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Assessment of Environmental "Hot Spots" in Iraq

United Nations Environment Programme

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United Nations Environment Programme
PO Box 30552
Nairobi
Kenya
Tel: +254 2 621234
Fax: +254 2 624489/90
E-mail: cpiinfo@unep.org
Web: http://www.unep.org

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UNEP

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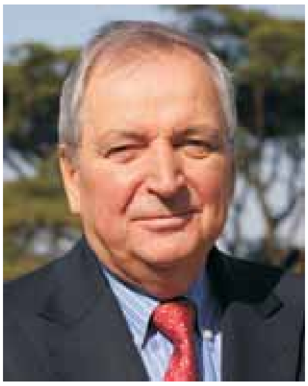


Foreword

I am delighted to present this report on the assessment of contaminated sites in Iraq. This pioneering work has been conducted by the Iraqi Ministry of Environment and its professional experts under the guidance and supervision of United Nations Environment Programme (UNEP). The project is part of a series of capacity building activities being undertaken by UNEP, with support from the Government of Japan through the UN Iraq Trust Fund.

While UNEP has been undertaking post-conflict environmental assessments since 1999, the situation in Iraq posed some unique challenges. Initial field visits by the UNEP team indicated the need to urgently assess the level of contamination at a number of industrial sites. However, the security situation did not permit UN staff to work inside the country. UNEP therefore developed a specific approach to assess the contaminated sites using a team of Iraqi experts from various Ministries that were selected and trained by UNEP experts to undertake the work. The data gathered inside Iraq was supplemented with satellite imagery, and samples were analysed in international laboratories. All of the field work was documented in great detail using global positioning systems and digital cameras.

The outcomes of the work highlight a number of important findings and lessons. First and foremost, the report demonstrates that while there are contaminated sites in Iraq, the environmental risks are still very localised and the opportunity exists to initiate immediate clean-up before public health is threatened. Urgent action should be taken as soon as possible to contain the large quantities of toxic chemicals lying unattended and unguarded. In this regard, I am extremely pleased that the findings of this project have resulted in UNEP being awarded additional financial resources by the UN Iraq Trust Fund to initiate clean-up activities.

Throughout this work, UNEP has also learned that an approach based on remote supervision, modern communications equipment and remote sensing can produce very useful results even in conditions where the United Nations cannot be present on the ground. This vastly expands the operating envelope for future UNEP interventions in other parts of the world.

I wish to congratulate the Iraqi experts from various Ministries who undertook the field work, and demonstrated professionalism and dedication at all times, despite the difficult security environment. I also want to thank all of our UN colleagues in Baghdad and Amman, who have supported this very complex work. Finally, I would like to express my deep gratitude to the Government of Japan for the generous financial support that made this assessment possible.

In the months and years to come, additional work will be necessary by the Ministry of Environment in Iraq to continue the assessment process and prioritize additional "hot spots". I look forward to continued close cooperation with our Iraqi counterparts, and hope that environmental issues can continue to be an important part of the reconstruction process.

Klaus Töpfer
United Nations Under-Secretary General
Executive Director of the United Nations Environment Programme

Foreword

It gives me great pleasure to learn that experts from various Ministries in Iraq, led by the Ministry of Environment, under the guidance of the United Nations Environment Programme (UNEP), have successfully completed the assessment of five contaminated sites in Iraq.

Iraq faces a number of environmental challenges. While some of them are directly related to the conflict, many stem from years of insufficient investment in environmental management. The newly established Ministry of Environment is currently addressing these challenges by creating a legal framework and administrative capacity to manage the environment in an appropriate manner.

UNEP has been a partner to the Ministry of Environment since its inception. The Ministry and UNEP are working together in areas ranging from institutional capacity building, to Marshlands restoration, to the environmental site assessments which are presented in this report.

This project is only a beginning. The challenge now is to identify and assess all such areas of contamination in Iraq and systematically remediate them in order to protect health and prevent contamination of key natural resources. We hope to have the support of the international community in the months and years ahead as we undertake this critical task.

Narmin Othman Hassan
Minister of Environment,
Republic of Iraq

Executive summary

Introduction

In July 2004, the United Nations Environment Programme (UNEP) was awarded a project for "Strengthening environmental governance in Iraq through environmental assessment and capacity building". This project was supported by the UN Trust Fund for Iraq through funds made available by the Government of Japan. One of the major elements of the project was to assess contaminated sites in Iraq, in partnership with Iraq's Ministry of the Environment (MoEn).

UNEP's Approach to Environmental Site Assessment in Iraq

Since the prevailing security constraints prevented UN experts from travelling to Iraq to undertake field work, the project was designed such that capacity building activities were undertaken outside Iraq while field work was done by Iraqi officials. The site assessment project had the following major components:

1. Identifying sites within Iraq which are potentially contaminated and creating a database which will assist in prioritizing intervention;
2. Building the capacity and institutional knowledge in the MoEn to enable it to conduct site assessment programmes;
3. Detailed assessment of five priority sites (See figure E.1 at the end of this chapter), via a phased process of desk studies, site inspections, environmental sampling, laboratory analysis, interpretation and qualitative risk assessment;
4. Preliminary assessment of contaminated land issues in Iraq at the national level. Issues addressed included a broad range of current problems including conflict-related impacts, identifying needs and setting the priorities for future policy and infrastructure development.

The field teams were provided with questionnaires, cameras and global positioning systems to bring back information about the sites visited to the UNEP expert team in Geneva. The data collected in the field were supplemented with information collected from satellite images and secondary sources.

Site and national scale assessment work resulted in a range of specific recommendations and associated cost estimates. As of September 2005, the project has also resulted in an urgent follow-up project to be managed by UNEP in late 2005.

Site assessment theory and equipment training

Project Implementation

1. Capacity building

A course of intensive theoretical and practical training on environmental site assessments was provided to delegates from MoEn and other Ministries. Training courses included planning site assessments, site assessment techniques, preparing sampling and analyses protocols, field sampling and analyses and, finally, risk assessment. A number of field instruments were procured and staff trained in their use. Iraqi experts were trained in health and safety practices for undertaking field work and were provided with appropriate personal protective equipment. Having successfully completed their fieldwork on the five sites, the MoEn now plans to commence a screening and assessment programme for over 100 other sites.

2. Assessment of priority sites

Five sites for priority assessment were selected by the MoEn. The sites were mainly in the industrialised region surrounding Baghdad. All were damaged or in an environmentally poor condition, due to either looting, fire, conflict or poor operating practices. None of the sites visited was operational in the conventional sense.

The main findings and recommendations for the five priority sites are:

Hazardous waste at Al Qadissiya

Al Qadissiya metal plating facility. This facility, located 30 km south of Baghdad, was successively bombed, looted and then demolished in an uncontrolled manner. Hazardous wastes including several tonnes of high purity cyanide compounds are scattered across an unsecured site accessible to the public. The site represents a severe risk to human health.

The recommendations are to contain and/or remove the most hazardous wastes as a matter of urgency and this is being addressed in a follow up project.

Al Suwaira pesticides warehouse complex. This facility, located 50 km south east of Baghdad, was looted in March 2003 and over 100 tonnes of obsolete and highly hazardous pesticide were stolen. In the process the warehouse interiors were coated with pesticide dust and littered with damaged containers. The site in its current state does not represent a severe human health risk, but only due to controls preventing access to the warehouses. The warehouses are unsafe to use or even enter.

The recommendations are to re-package the pesticide wastes and decontaminate the warehouses to allow their continued use.

Pesticide waste coating the floor inside the Al Suwaira warehouse

Khan Dhari petrochemicals warehouse site. This facility, located 30 km west of Baghdad, contained several thousand tonnes of refinery chemicals until it was looted and partially burnt down in March 2003. Damaged drums and spilled chemicals cover a large part of the site. The site in its current state represents a risk to the health of site workers, making it unfit for use.

The charred remains of the Khan Dhari chemical warehouse

The recommendations are to demolish the damaged buildings and clean up the damaged drums and chemical spills prior to recommencing operations.

Acidic and mineral rich drainage from the Al Mishraq mine

Al Mishraq sulphur mining complex. The Al Mishraq complex, located 50 km south of Mosul, is one of the world's largest sulphur mines. In June 2003 it suffered a catastrophic fire which consumed up to 300,000 tonnes of stock-piled pure sulphur and sulphur waste and caused regional air pollution, crop destruction and at least two deaths. The site is now idle and semi-derelict due to looting.

Surface and groundwater pollution from the Al Mishraq site was significant at the time of its operation but has now largely ceased. Preliminary work in relation to the 2003 sulphur fire indicates that the permanent effects on the environment are localised and limited. The site in its current state represents a low risk to human health and the environment, principally due to acidic surface water ponds.

The recommendations, in the event that it reopens, are to carry out a comprehensive upgrade of the facility to improve its environmental performance and resolve existing legacies such as acid drainage.

Ouireej military scrap yard site. Ouireej is a planned residential area located 15 km south of Baghdad that in 2003 was allocated as one of the main dumping and processing sites for military scrap arising from the conflict and the subsequent destruction of the Iraq arsenal. At the peak of activity the site held hundreds of items of potentially hazardous military hardware including tanks and missiles still containing unexploded ordnance and hazardous chemicals. Two people were reportedly killed, by explosions and by poisoning, in the uncontrolled scrap metal recovery operations that occurred over the period mid 2003 – early 2005. The site in its current state represents a risk to human health, principally to site workers, but also to site residents.

The recommendations, in summary, are to separate the military and civilian scrapping operations and the residential development to mitigate the obvious risks of combining all these land uses.

Children playing in the Ouireej military scrapyard

3. Assessment of national scale issues

The key findings of the assessment of national scale issues on contaminated sites and hazardous waste are as follows:

Industrial and military legacy of contamination and hazardous waste. Iraq has a significant legacy of contaminated and derelict industrial and military sites. Many facilities are unlikely to re-start operations but a portion of the sites in urban areas may be redeveloped for other uses. These sites have major problems with hazardous waste and variable but generally lesser problems with contaminated soil and water. In a minority of cases, the sites represent a severe risk to human health, specifically to site workers and trespassers. Each of the sites has to be assessed separately in a systematic manner so as to identify specific issues and corrective actions.

Reduction in industrially sourced pollution. The closure of many of the sites has resulted in a net reduction in waste production and pollution loading of the air and water, as many large-scale polluting processes have now ceased.

Special case post-conflict sites – military scrap yards and munitions disposal. The destruction of the Iraq military arsenal is creating isolated cases of new contamination and hazardous wastes. Some basic improvements in working practices and planning could reduce the environmental and health risks and reduce the cost of future cleanup.

Oil industry. The oil industry is a major source of land contamination and hazardous wastes, which needs a comprehensive study. It is, however, expected that the oil industry will have the resources to tackle this issue in the longer term provided there is a legal framework which promotes such assessments.

Policy and legislation. In the longer term, national strategies, policies, legislation and enforcement are needed for hazardous waste management and contaminated land.

National facilities for hazardous waste management: Currently there are no properly designed facilities for hazardous waste management in Iraq. Availability of properly designed hazardous waste management is essential for undertaking clean up work in individual contaminated sites.

4. Recommendations

Recommendations and associated cost estimates have been developed for both the priority sites and the national issues. They include urgent work to reduce the health risk from hazardous waste at the worst sites. The summarised national level recommendations and associated cost estimates are:

- Identify the remaining sites warranting quick corrective action – US$ 400,000.
- Corrective action programme at up to 20 sites – US$ 2,000,000.
- Capacity building for corrective action – US$ 400,000.
- Construction of a hazardous waste treatment facility – US$ 22,000,000.
- Oil industry management of related contaminated sites – over US$ 10 million.
- Buy back and separation of hazardous military scrap – several US$ million.
- Development of national strategies, policies and legislation – US$ 300,000.

5. Urgent follow up project

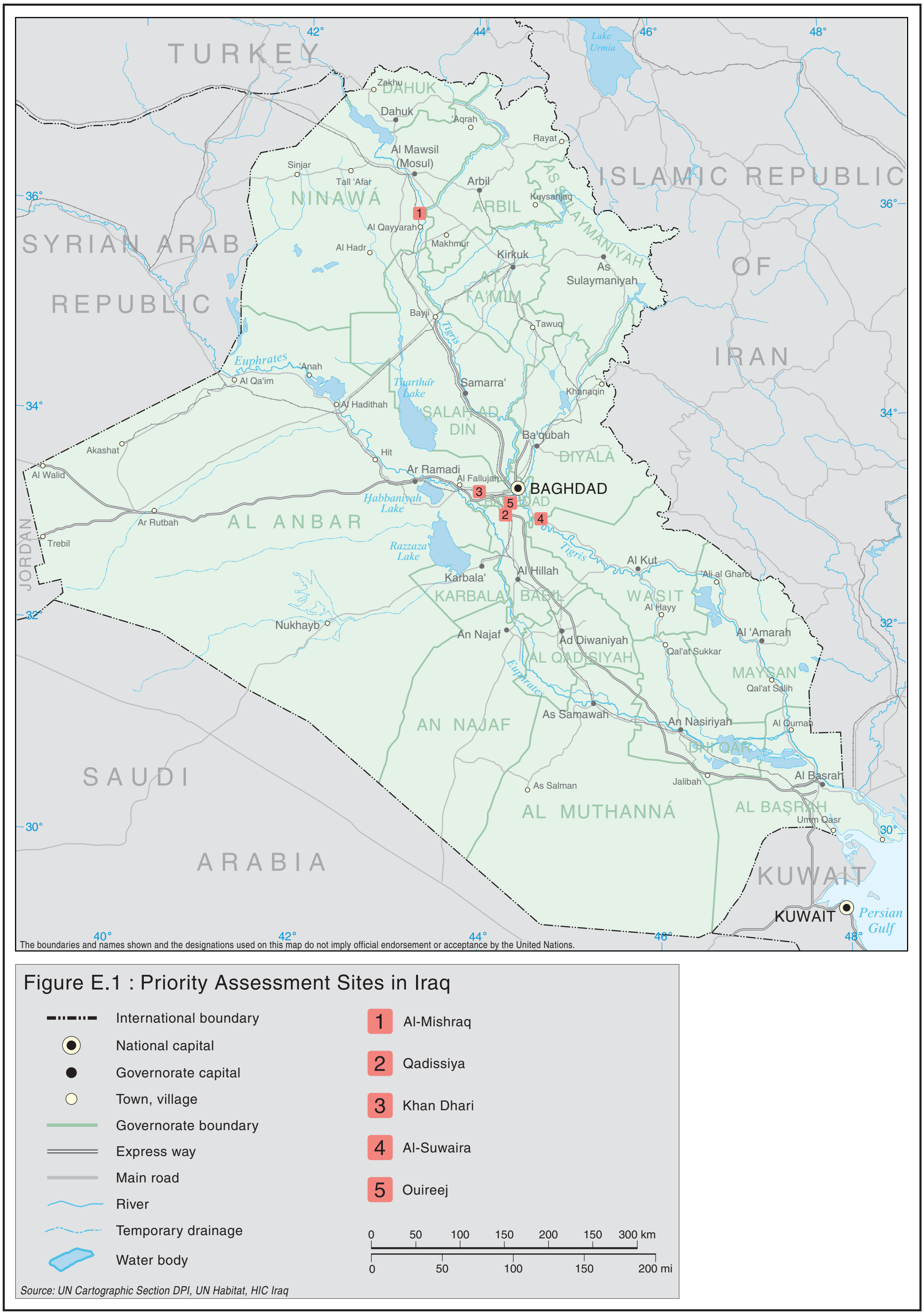
Subsequent to the completion of the site assessment project and based on the initial risk assessment, UNEP proposed to the UN Trust Fund a project to urgently contain and clean up the hazardous material at Al Qadissiya and possibly at Al Suwaira. This has been supported by the Trust Fund, through its Fast Track approach. The work will involve;

- Removal and safe storage of the cyanide waste at Al Qadissiya;
- Decontamination of the warehouses at Al Suwaira;
- Building the capacity of the Iraqi ministries to carry out similar works in future.

The project is planned for commencement in September 2005 and substantial completion by February 2006.

Electro plating chemicals lying on the open ground at Al Qadissiya – the focus of the UNEP follow-up project

➤ Figure E.1 Priority assessment sites in Iraq



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Introduction

1.1 Scope and structure of this report

This document is a report of the results of a project managed by the United Nations Environment Programme (UNEP) to assess contaminated sites in Iraq. The work was carried out over the period January 2004 to July 2005 in Iraq, with support activities in Jordan, Switzerland and the United Kingdom.

The project was managed by the UNEP Post-Conflict Branch, based in Geneva. The project was overseen by the United Nations Development Group for Iraq in its role of coordinator for the entire UN development programme within Iraq. The Iraqi Government partner was the Ministry of the Environment (MoEn).

The project covers contaminated land issues at the national level and also for five individual sites selected for priority assessment. The scope of the project covered capacity building for the MoEn, site selection and assessment, analysis of national issues, interpretation, development of recommendations and reporting.

This document is the main reporting product and is designed for a wide audience. It is complemented by a separate, more detailed report on the capacity-building process and by factual technical reports for each of the five individual site assessments, all of which can be found on the UNEP Iraq website http://unep-iraq.org.

The report begins with a general introduction and background to the environment in Iraq, the UNEP programme in Iraq and the Environmental Site Assessment project, together with a discussion of the management approach, local partners and security issues.

Chapter 3 provides an overview of the situation in Iraq with respect to contaminated land and hazardous waste.

Chapter 4 describes UNEP's capacity-building activities including training and equipment provision to the MoEn.

Chapter 5 describes the site screening and identification process and the results obtained, whilst Chapter 6 summarises the process and main tasks of assessment for five priority sites.

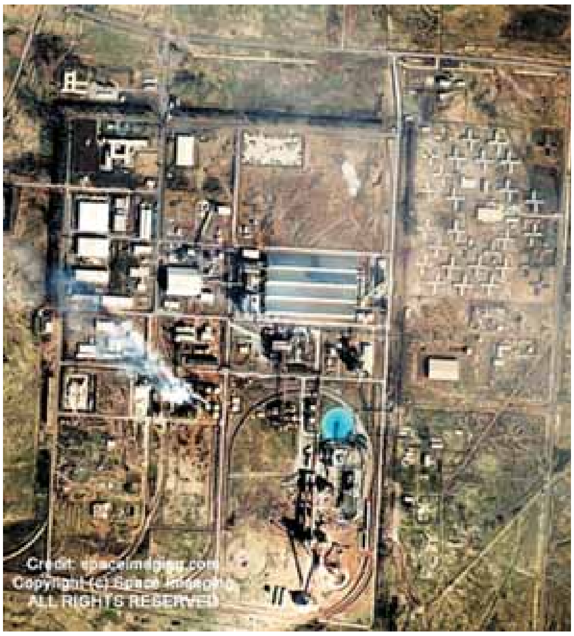
Chapters 7 to 11 summarise the assessment results and recommendations for each of the five priority sites.

