efforts and environmental restoration projects.

Cleanup as an opportunity for capacity building and local employment

UNEP's work in the Balkans, Iraq, and Sierra Leone demonstrate that remediation programs go beyond physical cleanup activities and risk reduction; these projects play an important role in building local capacity, technical competence, and political visibility, as well as in generating local employment. For example, UNEP's remediation efforts in the Balkans were complemented by a range of training courses, seminars, and workshops that covered issues such as hazardous waste management, local environmental action plans, cleaner production, sustainable consumption, foreign direct investment, and multilateral environmental agreements.

In Iraq training topics included environmental emergency response, environmental inspection and control, environmental impact assessment, multilateral environmental agreements, environmental law, biodiversity and natural resource management, and office management. A detailed training program on assessing depleted uranium contamination was delivered to the Radiation Protection Center of the Iraqi Ministry of Environment (see Mario Burger, "The Risks of Depleted Uranium Contamination in Post-Conflict Countries: Findings and Lessons Learned from UNEP Field Assessments," in this book). In addition to training, UNEP provided lab and field equipment, established an environmental information center containing 1,500 publications, and facilitated participation in regional and international meetings.

In all cleanup efforts, the role of UNEP, the UN, and the wider international community should be to assist and advise national authorities and stakeholders while offering objective scientific and technical expertise. National authorities and stakeholders should manage cleanup efforts and take overall responsibility for operations. In the case of Sierra Leone, the EPA-SL's ownership of the project was critical to its success, particularly the EPA-SL's support in negotiating local services, hiring a local workforce, and clearing the necessary equipment through customs.

When possible, remediation and cleanup efforts should be designed to serve as a platform for building national and local environmental management capacity, initiating reform of local and national environmental governance institutions, and contributing to the resumption and strengthening of regional and international environmental cooperation.

Cleanup operations should also be designed to generate employment and procurement contracts that prioritize local companies. During UNEP's cleanup operation in Serbia, 80 percent of the staff were national experts, and 75 percent of contracts were awarded to local companies or institutions that employed local experts and used local technologies. When the UNEP program closed down, many of the staff employed by the program went on to open their own highly successful engineering companies.

CONCLUSIONS

Remediation of contaminated sites is often only one small step in the much longer and larger process of environmental restoration and governance required in post-conflict countries. In many cases, cleanup of environmental hot spots can be used as a starting point for raising environmental awareness and building greater public support for projects that safeguard the environment. When possible, cleanup operations should be used to catalyze greater political interest in tackling broader environmental challenges facing the country. In both Iraq and Serbia, the environmental risks posed by contaminated sites helped to bring environmental issues and governance needs to the political agenda and into national reconstruction plans.

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