Chapter 12 sets out the general and national scale project findings and recommendations.

The Conclusions (Chapter 13) summarise the project findings and recommendations and discuss ways to implement them.

1.2 State of the environment and related programmes in Iraq

Iraq has had limited international cooperation and assistance in the environmental sector since the 1980s and this isolation intensified over the period 1990 to 2003. Environmental authorities and data collection agencies did exist, but they had limited powers and resources. The country opened to the international community only for a brief period in 2003, before escalating violence curtailed access to international expert staff.



SPACE IMAGING

Satellite images can yield detailed information on Iraqi industrial sites – such as the Al Qaim phosphate complex

As a result, the state of the environment in Iraq is not well documented or validated by robust scientific data. Indications of overall status can however, be judged from a combination of locally supplied information and remote sensing datasets (analysis of data such as satellite images and aerial photographs).

At the time of writing, Iraq is facing a range of immediate and severe environmental problems. Some can be directly linked to the effects of recent military conflicts and the ongoing security crisis. Others have been triggered by internal Iraqi policies and actions, and exacerbated by factors such as the impact of economic sanctions and long-term under-investment.

Many of Iraq's environmental problems are linked to development and infrastructure issues[1]: the lack or poor state of infrastructure can be a source of environmental problems. Examples include the impact of insufficient sewage treatment capacity[2] on river water quality and the lack of facilities to manage hazardous wastes.

The prevailing security situation means that access to much of the country is constrained, both for national and international personnel. Fieldwork in the central regions of Iraq presents particular risks. The need for programmes offering potential longer term improvements in human health and the environment must be weighed against the short-term risks to human life.

Uncontrolled dumping of industrial wastes is a recurrent problem in Iraq – South of Baghdad 2005

1

The UN programme for reconstruction and redevelopment in Iraq[3] includes a range of environment related projects including sewage rehabilitation, provision of clean drinking water treatment systems, water monitoring and analysis facilities. Other international agencies are also active in Iraq and many of their projects are related to the environmental sector. The most significant of these projects in terms of scale is the construction of two modern sanitary landfills in the Baghdad region[4].

Against this background, UNEP's work in Iraq is based on the following principles:

Scientific validation of anecdotal evidence. An early focus for action should be the replacement of anecdotal evidence with adequate, valid technical data to allow rational decision making and prioritisation of efforts.

Interlinking with recovery and development. Given the breadth and overwhelming scale of Iraq's needs, all expenditure on the environment should be closely linked with human health, recovery and development issues.

Capacity building. The isolation of the previous Iraqi regime over the last 30 years curtailed the development of a culture of governance and local technical capacity in the environmental field[5]. Nonetheless, the country is semi-industrialised, has a solid base of well-educated scientists and engineers and is now building the appropriate government structures. Conditions are therefore right for capacity-building efforts on environmental management to provide both rapid and long-lasting benefits.

Flexibility in a conflict setting. Although the current unrest is having a severe impact on daily life, the Iraqi MoEn and participating staff have expressed their desire to push on with recovery and development work despite the problems and personal risks. UNEP has modified its standard operating approach and is maintaining a high level of flexibility to deliver the programme while attempting to manage the security-related constraints.

The following sections introduce the history of UNEP activities in Iraq, its current overall programme and the site assessment project.

1.3 UNEP post-conflict activities in Iraq before 2004

UNEP's post-conflict environmental activities in Iraq began after the 1991 Gulf War, with the production of a rapid environmental assessment report[6] that identified key environmental problems and needs. In 2001, after a period of restricted access, UNEP produced a comprehensive assessment of the degradation of the Mesopotamian marshlands[7].

Smoke from oil fire trenches – One of the short-term environmental issues associated with the 2003 conflict

During the 2003 conflict, UNEP monitored the potential environmental impacts of the conflict, and provided environmental information to key stakeholders, such as Iraqi government ministries, through a series of round table meetings. Following the conflict, UNEP issued a *Desk Study on the Environment in Iraq*[5] in April 2003 and the *Environment in Iraq UNEP Progress Report*[8] in October 2003. Both reports outlined the key chronic environmental problems faced by the country, as well the environmental threats posed by the various military conflicts.

The desk study and progress report identified the need for an environmental assessment of selected contaminated sites in order to identify risks to human health and livelihoods and to initiate urgent risk reduction measures.

An additional need was to build and strengthen the environmental governance capacity of the Iraqi administration and to provide specific training to experts from the Ministry of the Environment in the areas of: contaminated sites assessment, environmental impact assessment, natural resources management, multi-lateral environmental agreements, environmental monitoring, environmental information and disaster management.

1.4 The UNEP post-conflict programme in Iraq 2004 - 2005

In consultation with the Iraqi Ministry of the Environment (MoEn), UNEP developed a comprehensive package of activities that will contribute to building the capacity of the MoEn to conduct assessments of contaminated sites, develop sound environmental policies and monitor environmental quality.

The programme[9] is entitled **"Strengthening Environmental Governance in Iraq through Environmental Assessment and Capacity Building"** and is being implemented over the period July 2004 to December 2005. The programme is divided into the following components:

Assessment of contaminated sites – the subject of this report

It is estimated that Iraq has several thousand contaminated sites resulting from a combination of general industrial activities, military activities and post-conflict damage and looting. The Environmental Site Assessment (ESA) programme is a combined package of capacity building and technical assessment that focuses on priority contaminated sites that potentially pose risks to human health and the environment.


UNEP

The UNEP Executive Director, Dr. Töpfer greets the Iraqi participants to the Capacity Building Workshop on Environmental Inspections and Laboratory Analyses

1

Capacity building in technical and policy areas

Iraq's MoEn identified urgent capacity-building, training and infrastructure needs for 2004 – 2005. These include provision of equipment and training and technical assistance for 200 Ministry staff at the national and governorate level.

Institutional capacity assessment

In order to develop the MoEn into an effective lawmaking and law-enforcement body, substantial, urgently-needed capacity-building efforts have been identified and are being carried out. An Institutional Capacity Assessment to review systematically and assess current resources (physical, financial, information and human) available within the MoEn is planned for 2005.

Infrastructure and equipment

Iraqi professionals have been isolated from their peers, resulting in a serious need for institution building, restoration of information-sharing and the rehabilitation and modernisation of infrastructure. UNEP is strengthening MoEn facilities and other selected government agencies with an environmental remit. Urgently-needed equipment, training and technical assistance are being provided to Iraqi policy makers and technical experts, mainly among MoEn staff and other governmental agencies that share cross-cutting issues and activities.

UNEP

Iraqi participants to the Capacity Building Workshop on Environmental Inspections and Laboratory Analyses receiving training on vegetation sampling in Spiez, Switzerland


IRAQ MINISTRY OF ENVIRONMENT

The Mesopotamian marshlands, once nearly destroyed, are now in the process of partial regeneration

Mesopotamian marshlands

Working in partnership with the Iraq MoEn, other government ministries and local non-governmental organisations, UNEP (Division of Trade, Industry and Economics – International Environmental Technology Centre in Japan) is providing a package of technical assistance to support the sustainable management and restoration of the Iraqi marshlands[13]. The project is comprised of a range of activities including facilitating strategy formulation, monitoring marsh conditions, raising the capacity of Iraqi decision makers and providing water, sanitation and wetland management options on a pilot basis. Remote sensing monitoring of marshland reflooding is being carried out by the UNEP Post-Conflict Branch.

2 The environmental site assessment project

2.1 Objectives and scope

The Environmental Site Assessment (ESA) project focused on chemically contaminated sites in Iraq. The project was scoped to include activities at both a high level (policy) and low level (individual sites) but does not attempt to identify or address all of the potentially contaminated sites in Iraq. Instead, efforts were concentrated on capacity building at the government level for the management of such sites. At the same time, site-specific work was conducted in areas with urgent short-term problems, so as to ensure the project delivered immediate practical benefits.

The two principal objectives of the project were:

1. The short-term objective of conducting priority site assessment work on the hot spots identified as potentially presenting serious risks to human health and the environment;

2. The longer term objective of building institutional knowledge and capacity within the MoEn for the very much larger programme of site assessment, remediation and improvements in hazardous waste management that is foreseen for Iraq as part of its overall development.

The scope of work was divided into seven closely linked main activities:

1. Provision of ESA assessment training;
2. Selection of a list of high priority contaminated sites;
3. Provision of ESA equipment;
4. Provision of information technology (IT) and document-based assessment support tools;
5. Field surveys of the contaminated sites;
6. Provision of laboratory analytical services;
7. Interpretation and reporting of results on assessment of selected sites.

Specific capacity-building work was concentrated in activities 2 to 4, although the theme of capacity building was central to the project and extended to all activities.

2.2 National partners

The Iraq Ministry of the Environment (MoEn) was the national partner for the site assessment project. The MoEn is a new ministry which evolved from the Environmental Protection and Improvement Directorate (EPID) within the Ministry of Health. The MoEn has approximately 700 staff, mainly based in Baghdad, with 15 offices located in the governates.

For this project a dedicated team was formed by the MoEn, consisting of an overall project manager, five site assessment managers and technical support staff. The critical fieldwork activities such as site reconnaissance, sampling and mapping were managed and carried out by local MoEn staff, who are to be highly commended for their efforts in the face of security risks and other problems.


Ministry of Environment staff sampling surface water

2.3 Project management

The security situation in Iraq presented some significant challenges to the project over the period 2004 and 2005. These were overcome by tailoring the project to the Iraqi environment, and also the efforts of the MoEn staff.

The UNEP Post-Conflict Branch has significant experience in the assessment and remediation of chemically contaminated sites in post-conflict countries. Normally, contaminated site work is carried out as part of a larger country-specific package of environmental assessment, capacity building and assistance.

The normal UNEP methodology for such assessments is to work on location, with a team of international experts partnering local and government scientists who provide local knowledge, expertise and resources. This approach both ensures the highest possible technical standards and assists in local capacity building and ownership of the issues that arise from the assessments.

In the case of Iraq, the prevailing security situation in 2003–2005 made this approach unworkable. UNEP therefore developed an alternative approach based on capacity building in the MoEn, to enable them to carry out the fieldwork and assessment activities that would normally be done by international experts.

Initially, UNEP experts provided intensive training and equipment to the MoEn teams and thereafter worked closely with the same staff for the duration of the project. For the priority site assessment, significant work such as laboratory analysis, map and report compilation was completed outside Iraq by UNEP experts, consultants and contractors, with UNEP providing oversight and quality control.

2

Fieldwork activities such as site reconnaissance, sampling and mapping were managed and carried out by MoEn staff. Technical staff from other Ministries (Ministry of Oil, Ministry of Agriculture and ex-Ministry of Military Industrialisation (MIC)) were able to assist on three of the five sites.

This partnership approach is considered to have been successful in that the technical objectives have been achieved and the practical capacity of the MoEn in the field of contaminated land and site assessment has been significantly increased. The disadvantages of the approach are the increased cost and time required compared with the conventional approach, together with the security issues described below.

2.4 Security

Security issues affected the project in several ways: it made travel hazardous in Iraq and constrained the ability of UNEP and the MoEn to perform their duties. The most pressing security issue was managing risks in the course of the necessary fieldwork at the five priority sites.

The MoEn office is in central Baghdad and the selected sites were mainly in the surrounding industrialised region, all of which are classed as highly dangerous with respect to security. UNEP was able to carry out preliminary fact finding-missions to Iraq in July – August 2003. With the deteriorating security situation, however, routine access to these areas was not possible for international staff, including UNEP experts and consultants, and accordingly follow-up visits were not made.

During its fact-finding mission, UNEP in collaboration with the former Environmental Protection and Improvement Directorate (EPID) of Ministry of Health, identified and visited three of the sites that were subsequently selected by the MoEn in this assessment project. These sites were damaged or in an environmentally poor condition, due to either looting, fire, conflict or poor operating practices. None of the sites visited was operational in the conventional sense. Site security was variable, with two secured sites, one partly secured and two completely unsecured and publicly accessible sites. Follow-up surveys by MoEn staff on other sites indicated similar conditions in a majority of industrial facilities.

The MoEn's approach to fieldwork security was to maintain a very low-key presence and to minimise the duration and profile of site-work. Taxis and unmarked vehicles were used for transport, both due to the limited availability of government vehicles and the desire to maintain a low profile both in transit and on site. All equipment was hand carried and removed at the end of each day of fieldwork. In some cases armed site security was provided on site by the site owners, the MoEn or other Iraqi government agencies.

The approach to fieldwork security was successful in that no incidents were recorded. The MoEn staff are to be highly commended for their commitment in working in such difficult circumstances. In the long term, however, this low-profile approach may not be viable for more intensive assessment activities due to the unavoidable risks and the need to transport, use and store more substantial equipment on site.

FARIS MEHDAWI - REUTERS

Iraqi police look at a wreckage at the scene of a car bomb in the town of Kenaan

3

Country context

3.1 Introduction

This chapter presents selected geographical, demographic and technical background information relevant to the discussion of land contamination issues in Iraq. For a broader context, the general environmental situation in Iraq was previously outlined in the *UNEP Desk Study on the Environment in Iraq*.

3.2 Geography, demographics and land use

Iraq has a land area of approximately 437,000 km^2, which can be divided into four major geographical zones[14]. These are described briefly below and in Figure 3.1.

Desert plateau. Approximately 40% of Iraqi territory consists of a broad, stony plain with scattered stretches of sand, lying west and southwest of the Euphrates River.

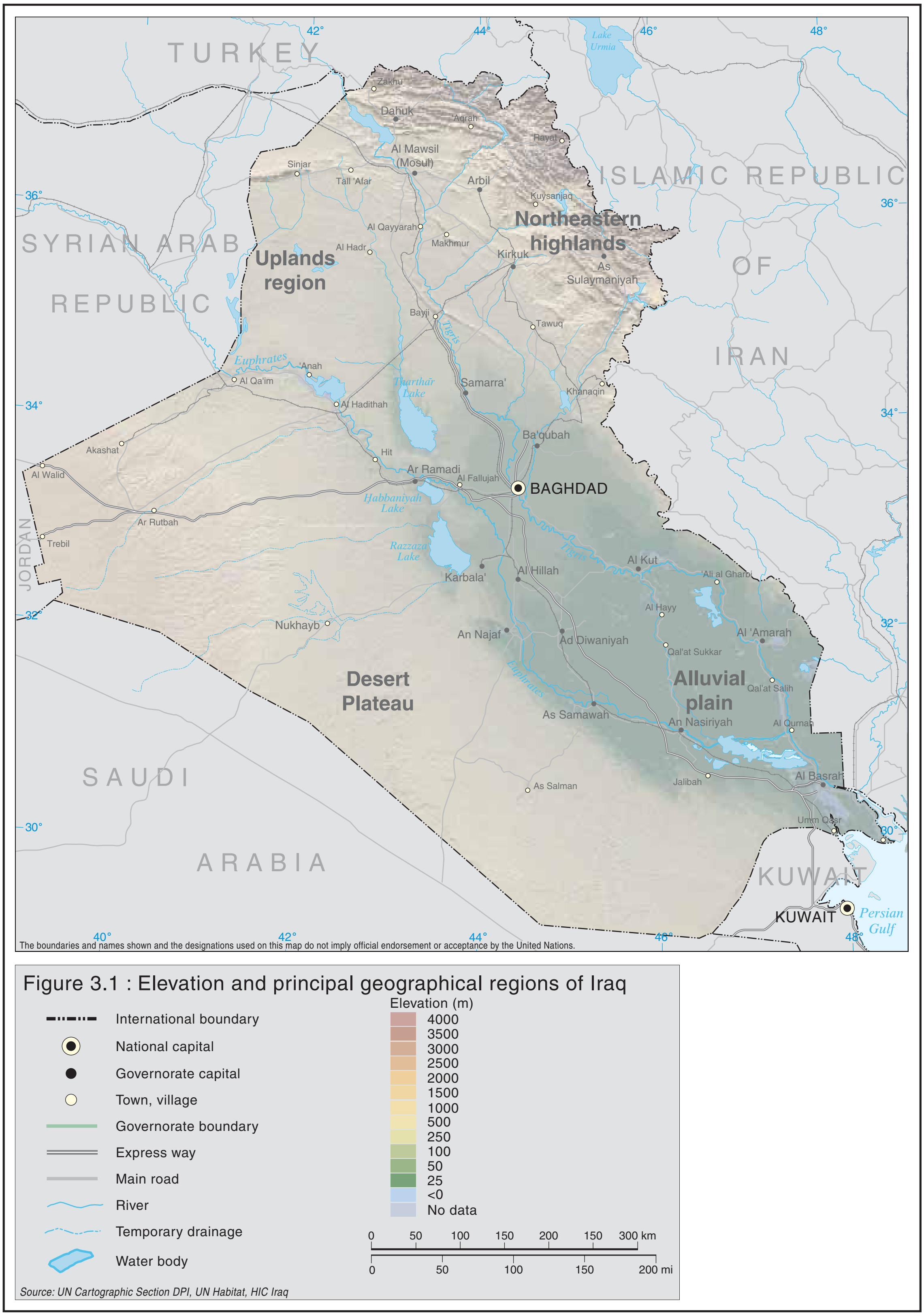
North-eastern highlands. Covering approximately 20% of the country with mountains ranging up to 3,600m high, this region extends north of a line between Mosul and Kirkuk towards the borders of Turkey and Iran.

Uplands region. Approximately 10% of the country, in the northwest, comprises a transitional area between the desert plateau and the highlands. The region is arid, with irregular topography and deeply cut watercourses.

Alluvial plain. Approximately 30% of Iraq is composed of the flat alluvial plain formed by the combined flood plains and deltas of the Tigris and Euphrates rivers. The region extends from north of Baghdad to the Gulf coast bordering Iran.

The uplands support grazing and cereal crops

➤ Figure 3.1 Elevation and principal geographical regions of Iraq



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Iraq has a population of approximately 26 million[14] with over 75% of the population concentrated in urban centres located along the Tigris and Euphrates river systems. The region surrounding Baghdad has in excess of 6 million inhabitants.

As only 14% of Iraq is considered arable land, the historical pattern of land use and development principally reflected the constraining effect of limited water resources. The alluvial plains and riverine regions are densely populated, whilst in general population density is low to very low in the more arid regions distant from sources of irrigation water.

In the second half of the twentieth century Iraq became increasingly urbanised and industrialised[15]. Urban growth was highest in the Baghdad and Basra regions. Over the period 1970 to 2000 the economy became dominated by the oil sector which has come to account for 95% of foreign exchange earnings[16].

Oilfields and mining areas are found throughout Iraq, with the great majority of oil production focused in the south around Basra and in the north around Kirkuk. The majority of general manufacturing, including the military industrial complex, is within 100 km of Baghdad[17].

The demographic trends and patterns of land use in Iraq underscore the importance of good management of contaminated sites. Industrial sites are mainly located in urban regions subject to increasing population growth, and therefore the re-use of old industrial sites can be expected to increase.

3.3 Water resources

Precipitation in Iraq is limited and the majority of the country is arid to semi-arid. Annual precipitation in the northern hills and mountain ranges varies from 300mm to 1000mm whilst in the extreme south and west it is in the order of 100mm to 200mm and highly irregular[18]. The central alluvial plain relies substantially upon the flow of the Tigris and Euphrates rivers and tributaries.

Catchments and groundwater recharge zones are concentrated in the north and east of Iraq and the neighbouring countries. In the more arid hilly areas to the east, networks of wadis – seasonal watercourses – provide isolated areas with significant recharge. Evaporation rates in the arid areas are much higher than precipitation and natural recharge rates, resulting in natural salinisation of groundwater.

Both surface water and groundwater are heavily extracted, with most urban centres serviced by river water extraction and purification plants. In rural areas, village wells and springs are the predominant water sources.

Obtaining and maintaining the necessary quantity and quality of water represents a significant problem for Iraq[1].

The Tigris River south of Baghdad

3.4 Environmental and population vulnerability

The importance of hazardous waste and land contamination issues on a particular site is strongly linked to its surroundings and in particular to the vulnerability of the local natural environment and population. Assessing these factors on a national scale can help to identify important areas and topics for assessment.

For the natural environment, the indicators of importance are biodiversity and sensitivity to degradation. In general, the industrial areas in Iraq are sited in heavily developed regions of low biodiversity and sensitivity. Biodiversity is particularly low in the central plain and the Baghdad region due to the history of sustained agricultural activity and the population density in the riverine areas[21].

The most significant environmental receptors – people or environments – are the Tigris and Euphrates river systems and underground water aquifers. In the south of Iraq the most important areas are the Mesopotamian marshes, riparian zones, the estuarine Shatt Al Arab and the coastal mudflats[21].

Communal wells are the primary water source for many villages

For the population, the pattern of land use in Iraq indicates that the human health issues for contaminated land and hazardous waste are similar to those observed worldwide. Potential pathways to exposure from toxic chemicals on such sites include direct contact (site workers and trespassers), blown dust and drinking water.

The most important sources of drinking water are the Tigris and Euphrates river systems, with dozens of large-scale municipal supply river water intakes located in the central plain region. Much of the developed central plain has saline or polluted groundwater which prevents its use. Shallow village wells are however still widely used in rural areas, even if saline.

An issue particular to Iraq is the continued looting and lack of security on many derelict and abandoned industrial sites. This implies that the risk to the public from direct contact with hazardous chemicals and wastes left on such sites is particularly high.

Based on this broad assessment of vulnerability to contaminated land in Iraq, human health risks appear to be the predominant issue. The vulnerability of the rivers and groundwater to pollution is a critical and joint human health/environmental concern. Other environmental risks, though far from negligible, are of less concern.

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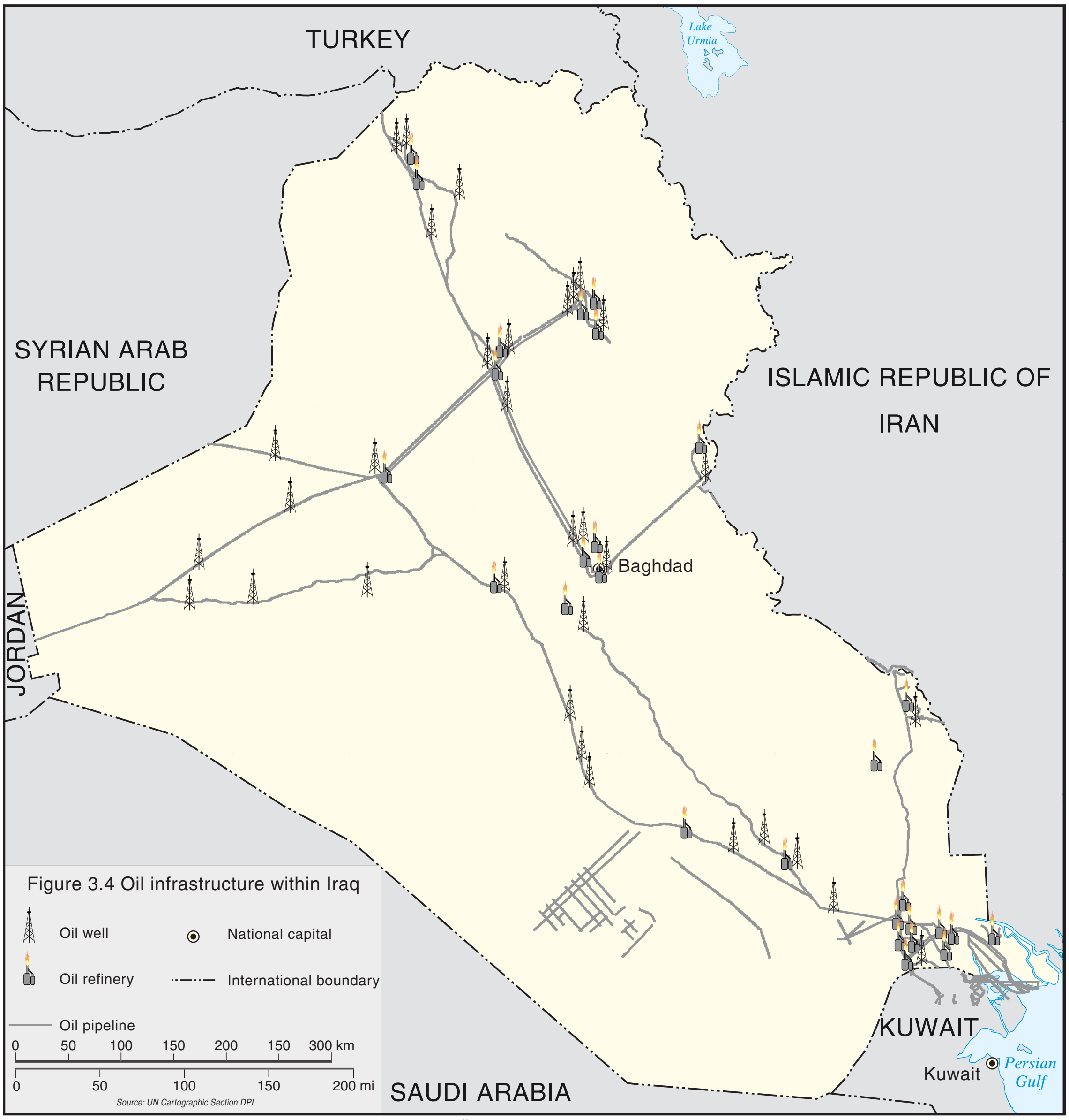
3.5 Industrial development background

Contaminated sites and hazardous waste arise principally from industrial sites. An understanding of the history and status of Iraqi industry can therefore assist in the direction of efforts to identify and assess contamination and hazardous waste issues.

Iraq's industrial development has had a turbulent history[15], with periods of rapid growth and decline. Development began at the start of the twentieth century with the commencement of significant oil production near Kirkuk and Basra. This growth, however, was largely limited to the oil industry and related services, and most of the equipment was imported.

Broader industrial development began in the 1970s when the Iraqi government started a development programme largely funded from oil export revenues. The focus was on medium technology industries such as textiles, food production and construction materials and heavy industry including iron, steel and basic petrochemicals[22]. Higher technology goods were, and still are, largely imported.

Figure 3.4 Oil infrastructure within Iraq



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.


Sulphur purification plant at Al Mishraq

The minerals industry grew gradually with a focus on sulphur, phosphate and potash, including post-processing of ores to produce sulphuric acid, alum and fertilisers. At its peak in the 1980s, Iraq was one of the world's largest producers of fertiliser[23].

From the 1970s, Iraq developed a domestic arms industry that produced the full range of low to medium technology goods, such as explosives, small arms and artillery munitions as well as higher grade items such as missiles.

Oil was discovered in commercial quantities in Iraq in 1927 but production was relatively limited until the 1970s. Following nationalisation in 1972 and the rise in oil prices, oil production rose rapidly. By 1979, oil production represented 63% of Iraq's GDP. Peak production of 3.7 million barrels per day (bpd) was achieved in 1979, compared to a low of 1.5 million bpd in 2002 and the current rate (June 2005) of approximately 1.9 million bpd [24, 22].

Most industrial development in Iraq was based upon a nationalised system with central government ownership and direction of industries[15]. The internal market was tightly controlled and uncompetitive: uneconomic industries were commonly underwritten and subsidised with funds from oil exports. This system deterioriated and then largely collapsed in the period from 1980 to 2003, due a combination of inherent inefficiencies and external events. As of mid 2003, there were 45 major state-owned enterprises, many effectively derelict[25].

The Iran-Iraq war from 1980-1988 led to the diversion of funds to the arms industry and drained the national treasury. Industries which were previously highly subsidised, began a slow but near terminal decline. Production levels dropped, new capital projects were limited and existing plants began to degrade due to limited maintenance and a lack of imported spare parts.

The 1991 Gulf War dealt an immediate blow to the Iraqi economy and the subsequent programme of UN sanctions accelerated the process of industrial decay. Imports of key spare parts and source chemicals were effectively cut off and the local market for goods became depressed[15].

Many plants continued to operate on a limited basis, salvaging equipment for spare parts and devising alternative solutions for missing parts and chemicals. This process was particularly

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pronounced in the arms industry, which in many cases reverted to older technology, e.g. for explosives production, which could be produced using domestic goods and services.

UN sanctions, which were in place from 1990 to 2003, the 1991 conflict and other problems either curtailed or prevented the export of minerals and finished materials. As a result, large stockpiles of unsold material built up at some mining and mineral processing sites. As an example, up to 500,000 tonnes of sulphur were stockpiled at the Al Mishraq mining complex pending export.

Irrespective of the production levels and economic conditions, state-owned industrial companies employed very large workforces, which were largely retained at least until 2003. Many of the management and technical staff were highly qualified, with particular expertise in science and engineering.

The arms industry in Iraq suffered from sanctions with respect to the procurement and manufacturing of more advanced weaponry and some explosives, although the overall volume of production remained high. Environmental issues associated with munitions disposal are therefore potentially significant in Iraq.

The environmental performance of Iraqi industry pre-2003 is poorly documented and many records were lost from 2003 onwards. In general, however, the environmental performance of industry in Iraq can be classed as poor in line with typical international standards from the 1960s to the early 1980s, when most of the plants were constructed.

Discharges to air, water and soil were and are largely uncontrolled, with the exception of major plants discharging chemical effluents to the rivers. In such cases, modern (1970s – 1990s) water treatment plants were installed and their effectiveness monitored.

Industrial effluent from the alum plant at Al Mishraq

3.6 Hazardous waste background

The issues of hazardous waste management and contaminated land are commonly linked in two ways:

Hazardous waste dump on site at Al Qadissiya plating works

- Poor management of hazardous materials and wastes, e.g. by the dumping of wastes on site, is a common cause of land contamination;
- Remediation of contaminated land commonly results in the generation of hazardous wastes, which then require proper management including an appropriate treatment or disposal route.

In the case of Iraq, a third link is apparent. Previously sound sites have been extensively damaged by looting and, in the process, the chemicals previously stored on site have been dumped on site, thereby creating hazardous waste and initiating land contamination.

From the evidence available, it appears that hazardous waste management in Iraqi industry was particularly poor, with many industries disposing of waste on site in an uncontrolled manner. The predominance of large, state-owned industries and military priorities meant that external accountability for waste management was limited. In the Al Qaa Qaa explosives manufacturing site, for example, flammable wastes were burned in the open, non-flammable wastes were dumped on site and liquid wastes were dumped into large unlined evaporation ponds.

With respect to hazardous waste treatment and disposal, at present there is no national or regional facility. The most common solution for major facilities such as refineries, mines or factory complexes is unlined pits located on site.

Municipal waste management included the use of local and regional landfills: essentially uncontrolled dump sites. In some cases, hazardous wastes from industry were also disposed at such sites.

Aid initiatives since 2003 have commenced the upgrade of Iraq's waste management facilities to modern standards. A modern municipal landfill has been constructed on the south-western outskirts of Baghdad and a second facility is under construction in the north of Baghdad[4].

As of June 2005, however, based on public domain information, there are no firm plans for the construction of facilities for the treatment and disposal of hazardous waste, although the World Bank has produced proposals on this topic [27,28]. The lack of an appropriate central waste facility in Iraq is a serious constraint on the management of contaminated land and hazardous waste.

3.7 Conflict damage to Iraqi industry

Military targeting of industrial sites typically produces severe, localised chemical contamination, while the associated secondary explosions, chemical releases and fires can result in high levels of air pollution in the short term. Given the recent history of Iraq, conflict-related chemical contamination is potentially a significant issue.

In the 1991 Gulf War, key infrastructure and industrial sites were targeted by coalition air strikes. Important targets included the arms industry, power generation, oil refineries and export pumping stations[29]. Damage to the heavily bombed military industrial targets, such as the weapons research establishments, was often severe and irreparable, whilst facilities such as power stations and refineries were less severely damaged and commonly re-started in a reduced capacity after the war. It should be noted that, in many cases, the sites destroyed were abandoned and not cleaned up and so represent a contaminated site legacy of their own.

Conflict damage to the Al Qadissiya plating works

Uncontrolled demolition of Al Qadissiya

In the 2003 conflict, general industry was not targeted by Allied forces and so suffered little direct damage. In particular, oil industry sites were spared from bombardment and remained effectively intact early in the conflict.

Some industrial sites, particularly those south of Baghdad, were the scene of intensive ground force fighting, and so suffered collateral damage from air strikes, artillery, tank fire and small arms.

Industries associated with arms production and, in particular, sites potentially linked to the research, production or storage of weapons of mass destruction were deliberately targeted by Allied forces air strikes, mainly over the period 1998 to 2003.

3.8 The current state of Iraqi industry and industrial sites

The state of industry in Iraq from 2003 to the present is poorly documented and reliable statistics are extremely limited[30]. The general situation however has been gauged from anecdotal evidence, recent reports[31]and eyewitness reports from the MoEn teams and staff from the Ministry of Oil, Agricultural and ex-MIC (Ministry of Military Industrialisation).

In summary, Iraq's centrally controlled industrial and manufacturing economy has largely collapsed, with the sole exception of the oil industry. The short-term economic and development priorities for Iraq have shifted towards oil exports and aid-funded general reconstruction and development, with humanitarian issues having overall priority. General manufacturing and non-oil mineral extraction industries and associated employment have largely collapsed due a combination of shortages in raw materials, fuel, power, cash flow problems and the absence of a local market.

3

The decline of many industries has undoubtedly resulted in improvements in local environmental conditions. The widespread closure of industrial plants has resulted in a large-scale reduction in the ongoing pollution load to air, water and soil. The generation of process-based wastes has largely ceased, although in many cases, residual material may remain in the plant or its surroundings.

The physical state of industrial plants in general throughout Iraq depends on whether the management and workforce have managed to maintain security on site to prevent looting from March 2003 onwards. In the great majority of cases, this has not been possible and the sites have been looted in varying degrees by individuals and organised criminal elements.

In the most extreme cases, buildings were completely gutted of all equipment, goods and fittings, and much of what was left was smashed or burned. Sustained looting on some sites included the excavation and removal of underground cables and the demolition of buildings with heavy equipment to extract scrap metal. The majority of such sites remain unsecured, with open public access.

Excavations made to remove power cables for scrap

The damage sustained to the industrial sites from looting cannot be underestimated. Several examples known to UNEP illustrate the scale and severity of the issue and the resulting damage to the environment and human health.

In the case of the Al Mishraq sulphur complex, it caused a catastrophic sulphur fire resulting in the destruction of a 300,000 m^3 stockpile, regional air pollution, crop destruction and several deaths[32].

The Al Qadissiya small arms manufacturing site was looted and burned, resulting in the open air dumping of several tonnes of pure cyanide salts. The looting of the Al Suwaira pesticides warehouse resulted in the theft (and assumed uncontrolled use) of over 70 tonnes of obsolete pesticides.

Looting of the Tuwaitha nuclear research facility resulted in the theft of hundreds of drums containing radioactive uranium oxide[33]. Recovery programmes initiated by US military, Greenpeace and others found that some containers were being used for domestic water storage. Theft of radioactive steel parts (parts from the former nuclear reactors) from the site resulted in uncontrolled distribution of radioactive material.

Looters stripping metals from chemical reaction vessels

Anecdotal evidence suggests that the environmental damage caused by post-conflict looting throughout Iraq has apparently exceeded the damage caused by direct conflict in 2003. The looting of industrial sites presents a major risk to human health in itself, and this risk remains uncontrolled. As an example, photographs taken by ex-MIC staff at the Al Qadissiya site in mid 2003 show barehanded looters handling machinery containing concentrated cyanide salts, a potentially lethal activity.

3.9 Future use of industrial sites

Sites contaminated with chemicals and wastes present a risk to the environment and human health until they are contained and cleaned up. However, the extent of the risk depends largely upon the state of the site, its surroundings and its future use.

In the cases of facilities that recommence operations, site security will normally restrict access and so reduce the risk to the general public. The focus on operating sites is normally on site worker risks and management of process effluents.

For derelict or abandoned sites, the key issues are the site setting and the likely future land use, if any. For example, a derelict site in a sparsely inhabited desert region presents a lower risk to human health compared with an equivalent site in an urban area next to a school and under consideration for housing redevelopment.

Given the current level of instability and rates of change in Iraq, it is premature to draw conclusions about the likely development strategy for Iraq and the implications for industrial sites. However, the recent histories of other countries that have experienced rapid economic decline and reconstruction may provide an indication of the likely overall direction for Iraq and the implications for development.

For a range of reasons, it is considered highly unlikely that Iraq will return to its previous industrial policy. The previous, large-scale domestic arms industry has been formally shut down and is not expected to restart. Many other uneconomic industries will also probably not re-start. Mineral extraction industries may recover partially, if at all. The oil industry will probably be rebuilt and then exceed its historical limits with a focus (at least in the short term) on crude oil export and refining for the domestic market.

The trend towards urbanisation is expected to continue. Former agricultural areas may be rehabilitated and agricultural practices may be modernised, but water constraints will limit major expansions in cultivated areas.

The implications for the fate of industrial sites throughout Iraq are as follows:

- All of the military industrial sites and many of the mining and general industrial sites will remain closed and in a derelict state. In contrast, the oil industry will continue to secure and use its sites although, in the long term, rationalisation of assets may make some sites redundant.

- Derelict sites throughout Iraq are likely to remain largely unsecured with open public access to hazardous areas and materials. Ongoing looting will continue to degrade the condition of the sites and create new hazards.

- Land use pressure near urban centres means that some of the derelict sites will be redeveloped into other uses, principally housing, commercial and light industry.

- New industrial sites dealing with the aftermath of conflict (e.g. scrap yards) and the growth industries (oil) may emerge.

4

ESA capacity building activities

4.1 Introduction

The objectives of the Environmental Site Assessment (ESA) project included building the capacity of local partners to enable them to conduct and continue the work initiated by UNEP. This chapter describes the capacity building activities completed to date.

The capacity building activities provided by UNEP to the Ministry of the Environment (MoEn) for the entire environmental governance programme covered a range of topics, including:

- Multi-lateral environmental agreements;
- Environmental impact assessment;
- Natural resources and biodiversity restoration and management;
- Information management and reporting;
- Integrated disaster managements and emergency response;
- Environmental enforcement and site inspections;
- Depleted uranium;
- Environmental policy and law;
- Environmental site assessment (ESA);
- Remote sensing data interpretation (for the Iraqi Marshlands project).

This report covers only the ESA activities. Details of the other topics can be obtained online at http://unep-iraq.org

The objectives of the ESA capacity building programme were twofold:

a) Enable the priority site assessment work to be done in 2004 – 2005 by providing the MoEn teams with all of the specialist training, equipment and services needed to investigate the sites;

b) Build institutional knowledge and capacity within the MoEn for the very much larger programme of site assessment, remediation and improvements in hazardous waste management that is foreseen for Iraq as part of its overall development.

The scope of the capacity building included training and the provision of specialised equipment and other tools.

4.2 Training

The provision of training to the Iraqi Ministry of the Environment and other government staff was one of the largest components of the assessment project. The training covered theory, planning, methods and tools and focused on the specialist skills required for site assessment together with an intro-

Equipment demonstration at a training workshop

Field exercises with water analysis instruments in Spiez

duction to the broader subjects of contaminated land and hazardous waste management.

The training was provided as a series of technical workshops, which brought together international experts and Iraqi delegates under the umbrella of UN management.

The workshops were designed to follow the normal sequence of site assessment activities. This was done to enable the Iraqi MoEn teams to absorb and apply the learning from each workshop in actual site assessment work as the programme progresses. Progress on each site and proposed future actions were discussed at each successive workshop.

Training workshop attendees and project participants were selected by the MoEn. For security reasons, the workshops were held outside Iraq; in Amman, Jordan and Spiez, Switzerland. The training workshops were:

1. **Environmental site assessment workshop** – A broad introduction and detailed training in the first stages of site assessment. Held 4 -7 October 2004, in Amman, Jordan.

2. **Environmental assessment planning workshop** – An introduction to the planning and management of site assessment projects. Held 21 -22 November 2004, in Amman, Jordan.

3. **Environmental sampling workshop** – Detailed hands-on skills training in site assessment equipment and techniques. Held 12 -14 December 2004, in Spiez, Switzerland (at Spiez Laboratory, the Swiss civil protection facility).

4. **Field sampling preparation**. A meeting that drew on learning from earlier workshops to develop detailed plans for each site. Held 16 -17 March 2005, in Amman, Jordan.

5. **Interpretation, risk assessment and remediation**. – A detailed review of the field and laboratory results obtained, combined with training on data interpretation, reporting, risk assessment, remediation and hazardous waste management. Held 22-24 August 2005 in Amman, Jordan.

Laboratory analysis training in Spiez

4.3 Equipment

The specialised equipment required to investigate contaminated sites adequately and safely was provided to the MoEn teams in parallel with the training workshops. A total of approximately US$ 250,000 was spent on a wide range of equipment from the following categories:

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- Health and safety equipment;
- Computers, cameras and navigation equipment;
- Soil, water, gas and dust sampling and monitoring equipment;
- Laboratory sampling and analysis consumables;
- Portable chemical testing kits.

The detailed list is set out in the Annexes of this report.

Where possible, the equipment was selected for long-term use as well as for the immediate project. Selection criteria included durability, portability and suitability for the operating environment of Iraq.

Personal protective equipment (PPE) was provided to each workshop participant in each session to use and take back to Iraq. The field training exercises provided a forum to demonstrate the importance of PPE and its correct use.

Virtually all of the equipment provided was put to immediate use. As an example, nearly all of the photographs presented in this report were taken by MoEn staff using the cameras provided.

The MoEn teams reported back that the majority of the equipment provided performed well. Some of the more sophisticated chemical and toxicological testing kits proved vulnerable to error due to the ground conditions, which included highly saline or acidic surface waters.

4.4 Information technology and document-based tools

UNEP has developed and delivered three major IT and document-based items to assist the project and the ongoing management of the Iraq contaminated land portfolio:

- A project website;
- ESA templates and guides;
- A contaminated site database.

The Iraq project website, located at http://unep-iraq.org, contains an online directory of key information generated in the course of the project, such as workshop proceedings and site information. It has different levels of access in addition to the public area, to allow all those involved in the project to share information.

ESA templates and guides were provided by UNEP to the MoEn, either as-is or specifically modified to match the Iraqi circumstances. These are pro forma guides to assist in the tasks of site reconnaissance such as taking photographs, interviewing, and describing samples. Wherever practical, technical documents are being supplied in Arabic as well as English.

UNEP provided a contaminated land database template to assist the Iraqi MoEn in collating and managing information concerning the estimated several thousand contaminated sites in Iraq. The programme runs on a standard PC using Microsoft Access™. The database is designed for the collation, tracking and screening of contaminated sites using a basic risk ranking process. Existing information about the five priority sites has already been added to the database by UNEP staff. Once new site data is added by the MoEn the database can be used to prioritise issues, map hazards and screen sites for redevelopment.

4.5 Lessons learned from capacity building

The capacity building activities for the ESA project were completed in August 2005. Feedback from the training attendees was generally very positive and the skills they acquired have been put to immediate use in the assessment of the priority sites.

The overall strategy of capacity building followed by remote management to enable the ESA work to progress without international access to the sites was considered successful, but it has some limitations, specifically:

- Risks to MoEn personnel in the field remain significant;
- The effectiveness of training was constrained by the absence of significant true work-based field training (i.e. learning by working with experts);
- Training Iraq staff outside Iraq resulted in high travel and accommodation costs and limited the potential number of participants.

These limitations and costs mean that the remote method of capacity building should not be preferred over a more standard in-country arrangement, should this be possible.

5 Site identification and screening

5.1 Introduction

The UNEP strategy proposed for the management of Iraq's contaminated sites is to prioritise efforts in relation to the likely real risks to human health and the environment. This strategy was implemented from the outset for site identification and screening.

Anecdotal evidence indicates that contamination of industrial land and associated hazardous waste issues are widespread in Iraq. The background of conflict in Iraq since 1980 has also contributed to the environmental problems. As Iraq is a relatively industrialised country, with tens of thousands of industrial sites, at this early stage the issue is considered too large and costly to address in a uniform manner, i.e. by assessing and cleaning up each and every site.

International experience indicates that whilst a large percentage of industrial sites may have ground contamination or problems with hazardous waste management, only a very small fraction represent such an immediate and grave threat to human health or the environment that urgent action is warranted. To be most effective, efforts in Iraq should be focused on first identifying and addressing these most urgent cases.

The risks associated with contaminated sites can vary dramatically according to a range of factors[34] including:

- The chemical form and toxicological nature of the contamination and hazardous waste;
- The volumes and areas involved;
- The current use of the site and the extent of control over access to the chemicals of concern;
- The location and vulnerability of the people and environmentally important features surrounding the site.

UNEP used three methods to identify priority sites for screening:

Preliminary fact finding and onsite screening visits were conducted by UNEP in collaboration with Environmental Protection and Improvement Directorate in July – August 2003.

1. In 2004 MoEn officials identified a further range of sites that they considered to be of concern;
2. In 2004 UNEP reviewed available public information related to industry and conflict in Iraq to identify and screen sites that fulfilled one or more of the following criteria:
   a. Likely to contain significant quantities of the more toxic chemicals;
   b. Currently not fully under control of the authorities, thereby potentially allowing public access to these chemicals;
   c. Located in urban or agricultural areas or close to major watercourses;
   d. Linked to conflicts in some manner.

Iraq is unique in that its industrial sites have been under some form of international monitoring and assessment since 1991, for military reasons. The 15-year search for weapons of mass destruction (WMD) covered potential chemical, biological and nuclear weapons research and manufacturing programmes across Iraq. Due to the importance of the issue to the international community, investigations specifically for WMD have been relatively intensive.

The UN Special Commission (UNSCOM)[35] inspected hundred of military and industrial sites over the period 1994 to 1998 and the UN Monitoring, Verification and Inspection Commission (UNMOVIC)[36] inspected many of the same sites over the period 2001 to 2002. US forces carried out an equally intensive inspection programme[37] in 2003 and 2004. All parties used remote sensing and other desk study work in addition to physical inspections.

Much of this work has been released to the public and is widely available on the worldwide web. The result is that a great deal of information is available about industrial sites, which UNEP has used as part of the site identification and screening process.

5.2 Priority industries and activities

Based upon the initial research, UNEP's 2003 field visits and the input of the MoEn, the following industries were shortlisted for closer review and discussion:

- Conventional arms industry;
- Oil;
- Mining;
- Chemicals;
- Agriculture/pesticides;
- Steel;
- Cement.

Table 5.1 Important industrial and post-conflict sites in Iraq

Arms industry
A total of 38 major sites, including: a) explosives and propellant chemical manufacturing and, b) small arms and munitions manufacturing - Refer to Table 5.2. One site (Al Qadissiya) is assessed in this project.
Oil production and export
Northern and southern oilfields (15 in total), Export and trunk pipelines: Iraq-Turkey, Iraq-Syria, Strategic (reversible north-south), Saudi.
Oil refining
Major refineries and processing plants: Al Doura, Bayji, Basra. Minor refineries/facilities: Nasiriyah, Ammarah. Khan Dhari refining chemicals warehouse complex (assessed in this project).
Mining
Al Mishraq sulphur mining and acid production complex (assessed in this project). Akashat phosphate and uranium mine.
Chemicals (excluding arms related industries)
Basra - Khur Al Zubair: petrochemicals, ethylene. Al Furat - Musayab plant: chlorine, acids, caustic soda. Basra: ammonia-urea natural gas plant. Al Qaim: phosphate complex. Fallujah III: castor oil, fertiliser and pesticide manufacturing complex. Al Suwaira: pesticides warehouse (assessed in this project).
Steel industry
Khor al Zubair: iron and steelworks.
Cement
16 cement plants across Iraq.
Conflict related issues, activities and incidents
Military scrap metal industry: One major site confirmed - Ouireej (assessed in this project), plus 2-4 other large sites expected plus hundreds of small ad hoc sites. Munitions disposal: Six major sites confirmed (no names or precise locations to date), plus hundreds of small ad hoc sites. Oilfire trenches around Baghdad and Kuwait border.

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Table 5.2 List of military industry manufacturing sites in Iraq

No	MIC Site Name	Governorate / Location	Type of Pollutants
1	Al Qadissiya	Baghdad / Al Youssifia	Chromium and cyanide
2	Hatten	Babel / Al Askandria	Liquid wastes: include heavy metals such as Cr, Ni, Fe, cyanide and other heavy metal wastes
3	Al Qaqa'a	Babel / Latiffia	Acid wastes such as nitric acid, sulphuric acid, nitro glycerine, nitro-cellulose
4	Al Rasheed	Babel / Latiffia	Ammonium perchlorate aluminum powder
5	Tariq	Baghdad / Tigris Branch	Wastes of chlorine gases and liquid
6	Al Muthana	Salah AL Deen	Phosphorous compound, cyanide, halogens *Note: - site landfill existed nearby Al-Muthana*
7	Al Yarmouk	Baghdad / Abu Ghraib	Heavy metals such as Cu, Zn, Cr, cyanide, oil, concentrated acids and alkaline
8	-7 - Nissan	Baghdad / Nahrawan	Wastes of electroplating such as Cr, CN
9	Thaat Al Sawary	Baghdad / Al Ameria District	Liquid chemical wastes
10	Al Awsema Wa AL - Anwat factory	Baghdad / Hay Al Amil District	Chromium, cyanide, and concentrated acids wastes
11	Ibn Seena	Baghdad / Tarmiya	Organic and inorganic substances
12	Al Nu'man	Baghdad / Al Rasheed Camp Road	Electroplating wastes such as CN, Cr
13	Thu-Al Fiqar Factory	Baghdad - Taji	CN, Cr
14	Al Zahef Al Kabeer	Baghdad - Taji	No data
15	Al Salam	Baghdad - Taji	Heavy metals such as Fe, Pb, acids and organic solvents
16	Al Mansour	Baghdad - Kadhmiya District	No data
17	Al Atheer	Babel - Al Mussayab	No data
18	Al Hakam	Babel - Al Mussayab	No data
19	Al Rimah Factory	Mossul	No data
20	Jaber Bin Hayyan	Mossul / Badoush	Rubber and synthetic polymers
21	Al Somod Factory Al Krama	Baghdad / Abu Ghraib	Liquid fuel wastes
22	Al Ikha'a	Anbar - Falluja	Chromium, cyanide, and concentrated acids waste
23	Bader	Baghdad / Youssefia	Heavy metals wastes
24	Nasser	Baghdad / Taji	Heavy metals wastes
25	Al Harith	Baghdad / Tarmiya	Heavy metals, wastes and missiles scraps
26	Al Nida'a	Baghdad / Za'afaraniya	Heavy metals wastes
27	Al Fida'a	Baghdad / Saydiya District	Heavy metals wastes
28	Al Uboor	Baghdad / Khan Dhari	Heavy metals wastes
29	Um-Alma'arek	Baghdad / Youssefia	Heavy metals wastes
30	Al Eiz	Baghdad / Taji	Scrapped electronic parts
31	Al Zawra'a	Baghdad / Za'afaraniya District	Damaged electrical parts
32	Al Radwan	Baghdad / Khan Dhari	Heavy metals wastes
33	Ibn Al Waleed	Baghdad / Abu Ghraib	Heavy metals wastes
34	Al Nasir Al Adheem	Baghdad / Near Al Dorha Refinery	Heavy metals wastes and welding wastes
35	Al Tahadi	Baghdad / Al-Ubaidy District	Metals wastes
36	Al Faw	Baghdad / Taji	Construction tools
37	Al Amer	Anbar / Falluja	Metals wastes
38	Hamoraby factory	Babel – Al Hella	Metals wastes

In addition, conflict-related issues, activities and incidents were also considered for review and discussion.

The above list covers the majority of the larger sites in Iraq, but it is not a complete list of the potential sources of contamination. Important exclusions include the non-conventional arms industry (including WMD), power generation, general light industry/ manufacturing, printing, tanneries, construction and pharmaceuticals. In total, several thousand industrial or conflict-related sites are expected to be significantly contaminated and/or have ongoing hazardous waste problems.

Based upon the shortlist the most important industrial sites and conflict-related issues related to land contamination and hazardous waste are listed in Tables 5.1 and 5.2 and discussed on the following pages. Note that the extensive information on the military industry sites as presented in Table 5.2 was obtained with the help of ex-MIC engineers, who recalled the list from memory.

➤ Figure 5.1 Al Qa Qaa munitions manufacturing complex

Quickbird, 7 September 2004 Image courtesy of Digital Globe, 2005

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Explosives and propellant manufacturing sites.

Explosives and propellants are composed of a wide variety of often toxic and corrosive chemicals. Important components include nitrated aromatic hydrocarbons, acids, mercury and lead salts and powdered metals. The manufacturing processes use strong acids, organic solvents and large volumes of water.

Iraq had a large scale domestic explosives industry[38], with the bulk of production destined for munitions. The most important site was the Al Qaa Qaa complex south of Baghdad. This large complex (approximately 20 km^2) included several production lines for explosives, missile propellants and fuses, together with large research and storage facilities.

Informal site inspections in 2004 by ex-MIC engineers found the site to be bomb damaged, derelict and comprehensively looted. Liquid waste ponds and hazardous solid wastes such as failed explosive batches and intermediate chemicals remain unattended and open to public access.

Small arms and munitions manufacturing sites

Small arms manufacturing principally entails metalworking, with an emphasis on parts machining, casting and a range of metal treatments such as annealing, case hardening and electroplating. These treatment processes utilise solvents, concentrated cyanides, acids, caustics and chromium compounds in addition to the normal range of ferrous and non-ferrous metals.

Iraq had a large scale conventional munitions industry[38], producing small arms, artillery, rockets and bombs. Informal inspections of several sites in 2004 by ex-MIC engineers indicated that the sites were derelict and comprehensively looted. Liquid and solid waste wastes including mounds of pure cyanide compounds remain on site and open to public access. One of the sites, Al Qadissiya, was selected for priority assessment as part of this project.

Oil production and export

Oil and gas extraction and export (via pipeline and tankers) is the largest industry in Iraq and is also expected to be the greatest single source of contaminated land and hazardous wastes. Contamination and waste issues associated with oil extraction and export include drilling chemicals, drilling wastes, oily sediments and oil spills. Major oil facilities in Iraq are presented in Figure 3.4.

The principal issue for Iraq in 2005 is considered to be oil spills from pipelines caused by sabotage. The country has a network of approximately 6,900 km of aging trunk and local pipelines[39], crossing both north to south and east to west. The majority of the flow is north to south, from the major oilfields to the marine export terminals, with lesser allocations to domestic refining and export to the north.

The pipelines have been under attack since mid 2003, and attacks and breakages are currently occurring almost on a daily basis[40,41]. The principal form of attack is by explosives. In some cases, looters have drilled into the pipeline to tap the flow. The result is large-volume oil releases, often accompanied by fire.

Cumulative oil losses are thought to be in the order of hundreds of thousands of barrels. Much of this has been burned, while the remainder has soaked into the ground or evaporated. To date no there have been no reports of major oil spills to water, although numerous small spills and leaks have occurred.

As much of the oil remains on and in the ground in the areas surrounding a leak or breakage, each such incident effectively creates a new contaminated site. In the period between March 2003 and June 2005 there were 244 reported attacks on oil pipelines[40], so the problem is now significant.

Oil refining

Hazardous waste and land contamination issues for this sector include the production of oily, solid and acidic wastes and releases of raw, intermediate and finished products through incidents and leaks from process and storage facilities.

The refining sector in Iraq is relatively small, to the extent that it is failing to supply enough petroleum products (petrol, fuel oil etc) for local demand. There are three medium sized refineries and numerous smaller facilities. Refinery chemicals are imported.

Decades of under-investment have left the sector in relatively poor condition, however the facilities were not targeted in the 2003 conflict. Since the conflict the major facilities have been heavily defended and secured. In addition, a major rehabilitation and modernisation programme is underway to increase production at many sites[22].

While there may be a legacy of land contamination and hazardous waste from prior operations, the sector does not suffer so much from the dereliction problem faced by the rest of the heavy industries. Any existing problems are expected to be at least partly contained by site management. In addition, the improved financial health of the refining sector in particular indicates that the future prospects for improved environmental management practices are relatively good.

In summary, although the refining and petrochemical sector is expected to be an important source of hazardous waste and land contamination, for a range of operational reasons it is not considered a priority for urgent assessment and corrective action.

An important exception to this overview is the Al Doura refinery chemicals store, which is located in Khan Dhari, west of Baghdad. This site was unsecured in early 2003 and suffered major damage due to looting and a fire. It is one of the sites selected for priority assessment.

Mining industry

The mining sector in Iraq was completely state owned and is dominated by two large complexes; Akashat/Al Qaim and Al Mishraq[42], both of which are currently shut down due to looting, lack of spare parts, power, security and other problems.

The Akashat phosphate and uranium mine in western Iraq supplied the Al Qaim super phosphate plant (see on the next page).

The Al Mishraq sulphur mine and associated chemical works supplied raw sulphur, sulphuric acid and alum (aluminium sulphate). The mining operations commenced in the 1970s and by 1983 had reportedly resulted in pollution of the River Tigris. An incident at the site (looting or sabotage) in June 2003 caused a catastrophic sulphur fire. For these reasons it was selected for priority assessment in this project.

Limestone deposits are mined throughout Iraq for cement production, with the principal environmental issues linked to the cement plants rather than the mines (see on the next page).

The future prospects of the mining industry are mixed, with large-scale investment required in the long term to rebuild and re-start facilities. In the short to medium term, many sites are expected to remain idle and derelict. As a result, the overall pollution load from the mining industry is anticipated to be much lower in future than prior to 2003, but the sites themselves remain in a hazardous state.

5

Chemicals industry

The Iraqi chemical industry is based on simple post-processing of either hydrocarbons or locally mined minerals. The most important products are chlorine, alum, acids and fertilisers[14]. Since 2003, many sites have been looted and remain derelict.

Chemicals manufacturing sites can give rise to a wide range of land contamination and hazardous waste issues. Numerous sites in the Iraqi chemical industry have been previously recognised as major local environmental problems. In addition, conflict damage and post-conflict looting have created additional hazards. Two important examples are Al Qaim and Fallujah III.

- **Al Qaim phosphate plant.** In 1991, the uranium ore processing plant at Al Qaim was destroyed by bombing but the phosphate plant was rebuilt and in production until 2003[37]. When in operation, the effluent from Al Qaim reportedly caused widespread pollution of downstream water bodies. The site is reported to be currently idle and partly derelict.

- **Fallujah III**. Fallujah was part of a chemical weapons production complex that was largely destroyed by bombing in the 1991 Gulf War[37]. After 1991, Iraq rebuilt the facility for pesticide production and reformulation. The site was damaged by bombing again in 1998 and is now largely derelict. Significant quantities of pesticides and organic chemical wastes are expected to be present.

The future for the chemicals industry is uncertain. Strong demand is anticipated for petrochemicals and basic chemicals, but the current facilities are obsolete and uncompetitive. As a result, most of the current sites are expected to remain derelict.

Agricultural Sector – Pesticides

Al Suwaira. Al Suwaira is a pesticides warehouse complex which was looted in 2003 and was selected for priority assessment in this project.

Steel industry

Steel production can result in the generation of significant quantities of hazardous wastes including cyanides and caustic slurries. The steel industry in Iraq is focused on the Khor Al Zubair iron and steelworks near Basra. The site has been comprehensively looted and is largely derelict. Due to its un-competitiveness, the industry is unlikely to re-start on any scale.

Cement industry

Cement production is an important industry for Iraq[43] due to an abundance of limestone deposits and cheap fuel. In 2000, Iraq produced approximately 3.8 million tonnes per annum[44]. Due to a lack of spare parts and fuel, less than 10 of the 17 large plants were operating as of mid-2005 and production is less than 2 million tonnes per annum.

The principal environmental issue in cement plants is generally the cement furnace air emissions, followed by hazardous waste management for the dust collected in precipitators. This dust typically has a very high heavy metal content. Most sites disposed of such dusts either on-site or nearby in uncontrolled landfills.

Conflict-related issues, activities and incidents

Iraq has experienced continuous armed conflicts of varying levels of intensity since 1980. Important conflicts and related events and issues include:

- 1980 – 1987 Iran-Iraq war;
- 1991 Gulf War;
- Allied bombing campaign (1990s, strongest in 1998);
- UN sanctions and Iraq's economic decline;
- The 2003 invasion of Iraq;
- Post-conflict looting 2003 to 2005 (ongoing);
- Insurgency 2003 to 2005 (ongoing).

The cumulative effect on many sites and industries studied has been economic and physical degradation to the point of collapse. Most sites have escaped actual combat damage (bombing, shelling etc). The background of conflict and the resulting governance vacuum created has contributed significantly to the environmental problems described in this report.

In a few cases, however, conflict is at the core of the environmental issues identified. Four of the most significant conflict related problems are considered to be:

- Pipeline oil spills (previously discussed);
- Military scrap metal industry;
- Munitions disposal;
- Oil fire trenches.

Military scrap metal industry. Scrap metal export is currently one of the few thriving industries in Iraq. Looters and legitimate operators are together effectively demolishing many of the old industrial facilities in order to retrieve the metal contained in buildings, process and storage equipment and vehicles.

The scrap metal industry includes the recycling of the military hardware that Iraq built up from the 1970s onwards. This material ranges from combat damaged tanks and artillery pieces, missile engines and empty munitions to more routine equipment such as trucks and portable buildings.

Industrial scrap presents a range of chemical hazards and scrap yards are recognised world-wide as important sources of water pollution, land contamination and hazardous waste. Military scrap and scrap yards in Iraq present a number of additional hazards including:

- Explosion and fire risks from munitions;
- Unusual concentrations of toxic chemicals (e.g. each T72 tank contains up to 150 litres of pure polychlorinated biphenyls (PCBs);
- Asbestos (again from tanks and military vehicles);
- Depleted uranium (DU) fragments in destroyed tanks and vehicles.

One of the largest military scrap yards in Iraq is Ouireej, located 20km south of Baghdad. Ouireej was selected for priority site assessment in this project.

Munitions disposal. A vast amount of cached ordnance has been found by international forces since March 2003. Military sources estimate the total tonnage of ex-regime arms present in Iraq to be between 600,000 and 1 million tonnes[45]. A significant percentage contains explosives or propellants and requires proper and safe disposal. The most common method of disposal is controlled explosion or burning, either in place or at a dedicated site. There are no really safe and economically viable alternatives to this method, particularly for old and unstable munitions and the quantities found in Iraq.

5

Currently, the multi-national forces are stockpiling munitions as they are found and conducting a large scale disposal programme by controlled explosions. The target rate of destruction is 600 tonnes per day with an expected project duration of in excess of two years[45]. As of February 2005, the US Army and its contractors had destroyed 215,000 tonnes and had a stockpile of 92,000 tonnes in six main sites across Iraq. More munitions are being found daily.

The environmental aspects of munitions disposal arise mainly from the incomplete destruction of the chemical compounds such as TNT and the scattering of heavy metals. The 1991 Gulf War experience of Kuwait and Saudi Arabia was that the destruction sites became substantially contaminated. Due to the presence of unexploded ordnance, such areas are exceedingly dangerous and costly[46] to remediate.

Given the scale of the munitions problem in Iraq, large-scale contamination of the disposal sites is considered inevitable. Early action may however be able to limit the scale and severity of the damage and the related long-term risks to human health and the environment.

Oil fire trenches. Over 100 oil fire trenches were excavated, filled and set alight by Iraqi forces immediately prior to and during the 2003 conflict[5]. Most of the trenches were around Baghdad with others located near Basra and the Kuwait border. In urban areas, the trenches were mainly located in the median strip of major roads, close to strategic facilities. Whilst alight the trenches contributed to local air pollution. The dumping of oil into unlined trenches resulted in infiltration and contamination of the underlying soil. Following the conflict, many of the trenches remain open, collecting garbage and surface water and posing a risk to human health.

5.3 Sites selected for priority assessment

Site selection for priority assessment was led by the Ministry of the Environment (MoEn) with UNEP in an advisory role. An initial list of over 50 sites covering all of the above-listed sectors was developed by UNEP and presented to the MoEn for review and discussion. The UNEP-MoEn review covered issues such as the magnitude of the threat, internal resource constraints, suitability for capacity building work, site ownership and access, transport logistics and site security.

The final result was a list of five sites, each of which underwent a detailed assessment in the course of the project. The five sites are:

- **Al Qadissiya**. A destroyed small arms metal plating and annealing (metal treatment) works;
- **Al Suwaira**. A pesticides warehouse complex;
- **Khan Dhari**. A refinery chemicals warehouse;
- **Al Mishraq**. A sulphur mining and acid complex;
- **Ouireej**. A scrap yard containing conflict damaged military and civilian vehicles.

The approximate locations of the priority sites are highlighted in Figures 5.2 and 5.3. Each site is introduced in turn on page 52 and the assessment process and results are presented in the later part of this report. Factual reports on each site are also available online at http://unep-iraq.org.

➤ Figure 5.2 Priority assessment sites in Iraq

Figure 5.2 : Priority Assessment Sites in Iraq

- International boundary
- National capital
- Governorate capital
- Town, village
- Governorate boundary
- Express way
- Main road
- River
- Temporary drainage
- Water body

1. Al-Mishraq
2. Qadissiya
3. Khan Dhari
4. Al-Suwaira
5. Ouireej

Scale: 0 50 100 150 200 150 300 km; 0 50 100 150 200 mi

Source: UN Cartographic Section DPI, UN Habitat, HIC Iraq

5

Al Qadissiya. Al Qadissiya is a former small arms manufacturing site located 30 km south of Baghdad. It formerly contained extensive electroplating and metalworking plants. The site is unsecured, contains quantities of highly toxic chemicals and has been demolished in an uncontrolled manner, resulting in severe human and environmental hazards.

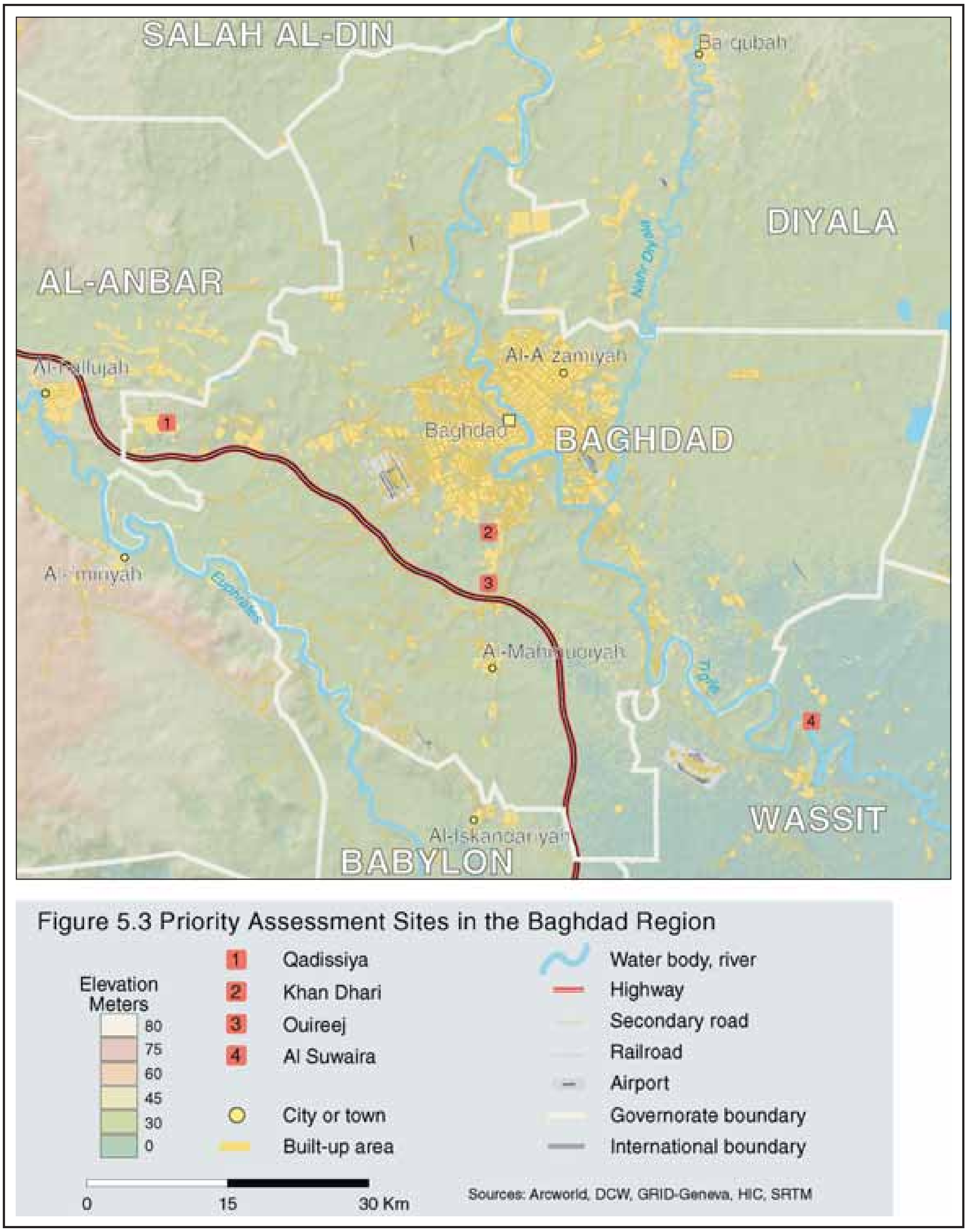
Al Suwaira. Al Suwaira is a warehouse complex located 50 km southeast of Baghdad where insecticides, pesticides and fungicides were stored by the Ministry of Agriculture. The stores held a large quantity of obsolete and highly toxic methyl mercury pesticides. The stores were comprehensively looted in 2003 with the loss and spillage of virtually all stored pesticides.

Khan Dhari. The chemical warehouses for the Al Doura Refinery are located in Khan Dhari district, near Abu Ghraib, 35 km west of Baghdad. This site is the Iraq central refinery chemicals warehouse facility, administered by the Midlands (Al-Doura) Refinery Company. The site was looted and burnt down in 2003 resulting in a major toxic chemicals spill and fire.

Al Mishraq. Al Mishraq is a large state-owned sulphur mine and acid manufacturing complex located 53 km south of the city of Mosul. In June 2003, looting caused a massive sulphur stockpile fire, causing regional scale damage to human health and crops. Thirty years of operation have also caused extensive local ground contamination, subsidence and erosion.

Ouireej. Ouireej is the location of a large stockyard 15 km south of Baghdad where civilian and military vehicles and equipment have been dumped and were being scrapped in an uncontrolled manner, resulting in localised contamination.

➤ Figure 5.3 Priority assessment sites in the Baghdad region



6

Site Assessment Activities

6.1 Introduction

The approach used to assess the priority sites was adapted from the environmental due diligence and audit processes commonly used worldwide for the assessment and transfer of industrial properties.

The objectives of the assessment were:

a) To assess the status and potential risks presented by land contamination and hazardous wastes for each priority site;

b) To provide preliminary recommendations, design solutions and cost estimates for the rectification of the problems identified.

The activities completed are listed and then described in sequence below.

Desk studies and mapping
- Research site and country history and setting;
- Research site-specific chemistry, processes and toxicology;
- Review and manipulation of remote sensing images data – satellite images.

Fieldwork
- Field reconnaissance and small scale mapping;
- Interviews with site staff (where available);
- Field sampling and monitoring.

Chemical analyses
- Portable analyses;
- Laboratory chemical analyses.

Interpretation
- Development of ground models (geology, hydrogeology, hydrology, receptors);
- Screening of analysis results against relevant standards;
- Qualitative risk assessment.

Development of recommendations
- Corrective action option assessment;
- Remedial action feasibility assessments;
- Outline costing of shortlisted options.

Reporting
- Factual reporting;
- Interpretative reporting (this report).

6.2 Desk studies and mapping

Desk-based research was carried out for all the priority sites. The scope of desk-based research for each site included:

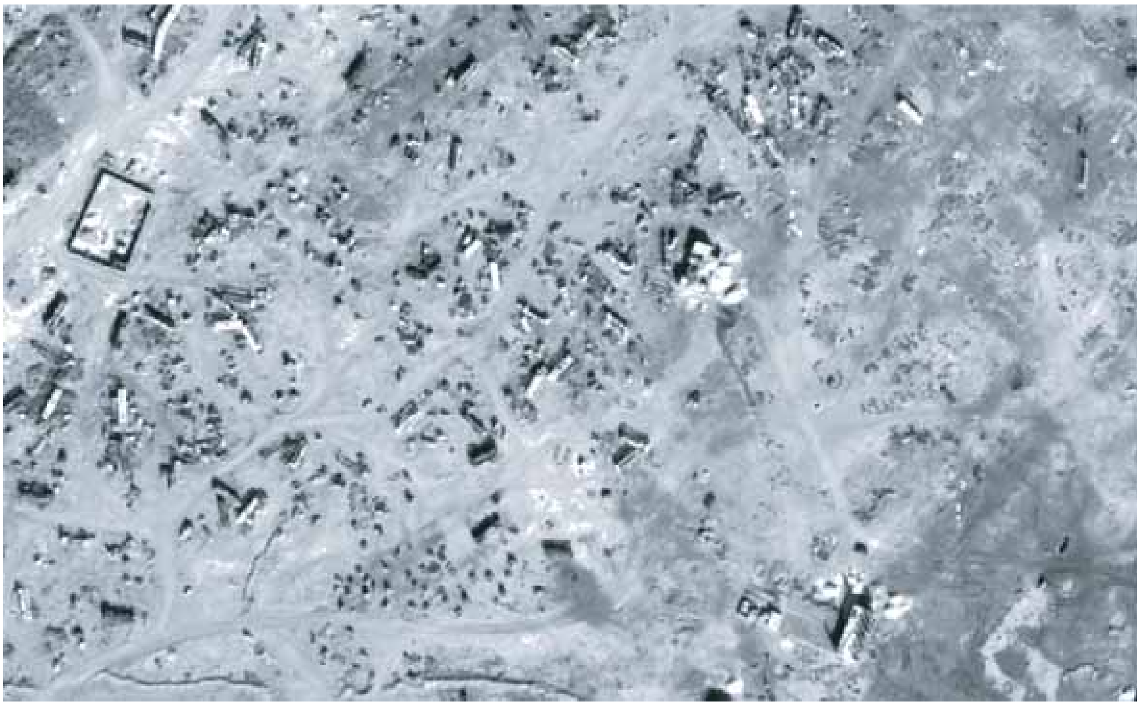
- Location, setting and neighbouring land use;
- History with a focus on 2003 to 2005;
- Facilities and processes;

- Chemicals and related toxicology;
- Soil conditions, geology, hydrology and hydrogeology.

The limited data available constrained the desk study work in a number of ways. Technical data on Iraqi sites is relatively scarce and much of what was originally generated either by the site management or the controlling Iraqi ministries has been lost or destroyed. Most of the sites were vacant at the time of inspection and so site staff were not available for interviewing. Ground truthing of satellite images was not always possible due to access constraints.

Remote sensing data was used extensively, both to compensate for the lack of detailed existing site plans and for interpretation. Quickbird Satellite Images with a 0.6m digital resolution were obtained for each site. These images are sufficiently detailed to allow identification of individual buildings and vehicles.

Figure 6.1 Individual vehicles at Ouireej scrap yard



Quickbird, 5 January 2005
Band combination: Panchromatic

Image courtesy of Digital Globe

6.3 Fieldwork

Initial fact finding visits were conducted by UNEP in summer 2003. Subsequently, fieldwork was conducted exclusively by the Iraqi ministry staff and led by the five Iraq Ministry of the Environment project teams. Staff were available to assist from the Ministries responsible for three of the sites; ex Ministry of Military Industrialisation (Al Qadissiya), Ministry of Agriculture (Al Suwaira) and Ministry of Oil (Khan Dhari).

Each of the priority sites was visited several times over the period May 2003 to May 2004. The fieldwork activities included:

- Field reconnaissance and mapping;
- Interviews with site staff (where available);
- Field sampling and monitoring.

Limited mapping of the facilities was conducted using high resolution Global Positioning System (GPS) units and the results were used to confirm the site locations on the satellite images.

Field sampling and monitoring was conducted using the equipment UNEP supplied which included hand augers (drilling kits) and groundwater bailers. The sampling programme for all of the sites is summarised in Table 6.1.

Table 6.1 Priority site environmental sampling

Site	Samples			
	Soil	Water	Waste / Chemicals	Total
Qadissiya	21	19	23	63
Al Suwaira	20	–	1	21
Khan Dhari	43	1	–	44
Al Mishraq	26	10	–	36
Ouireej	50	3	–	53
Total	123	40	28	217

Sampling a village well near Al Mishraq sulphur plant

Surface water monitoring and sampling of the Tigris in north Iraq

Sampling shallow soils at Ouireej scrapyard

The majority of the samples were from shallow soil and exposed chemical waste. Both standing surface water and groundwater from wells was sampled where existing and accessible. Samples were decanted into the specialised glass and plastic containers provided by UNEP, logged and packaged for export by air freight to the international laboratory.

Portable water monitoring probes were used to measure pH, temperature, dissolved oxygen and oxygen-reduction potential. Soil vapour was measured using Photo Ionisation Detector (PID) probes for the detection of volatile organic compounds such as solvents. Methane and carbon dioxide levels in soil were measured using a landfill gas detector.

6.4 Chemical analyses

Samples were exported via airfreight and analysed at three commercial analytical laboratories in the United Kingdom.

Alcontrol laboratory in Chester, United Kingdom, carried out the standard analyses and coordinated the specialist analyses. Alcontrol is accredited to the ISO 17025[47] standard for the testing and calibration laboratories and participates in the UKAS[48] and MCERTS[49] programme of certification as well as the AQUACHECK and CONTEST proficiency testing programmes. The list of standard analyses parameters and methods used by Alcontrol is set out in Table 6.2.

Table 6.2 Standard analysis parameters

Parameter	Laboratory analysis method and method detection limit for soil (mg/kg)
Arsenic, beryllium, cadmium, Chromium, copper, mercury, nickel, lead, antimony, selenium, silver, thallium, zinc	Induction coupled plasma Optical emission spectroscopy ICP-OES. Aqua regia digest (0.1 - 1.0)
Hexavalent chromuim	DIN 52368 (0.1)
Pesticides - organo chlorine and organo phosphorous	Gas chromatograph mass spectrometer
Volatile organic compounds (VOCs)	GC MS with NIST searchable library of compounds. Based on EPA 8620
Semi-volatile organic compounds (VOCs)	GC MS with NIST library. Based on EPA 8620
Extractable petroleum hydrocarbons-diesel range organics EPH -DRO	GC flame ionisation detector (GC FID) C10 - C30+. (1.0)
Petroleum range organics PRO	GC flame ionisation detector (GC FID) headspace C10 - C30+. (0.01)
Benzene, toluene, ethyl benzene, xylenes (BTEX) and MBTE	GC flame ionisation detector (GC FID) headspace (0.01)
Polyaromatic hydrocarbons (PAH) speciated	GC MS with NIST library (0.01)
Polychlorinated biphenyls (PCBs) 7 cogeners	GC MS with NIST library (0.001)
Calcium, magnesium, sodium	Flame photometer (4)
Sulphate- water-soluble	Spectrophotometric (0.003 mg/l)
Sulphide	Spectrophotometric (5)
Sulphur - elemental	Ion chromatography (50)
Acid-soluble carbonate	Acid treatment and gravimetric technique (10)
Chloride (soluble)	Spectrophotometric (5)
Free cyanide	Spectrophotometric (1)
Total cyanide	Acid treatment and spectrophotometric (2.5)
pH	pH meter
Asbestos	Visual analysis - miscroscopy

6

In some cases, the samples could not be analysed by Alcontrol and were subcontracted out to specialist facilities. For safety reasons, samples with potentially high concentrations of cyanide or organic mercury were unsuitable for the standard processes of quartering, grinding and acid digestion (for metals).

Hazardous samples were dispatched to London and Scandivanian Metallurgical Company Ltd for elemental analysis by X-Ray Fluorescence Spectroscopy (XRF) and X-Ray Diffraction (XRD).

Samples for organic mercury were dispatched to MountainHeath Services laboratory for specialised treatment and analysis.

The MountainHeath analysis entailed using a modified ICP (induction coupled plasma) technique to determine total mercury and a modified gas chromatograph mass spectrometer to determine organic mercury species.

The XRF and XRD analysis entailed use of XRF to determine elemental composition and, where appropriate, a follow up by XRD to attempt to determine the composition of important minerals. XRF and XRD provide results with percentage level accuracy and so are only suitable for samples with high concentrations of metals, metallic compounds and minerals[50]. Organic matter is not accurately analysed or differentiated.

6.5 Interpretation

The factual data provided by the desk studies, MoEn field work and laboratory analyses were interpreted by UNEP experts in liaison with the MoEn teams. The principal objective of the interpretation for each site was to determine whether current conditions on site represented a significant risk to human health or the environment.

The interpretation work for each site consisted of four activities:

- Development of a ground model;
- Preliminary screening;
- Qualitative risk assessment;
- Semi-quantitative risk assessment.

Development of a ground model. A ground model is a coherent picture of conditions on site, underground and in the surrounding area which can be used as a basis for further interpretation[51]. Ground model details can include site chemistry including the nature, concentration and distribution of contaminants, soil conditions, geology, hydrology, hydrogeology and local land uses.

Preliminary screening. Tables of screening values for chemical toxicity have been in use in Europe, north America, Australia, Japan and elsewhere since the 1980s. The tables are normally chemical and activity specific and provide values against which site-specific chemical data and analysis results can be initially checked for significance. If the site-specific values are higher than the screening values then the site normally warrants more detailed assessment.

Iraq has no such screening system so an appropriate substitute was needed. The systems used for this project were the current Australian (1999) [52,53] and Dutch (2000)[54] standards and accompanying guidance.

For the Australian system, the Health Investigation Limits A were used for soil screening and the Groundwater Investigation Limits (drinking water) were used for waters. These values represent the levels above which contamination is considered significant enough to warrant further investigation and assessment.

For the Dutch system, the soil remediation intervention values were used as terms of reference. These values represent the level above which significant contamination warranting corrective action is considered to be present.

These two systems are not precisely equivalent but combined, give a reasonable indication of the significance of the contamination according to international standards.

For interpretation of the significance, in factual reports the terms used normally refer strictly to a specific standard, e.g. the concentration in sample X exceeds Y standard. For this interpretative report for a general audience, more general terms are used as follows:

- **Uncontaminated** – Any contamination, if detected, is below the selected international standards;
- **Slightly contaminated** – Contamination is present, but in limited volumes and at concentrations limited to 1 – 10 times the selected international standards;
- **Moderately contaminated** – Contamination is present, in limited volumes and at concentrations of 1 – 100 times the selected international standards;
- **Heavily contaminated** – Contamination is present in large volumes and over large areas and at concentrations which can exceed 100 times the selected international standards.

Qualitative risk assessment. The use of risk-based methods to assess the significance of land contamination is effectively standard practice worldwide. There are a range of national systems and nomenclatures in use. For this project UNEP has adopted the RBCA (Risk-Based Corrective Action)[55] concepts and nomenclature.

RBCA is a flexible and technically robust framework for the assessment and management of risk to human health and the environment from contaminated land. It is based on a multi-tiered process, starting with limited data and basic qualitative risk assessment and progressing to fully quantitative risk assessment with associated high data demands and levels of complexity.

The data limitations for this project mean that only the first stage of RBCA, the Initial Site Assessment, can be applied, rather than the subsequent Tier 1 to Tier 3 assessments. Quantitative risk assessment other than RBCA is also clearly not possible due to data limitations.

The key principle of RBCA is the analysis of risk-based upon source-receptor-exposure pathways. An explanation of these terms follows.

Chemicals of concern. The specific compounds (or elements) that are identified for evaluation of risk. These are normally a subset of all of materials found on the site, as many of those found may not represent a risk or warrant further assessment.

Source areas. The locations of the highest concentrations of the chemicals of concern, or the location releasing the chemicals of concern.

Receptors. The persons that are, or may be, affected by a release of the chemical of concern.

Relevant ecological receptors and habitats. The ecological resources of value at the site. Note that, for risk assessment purposes, the site refers to the location where the chemicals are distributed, even if it extends beyond the property boundary to neighbouring land.

Exposure pathway. The course or route a chemical of concern takes from the source area to a receptor (human) or an ecological receptor or habitat. Note that there can be multiple exposure pathways between source areas and receptors.

Complete pathway. When all three factors (source, pathway, receptor) are aligned, a complete pathway is formed and a risk is present. In the absence of a complete pathway, the risk is also absent.

Risk summary. The risk that a receptor is actually exposed to land contamination is a function of the original source (the source area and chemicals of concern), the vulnerability of the receptor based on lifestyle and physiology (e.g. young infants are generally at higher risk due to their habit of eating dirt) and the exposure pathway between the source and receptor.

Chemical waste sources at Al Qadissiya

With sufficient data, the risk can be presented numerically as a probability of ill health, hazard quotients or additional cancer risk for specific receptors. At the Initial Assessment phase, the first goal is normally to determine whether complete pathways are present. However, for this report for a general audience the process is extended to provide preliminary assessments of overall risk levels of low, moderate and severe, defined as follows:

- **Low risk**. Elevated concentrations of toxins and complete but generally indirect exposure pathways indicate a real and measurable but generally low risk of injury, poisoning or other health damage from working in or entering the site or nominated areas of concern

- **Moderate risk.** High concentrations of toxins and complete exposure pathways indicate a moderate risk of injury, poisoning or other health damage from working in or entering the site or nominated areas of concern

- **Severe risk**. Very high concentrations of toxins and complete direct exposure pathways indicate a reasonable likelihood of injury, poisoning or other health damage from working in or entering the site or nominated areas of concern (e.g. inside nominated buildings) without specialised protection. There is the risk of acute (rapid) fatal poisoning.

People vulnerable to health risks from the source chemicals at Al Qadissiya

For this project the concept of RBCA and the above preliminary risk rating are also used to assess the significance of hazardous wastes present on the site.

Example of a direct pathway to exposure to toxins Children at the Ouireej scrapyard

6.6 Development of recommendations

Specific recommendations for short term and medium term corrective action have been developed for each of the five sites. General recommendations to cover broader and longer term issues are addressed in a separate chapter.

For the five sites assessed, the objectives behind the recommendations have been defined as:

1. Reduce any noted incidences of severe risk to human health and the environment to significant but acceptable levels;

2. Only if appropriate and cost effective, remediate the site sufficiently for it to be returned to its former use.

There is no Iraqi legislation or guidance material regarding acceptable levels of risk from hazardous waste or contaminated land. Existing formal standards from the UK[56], USA, Australia and the Netherlands were considered suitable as initial guidelines but are also considered to be generally too stringent and therefore too costly to be implemented in Iraq at present. International standards such as the WHO drinking water standards[57] are relevant mainly as end-user standards rather than directly applicable to contaminated land. Accordingly, recommendations are based largely on professional judgement and general guidance literature for remediation of contaminated sites[58].

The key concepts used in drafting recommendations were risk reduction, cost-benefit and suitability for Iraqi conditions. The development stages were:

- Wide-ranging identification and listing of potential corrective actions;
- Screening on grounds of cost and technical feasibility to select a preferred option;
- Conceptual design and outline costing of the preferred option.

Note that in many cases the recommended solutions are dependent in the long term on the development of a hazardous waste treatment and disposal facility in Iraq, an issue addressed separately in this report.

Removal of toxic waste is a straightforward method of reducing hazards from derelict sites – Al Qadissiya

6.7 Reporting

This document is the summary report for the project, available in hard copy and online at http://unep-iraq.org and also in electronic form from the MoEn central office in Baghdad. Further information, such as the detailed factual report for each of the five priority sites, is available online or from the MoEn.

7 Al Qadissiya results and recommendations

7.1 Site introduction

The Al Qadissiya military industrial site is located on the urban fringes of Baghdad, approximately 30 km south of the city centre. The site is approximately 50 hectares in

➤ Figure 7.1 Al Qadissiya site setting

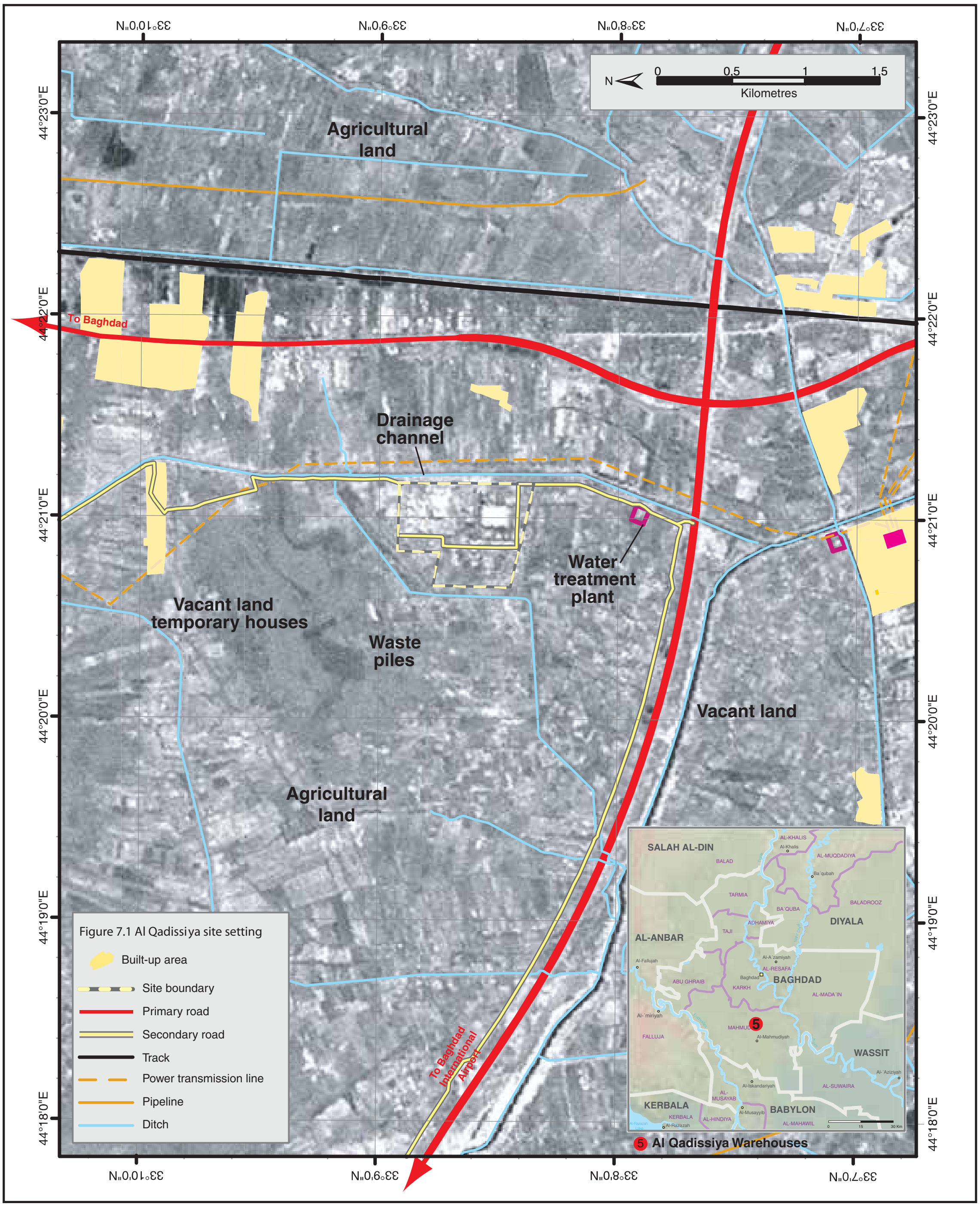
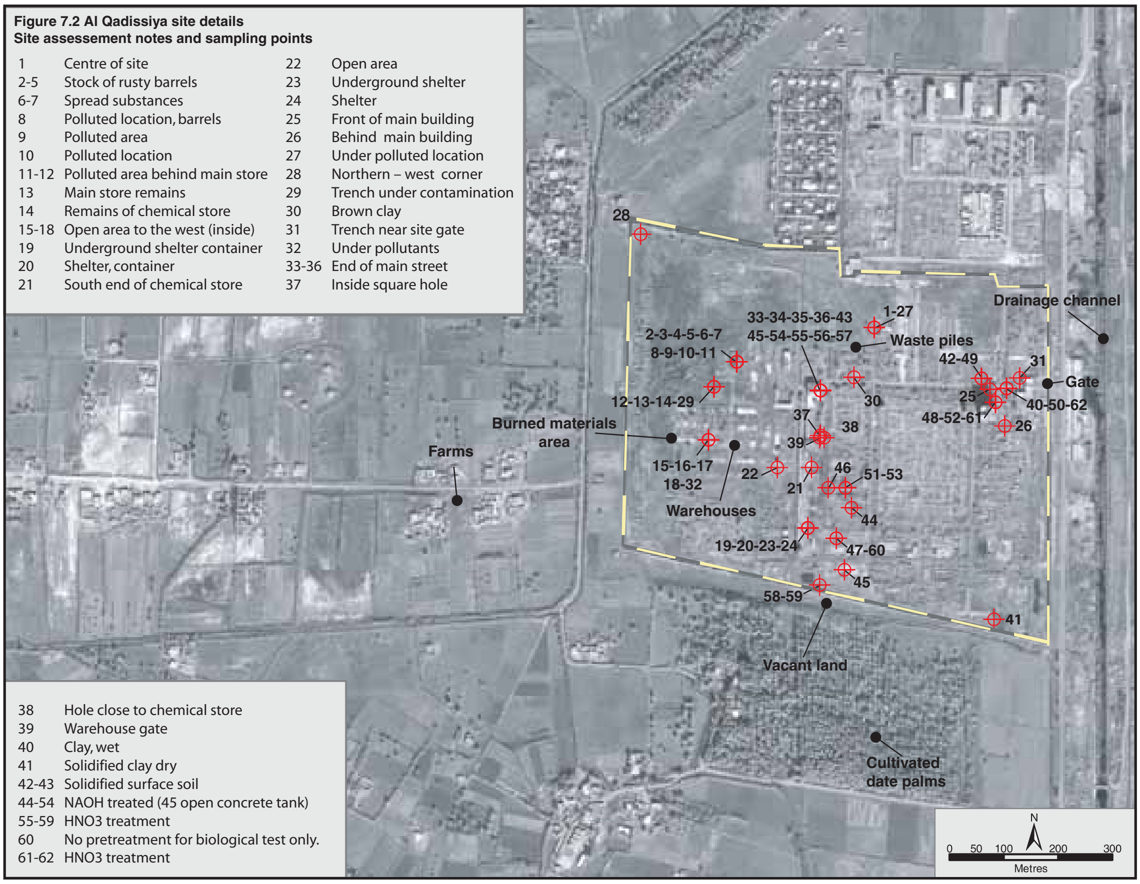


Figure 7.2 Al Qadissiya site detail



area and is located in the flat plain between the Tigris and Euphrates rivers. The surrounding land uses include agriculture, light industry and housing. Figure 7.1 shows the site location and surrounding land uses.

The site previously contained a complex of metal plating and machining units, all of which are completely or partially demolished. The major facilities on site included two plating units, a machining and maintenance workshop, chemical warehouses, an effluent treatment plant, administration buildings and waste disposal sites. Approximately half the site is unused land with sparse vegetation. Figure 7.2 shows the site layout, overlaid on a satellite image taken in January 2005.

Clayey sands underlie the site, with saline groundwater estimated to be at 3m depth. Surface drainage ditches encircle the site and drainage is expected to be the Euphrates River to the south. The site assessment team reported that the shallow ground water is saline and not used for drinking water supplies.

Site entrance at Al Qadissiya showing perched groundwater at 2 m depth

The site was constructed in the 1980s and operated continuously until March 2003. In the 2003 conflict it suffered some damage from ground force conflict and air strikes. Following the conflict it was comprehensively and repetitively looted.

Ex-Military Industrial Commission (MIC) engineers inspected the site in June 2004 and

Much of the site is vacant and used for grazing

found the site was effectively completely destroyed and that looters were continuing to strip metal from buildings and machinery for scrap. All buildings were damaged, missing windows, roofs, walls and fittings. Machinery was smashed and all portable equipment stolen. Furnaces and reaction vessels were destroyed but still had the batch chemicals inside. Stored chemicals were strewn across the site. Notable finds included large amounts of sodium cyanide in damaged drums.

Degraded 300 litre barrels full of sodium cyanide pellets

MoEn and ex-MIC staff returned to the site for a detailed assessment in October 2004. They found a demolition and scrap recovery contractor demolishing the site in an uncontrolled manner. Buildings were flattened and crushed. Tanks and reaction vessels were dismembered for scrap metal and all services including power cables and

Cyanide salt annealing vessel with solidified chemicals

The rear of the site contained a number of uncontrolled waste dumps. Accumulated wastes included used chemicals, chemical sludges, refractory wastes and rags for absorbing spent chemicals. In total, UNEP estimates that some 100 tonnes of chemical waste was scattered across the site.

Chemical wash tanks still containing spent liquor

Piles of hazardous waste litter the site

manholes covers were taken. The contractor had excavated over a hundred trenches in order to extract the power cables buried up to 1m underground. Figure 7.3 shows the demolition of the main process unit areas.

The site assessment team could not locate many areas where chemicals were noted previously, due to the destruction of buildings and the placement of piles of broken concrete. New piles and broad areas of chemical dumping were located where the demolition work had pushed or dumped them. The chemicals noted by drum labels and appearance included sodium cyanide, hexavalent chromium salts and sodium hydroxide. In total it is estimated that up to 5 tonnes of highly toxic chemicals were dumped onto open ground.

Site after uncontrolled demolition with chemicals dumped in place

Site after demolition showing destroyed chemical wash tank

The site assessment team interviewed the demolition contractor staff and found that none of the field crew had any knowledge of the hazardous materials that they were handling and inadvertently spreading across the site. Children from neighbouring residential areas were seen on the site.

At the time of the last site visit in May 2005, the site was reported to be still open to the public and had not significantly changed since the demolition.

➤ Figure 7.3 Al Qadissiya site demolition details

Quickbird, Date unknown

Image courtesy of Digital Globe, 2005

Quickbird, 5 January 2005
Band combination: Panchromatic

Image courtesy of Digital Globe

7

7.2 Chemicals and toxicology

The list of chemicals used at Al Qadissiya has been identified from ex-MIC staff interviews, photographs, laboratory analysis and research on the processes in use at the site [59, 60]. The four most important chemicals, compounds and materials noted are:

- Sodium cyanide;
- Sodium hydroxide;
- Hexavalent chromium salts;
- Hydrocarbon and chlorinated solvents.

In addition to the important compounds, it is assumed that the site is also contaminated with a range of heavy metals such as nickel, copper and lead from the metalworking processes, proof testing and firing.

This is not a complete list for two reasons: a) the research and assessment work may have missed important compounds, and b) industrial sites also commonly use a wide range of general chemicals and materials such as fuels, lubricants, hydraulic fluid, cleaners, detergents, ad hoc pesticides, cement, glues and refrigerants.

The characteristics of the four most important compounds including toxicology are discussed in turn below and on the next pages.

Sodium cyanide

In Al Qadissiya it is present as a white crystalline solid, formed into pellets or in the impure form in reaction vessels. It is used for filling annealing baths for high temperature case hardening of small arms. It is extremely toxic and fast-acting (acute toxin) [61,62]. Potential exposure pathways include skin, breathing and ingestion. A potentially lethal dose by ingestion for a human adult is in the order of 0.5 grammes. If mixed with acid or water it forms hydrogen cyanide, an extremely toxic gas.

Based upon the photographs and descriptions provided by ex-MIC site staff it is estimated that there is in excess of 2 tonnes of pure sodium cyanide at Al Qadissiya and an equivalent amount of impure used compounds mixed with other salts.

If exposed to air, water and soil, over time sodium cyanide decays by the release of hydrogen cyanide gas and complexation with metals such as iron.

Sodium cyanide pellets weathering in the open air

Sodium hydroxide

Sodium hydroxide is a alkaline (caustic) compound (high pH) [63]. In Al Qadissiya it is present as a white solid powder. It is used for metal treatment, chemical oxidation, neutralisation of spent cyanides and other treatment purposes. It is a powerful oxidising and corrosive agent, releasing chlorine gas if mixed with acids.

Based upon the photographs and descriptions provided by ex-MIC site staff it is estimated that there is in excess of 5 tonnes of sodium hydroxide at Al Qadissiya.

If exposed to air, water and soil over time sodium hydroxide decays to sodium salts and water through reduction with a wide range of other compounds.

Sodium hydroxide weathering in the open air

Hexavalent chromium salts

Chromium was used extensively at Al Qadissiya for plating and alloying. It is normally used for such purposes in both the hexavalent Cr (VI) and trivalent Cr (III) salt forms. The characteristics and toxicity depend to a large extent on the precise salt, however all Cr (VI) forms are both acutely toxic and carcinogenic[64]. One of the most commonly used compounds is chromic acid, a red crystalline solid that is moderately soluble in water.

Based upon photographic evidence it is estimated that there are in excess of 2 tonnes of metallic salts dispersed on the ground at Al Qadissiya. It is unknown what proportion of these are chromium compounds.

Heavy metal compounds dumped onsite

7

Hydrocarbon and chlorinated solvents

The processes used in Al Qadissiya entailed the use of organic solvents to degrease metals prior to treatment. Due to the effect of UN sanctions, it is suspected that chlorinated hydrocarbons were not widely available and more basic hydrocarbon solvents were used.

Chlorinated solvents are more mobile and much more toxic than simple hydrocarbon solvents. Both types are relatively volatile. Due to their volatility, large amounts of solvent are not expected to remain on site within the shallow, although some may be present in the soil at depth or in the groundwater.

7.3 Site assessment activities

The Al Qadissiya site was visited by MoEn staff twice in 2003 and 2004 for general fact finding and twice in 2005 (12^{th} and 19^{th} April) for detailed sampling and monitoring. Table 7.1 details the sampling and monitoring activities of the April 2005 site visits.

Table 7.1 Site assessment activities at Al Qadissiya

Sample type / activity	Number of samples or points
Soil	21
Waste / chemicals	23
Surface water	19
Groundwater	–
Total samples	63

In addition to the sampling work, the MoEn staff took over 100 photographs, many of which are included in this report.

The site assessment, sampling and analysis programme for Al Qadissiya could be described as low to moderate intensity with a focus on surface conditions. The subsequent assessment of conditions is therefore classed as indicative and preliminary, rather than detailed.

7.4 Hazardous wastes

From photographic and laboratory evidence it is clear that there is a significant volume of highly hazardous waste dispersed across the Al Qadissiya site. Chemical analysis of the waste piles indicates the principal contaminants are heavy metals, specifically lead, nickel, copper and antimony. Only relatively low levels (363 mg/kg) of chromium were detected.

Surprisingly, cyanide was not detected in significant concentrations by laboratory analysis. The maximum concentration of total cyanide detected was 48 mg/kg: approximately 0.005%, whilst the chemical in pure form is expected to have a concentration of in excess of 90%. Pure cyanide was, however, sighted and photographed in large drums prior to the demolition. The potential reasons for the limited detection of cyanide include:

Hazardous waste is distributed as loose piles across the compound

- The cyanide was removed from site by looting prior to demolition;
- The cyanide waste is covered by demolition rubble – considered likely;
- Sampling bias- none was sampled although it was present on site – considered likely;
- Sub-sampling or detection failures in the laboratory – unlikely, but possible;
- Degradation of the cyanide compounds, particularly on the top surface sampled – considered likely.

The majority of the hazardous waste appears to come from the period of operation

Normally highly hazardous chemical waste represents only a small fraction of the waste present on derelict sites. Other inert or low-hazard wastes include wood, concrete, scrap metal, plastic, furniture and fittings etc. Low-toxicity solid waste materials identified by XRF included barium, graphite, sodium sulphate, calcium chloride and casting sand. The uncontrolled demolition at Al Qadissiya has, however, intermingled hazardous chemicals with inert materials, turning the entire mixture into hazardous waste.

Without a detailed survey only broad estimates can be given for the volumes involved. It is estimated that up to 100 tonnes of hazardous waste is present on site and that this is partly mixed with several thousand tonnes of building demolition rubble and soil.

The uncontrolled demolition has resulted in the mixing of inert waste such as bricks with hazardous waste such as the contents of damaged reaction vessels

7

7.5 Land and water contamination

Laboratory analysis indicates that the shallow soil at Al Qadissiya is moderately contaminated with heavy metals. Trace amounts of polychlorinated biphenyls (PCBs) were also detected at one location.

Laboratory analysis of standing rainwater indicates slight contamination by metals and petroleum hydrocarbons. One groundwater sample was taken from a recently dug well near the site entrance. The results did not indicate contamination, however one sample is insufficient to draw conclusions for a site of this size and complexity.

In summary, the soil on site is considered to be **moderately contaminated.** The condition of the groundwater is largely unknown.

7.6 Risk assessment

The qualitative assessment of the risk to human health and the environment at Al Qadissiya is based upon the RBCA framework and a review of the site-specific sources (including hazardous wastes), pathways and receptors. The key points for Al Qadissiya are described below and on the next pages:

Sources – areas and chemicals of concern

The observed sodium cyanide waste is considered the most important source, given its a cute toxicity and volume. The lethal dose for sodium cyanide can be less than one gram. Lesser important sources include heavy metals, hydrocarbons and PCBs.

Surface soil contamination is widespread due to contact with the hazardous wastes but the penetration of contaminants appears to be relatively limited


Analysis of standing rainwater detected low levels of contamination

Receptors – human health

As the site is currently open access near urban areas, the most vulnerable receptors are expected to be site trespassers, particularly children.

Environmental receptors and habitats

The site is in a generally built-up area. There are no relevant environmental receptors on or immediately surrounding the site. The River Euphrates is considered to be too distant to be significantly affected.

Exposure pathways

As waste is observed on the ground surface, the most important exposure pathway is considered to be direct contact with the skin and accidental ingestion by site trespassers.

Dispersion of the chemicals is expected to be limited. Soil and water analyses to date indicate only limited migration of compounds from chemical wastes into the soil and surface water. Migration as dust is only relevant for short distances.

Cyanide will breakdown with contact with water and is considered to represent a hazard on site only. Other compounds, specifically solvents and chromium (VI) salts may have a relatively high mobility in groundwater, but to date there is no evidence of this on site.

Risk summary

In summary, the Al Qaddisiya site is considered to represent a **severe risk** to human health, principally to site trespassers.

Site trespassers in direct contact with a vessel containing cyanide

7.7 Findings

The key findings for the site are:

- The site in its current state represents a severe risk to human health;
- The principal risk arises from direct contact with hazardous wastes by site trespassers; particularly children;
- The greatest hazard is presented by the dispersed piles of sodium cyanide pellets;
- The volume of hazardous waste has potentially been increased by uncontrolled demolition. Much of the waste may be covered by or mixed in with demolition rubble;
- In the absence of corrective action, the hazard levels from chemical wastes will remain high for up to a decade until the chemicals weather and degrade significantly;
- Current data indicates that contamination of the underlying soil and water has been relatively limited in extent and concentration.

7.8 Recommendations

Summary

1. In the short term (less than one year) corrective action is taken to contain and remove the small volume of the most hazardous wastes (UNEP has already started a project to clean up this site with support from the United Nations Development Group Iraq Trust Fund);

2. In the medium term (1 – 5 years), all of the hazardous waste on site is contained and removed;

3. In the medium term, the hazardous wastes collected need to be treated or permanently disposed to an appropriate facility;

4. In the long term, redevelopment of the site is expected, because of its location close to Baghdad. Any redevelopment would need to be preceded by remediation works to make the site safe for the future site users.

Recommendation No.1 in detail

Title: Containment and removal of the most hazardous wastes.

Responsible party: The responsible party for the work should be the site owners, who are thought to be the Ministry of Finance, however this is unconfirmed.

Scope of work: A more detailed assessment of the volume and precise location of the most hazardous wastes is required as a first step. These wastes can be identified and marked out for containment and disposal.

The proposed methodology of containment and disposal is as follows:

- Compounds are collected into 50 litre resealable steel drums;
- The drums are stored offsite in a secure warehouse;
- Laboratory analysis samples are taken for each drum, pending decisions on the final method of treatment or disposal.

The first stage estimate of the volume of waste to be removed is 10 tonnes, equal to 150 – 250 barrels of 50 litre capacity.

The work can be done mainly using manual labour with some excavation equipment needed for the heavy lifting and shifting of rubble. High level Personal Protective Equipment (PPE) is needed, in the form of suitable masks, gloves, boots and suits. Additional worker safety equipment is needed, such as decontamination units, emergencies showers and specialised first aid kits (with hydrogen cyanide antidote).

Timing. The project is anticipated to require four months for planning and implementation. Capacity-building activities, if needed, are anticipated to require six months.

Cost estimate. Based on removal of 10 tonnes of waste the project cost is estimated at US$ 100,000. This estimate assumes the predominant use of local staff, no additional capacity building and the use of existing equipment. The required equipment provision and capacity building is separately estimated at US$ 400,000.

8 Al Suwaira results and recommendations

8.1 Site introduction

Al Suwaira is the location of the central pesticide store for the Ministry of Agriculture. The site is located 50 km southeast of Baghdad, 1.5 km north of the River Tigris and 3 km north of the town of Al Suwaira.

➤ Figure 8.1 Al Suwaira site setting

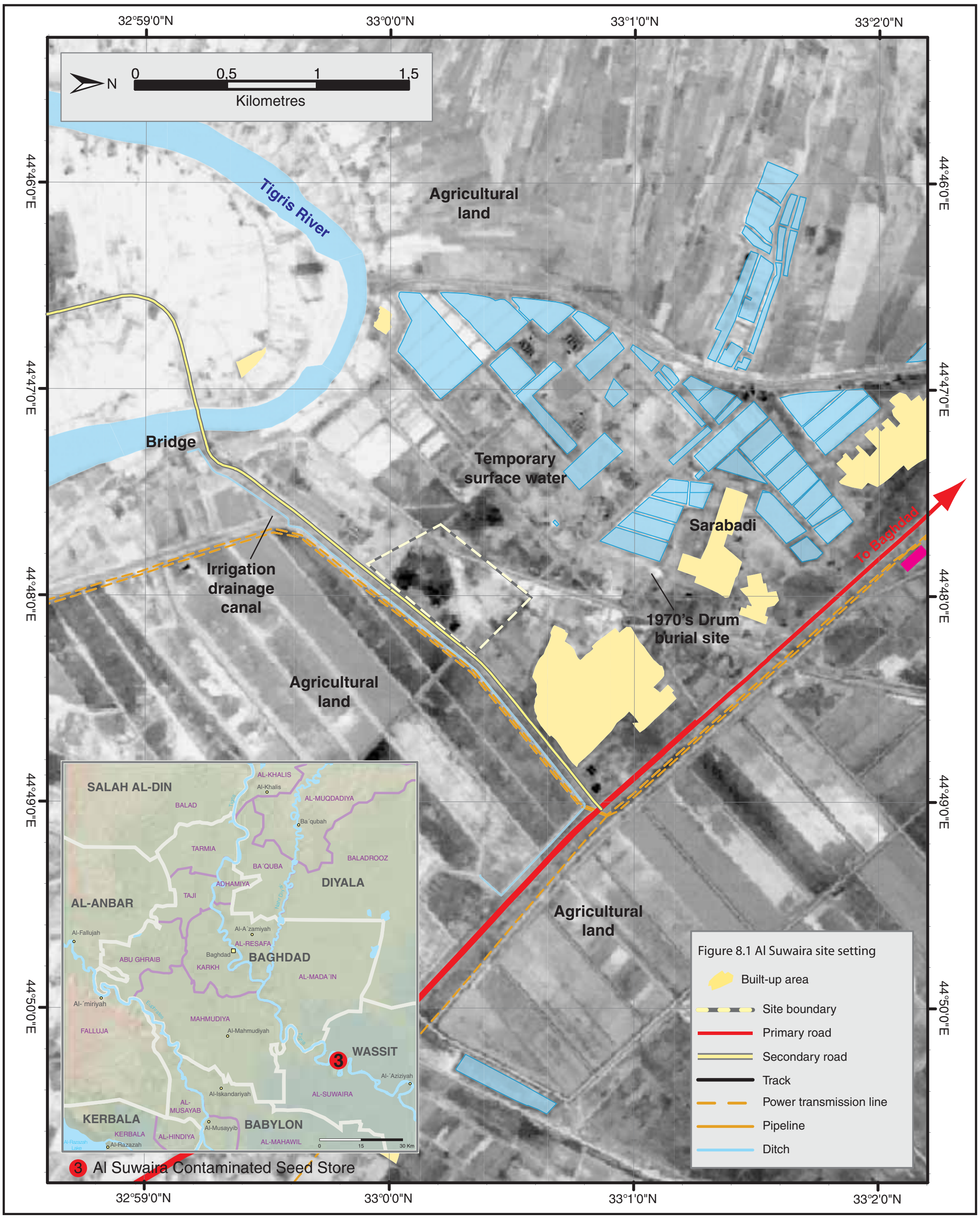
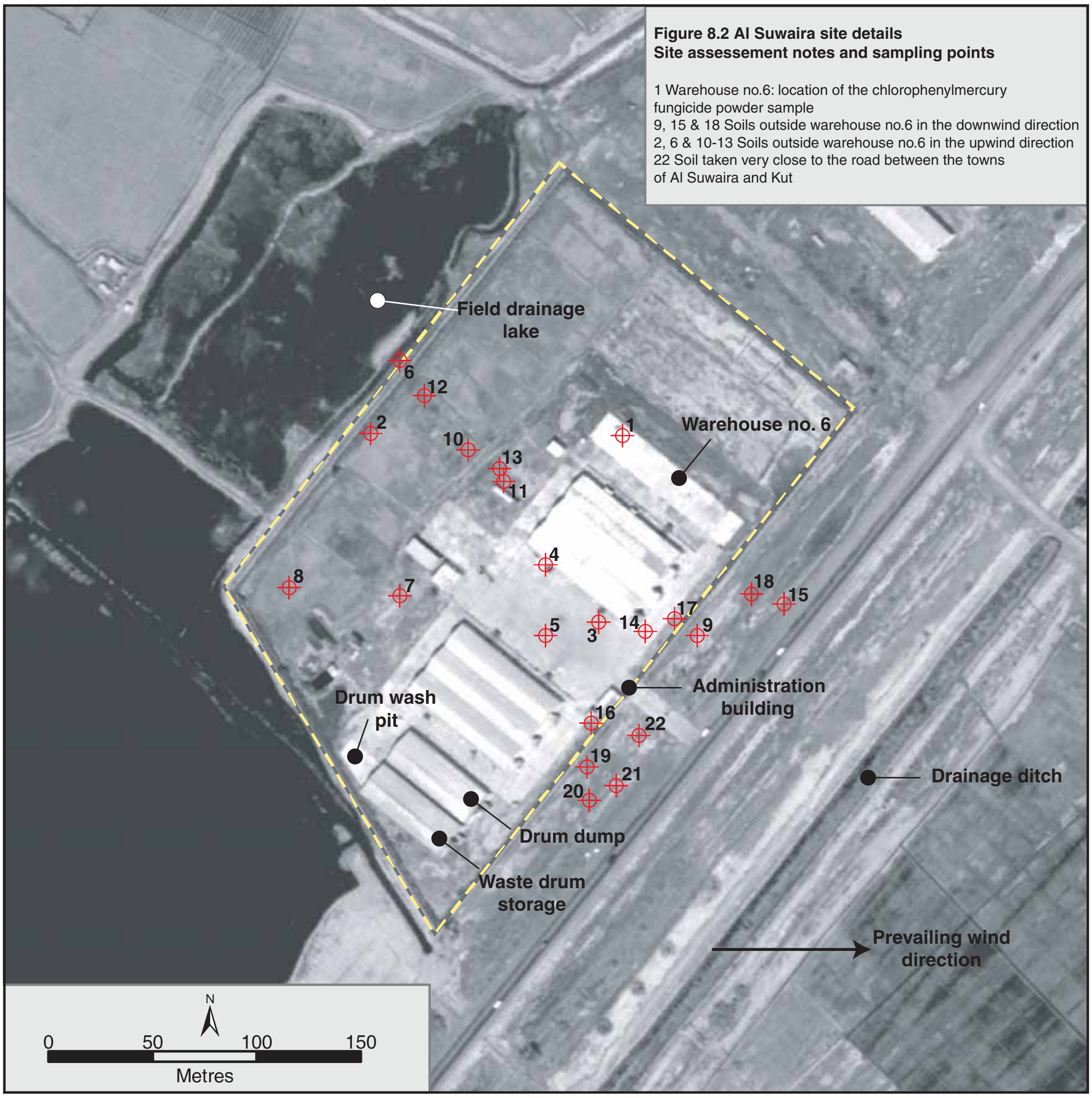


Figure 8.2 Al Suwaira site detail



The 4-hectare site contains a complex of six warehouses and an administration building. The facility was used to store, mix and dispatch a range of pesticides over a 30-year operating period. The empty imported pesticide containers were washed and re-used for local sale of pesticides, with some damaged drums being dumped on site.

The warehouse contents were looted but the buildings are largely undamaged

The facility operated normally until March 2003, when it was comprehensively looted. The majority of pesticides stored were stolen, together with the containers. There was only limited building damage, but the looters smashed containers and spread pesticides throughout the building and in part of the compound in the process of stealing the materials.

The hazards of the materials stolen were well known to the Ministry of Agriculture and they arranged for a local newspaper to

The site is now guarded and has a substantial boundary wall and fence

announce this. A buy-back scheme organised in 2003 and 2004 obtained a small quantity of zinc phosphide but no other pesticides.

As of July 2005 the facility is secure but idle and no clean up has been carried out. At least three of the warehouses remain unsafe to enter due to spilled pesticides. The Ministry of Agriculture reports that the warehouse complex is needed for storage and distribution of pesticides.

The mercury storage warehouses is now largely empty with a thick layer of chemical dust spread on all surfaces

The warehouses storing cyanide compounds are intact but currently too hazardous to enter without protection

8.2 Site assessment activities

The Al Suwaira site was visited by Ministry of the Environment staff five times in 2003, twice in 2004 for general fact finding and once in 2005 for detailed sampling and monitoring. Table 8.1 details the sampling and monitoring activities of the April 2005 site visit.

Table 8.1 Site assessment activities at Al Suwaira

Sample type / activity	Number of samples or points
Soil – to a maximum of 0.85m depth	20
Waste / chemicals	1
Surface water	–
Groundwater	–
Total samples	20

No water samples were taken as no surface water was present and there is no on-site groundwater well. The remaining chemicals could be identified by packaging and so were not sampled. Dust on the floor and internal walls of the warehouse previously containing the methyl mercury was sampled.

In addition to the sampling work, the MoEn staff toured the site with a video camera and took over 100 photographs, many of which are presented in this report.

8.3 Chemicals and toxicology

The Ministry of Agriculture confirms that the following pesticides (fungicides, insecticides and rodenticides) were stored in large quantities at Al Suwaira:

- Methyl mercury (expected to be dimethyl mercury);
- Zinc phosphide;
- Calcium cyanide.

The Ministry used other pesticides including organo-chlorine (OC) and the more modern organo-phosphorous (OP) compounds, but these were not stored in any quantity at the time of the looting. Laboratory analysis of soil and warehouse surfaces identified a range of OC and OC compounds:

- Chlorophenylmercury;
- Lindane;
- Diazinon (OP);
- Heptachlor;
- Fenitrothion (OP);
- Malathion (OP);
- Endosulphan;
- Dieldrin;
- DDT and decay derivatives DDE;
- Methoxychlor.

The seven most significant of the reported or identified pesticides are explained in more detail on the following pages. The pesticide hazard classification used by the World Health Organisation[65] is listed where available.

8

Organic mercury compounds

The organic mercury stored at Al Suwaira was obsolete material which had been in storage for at least 20 years. It was previously used in Iraq as a fungicide to coat wheat seeds. In 1971, methyl mercury was the cause of an infamous poisoning crisis when 6,500 people were hospitalised and 459 died from eating bread made from the treated seeds [66].

Prior to looting, the warehouse held 76 tonnes of organic mercury compounds in 50 kilogramme drums. From photographs and video evidence, the volume of material remaining is estimated at less than 100 kilograms, in broken sacks and scattered powder.

The loss of detailed records through looting has hampered the accurate identification of the organic mercury compounds. The material was originally thought to be dimethyl mercury, however limited laboratory analysis identified only chlorophenyl mercury. Accordingly both materials are described.

Methyl mercury (dimethyl mercury)

In pure form, methyl mercury is a crystalline, white-red solid[67]. When used it is commonly combined with a binding agent, resin or solvent which may change its appearance.

It is no longer widely used as a pesticide due to its toxicity to humans and persistence in the environment. It is both an acute and chronic toxin (i.e. it has both short and long term effects). It causes central nervous system damage and also birth defects. WHO Hazard Class: Obsolete/ Use restricted under international convention (due to hazard).

Chlorophenyl mercury

Chlorophenyl mercury is a white crystalline solid [68, 69]. It was historically used as a fungicide. Its toxicity and other characteristics are very similar to methyl mercury.
WHO Hazard Class: Obsolete / Use restricted under international convention (due to hazard).

Mercury compounds were readily identified as a pink-purple coloured dust

Zinc phosphide

In pure form, zinc phosphide is a heavy, crystalline grey-black powder [70,71]. It is used widely as a rodenticide as it is a selective toxin with reduced toxicity for humans. If ingested, the compound affects the gastrointestinal, respiratory and nervous systems.
WHO Hazard Class: 1b Highly Hazardous.

Prior to looting, the warehouse held 34 tonnes of zinc phosphide in 20, 50 and 100 kilogramme sacks and drums. From photographs and video evidence, the volume of material remaining is estimated at less than 1 tonne, in broken sacks, opened drums and scattered powder.

Calcium cyanide

In pure form, calcium cyanide is a white crystalline solid[72]. It is used widely as an insecticide and rodenticide. It is extremely toxic and fast-acting (acute toxin). Potential exposure pathways include skin, breathing and ingestion. A potentially lethal dose by ingestion for a human adult is in the order of 0.5 grammes. If mixed with acid or water it forms hydrogen cyanide, an extremely toxic gas.
WHO hazard Class: 1a Extremely Hazardous.

Prior to looting, the warehouse held 18 tonnes of calcium cyanide in 25 and 50 kilogramme sacks and drums. From photographs and video evidence, the volume of material remaining is estimated at 1-3 tonnes, in broken sacks and scattered powder.

DDT and DDE derivatives

DDT and the degradation product DDE were identified from laboratory analysis only. There are no details of its history on site. In pure form, DDT is a white, waxy solid[73, 74].

DDT was used as an insecticide and has moderate toxicity to humans. It is, however, highly persistent in the environment and has chronic toxicity characteristics. Due to its stability, the DDT detected could be related to its use up to 30 years ago.
WHO Hazard Class: II – Moderately hazardous. Use restricted under international convention (due to persistence and hazard).

Dieldrin

Dieldrin was identified from laboratory analysis only. Dieldrin is an organochlorine based insecticide of moderate toxicity to humans[75, 76]. It is no longer widely used internationally, due to concern about its impact and stability in the environment. WHO Hazard Class: Obsolete/ Use restricted under international convention (due to persistence and hazard).

8.4 Hazardous wastes

The remaining pesticides at Al Suwaira are still contained in the warehouses. In many cases they are mixed together, containers are damaged and they are contaminated with dirt. As such these materials are not usable and so become hazardous waste.

From photographs, videos and eyewitness reports it is estimated that 3-5 tonnes of hazardous pesticide waste are present in Al Suwaira, located in three warehouses. The total volume of wastes inside the warehouses appears to be in the order of 100 m^3. However, much of this is empty but contaminated containers.

The floor of one warehouse has a thick coating of mercury containing dust

A pile of approximately 200 damaged and severely rusted empty drums are located inside the compound. Considering the age of the drums and the likely absence of any significant amounts of pesticides, it is expected that these would not be classed as hazardous waste, but this would need to be confirmed by inspection and possibly analysis.

Due to age and weathering these empty pesticide drums are not likely to contain significant hazardous wastes

In addition to the packaged wastes and empty drums, photographs show that the floor and internal walls of the warehouses have a thick coating of dust, often coloured either purple, pink or white. It is clear from the site history, visibly damaged containers and the laboratory analysis, that this dust contains pesticides and should be classed as hazardous waste.

The purple-pink powder was associated by the Ministry of Agriculture staff with the storage of methyl mercury. However laboratory analysis of the powder did not find any dimethyl mercury and only 19,400 mg/kg (approximately 2%) of total mercury. Further analysis identified chlorophenyl mercury at a concentration of 6,000 mg/kg. This compound has a similar appearance, use and toxicity to dimethyl mercury.

Given that the store reportedly contained many tonnes of methyl mercury, its complete absence from the samples requires explanation. One possibility is that the material was not sampled. The samples taken were however considered indicative of the conditions, so that is considered unlikely. The second possibility is that the methyl mercury is no longer present.

Literature reviews indicate that the shelf life of organo-mercury pesticides is limited, especially in hot climates and with exposure to air. Over time, the organic form breaks down to form mercuric oxide and elemental mercury[77]. The elemental mercury would vaporise, leading to a gradual lowering of the concentration.

As the material has been stored for up to 30 years in conditions of up to 50 degrees Celsius, it is considered highly likely that much of the original organic mercury pesticides is now either gone or degraded to inorganic forms. This applies to both dimethyl mercury and chlorophenyl mercury. This is a positive effect, in that the toxicity of inorganic mercury is lower than the organic forms. The mercury containing dust is, however, still considered a hazardous waste.

8.5 Land and water contamination

Laboratory analysis of soil samples detected low concentrations of a total of 11 organo-chlorine pesticides and derivatives. Other contaminants detected include mercury, copper and petroleum hydrocarbons, all at relatively low levels. As the density of soil sampling was relatively low it is possible that areas of contamination were missed. In particular, the ground under the dumped drums and the drum wash basin was not sampled.

Laboratory analysis indicates that the shallow soil within the compound is slightly contaminated by a range of pesticides

In summary, the shallow soil inside the compound could be classed as **slightly contaminated,** with potential hotspots of moderate contamination.

8.6 Risk assessment

The qualitative assessment of the risk to human health and the environment at Al Suwaira is based upon the RBCA framework and a review of the site-specific sources (including hazardous wastes), pathways and receptors. The key points for Al Suwaira are described below.

Sources – areas and chemicals of concern

There are multiple sources of acute and chronic toxicity on the site. The mercury dusts and the cyanide pesticides are considered to be the most important sources, given their volume, acute toxicity and distribution. The zinc phosphide is a less important source but still significant if found in high concentrations. The low levels of organo-chlorine and organo-phosphorous pesticides detected to date are not considered a significant source of risk.

Receptors – human health

The site is currently non-operational, fenced and guarded. Entry into the warehouses is restricted. The levels of contaminants detected outside the warehouses are relatively low. Thus, the most important receptors are limited to staff who enter the warehouses.

Environmental receptors and habitats

There are no relevant environmental receptors on or immediately surrounding the site. The River Tigris is considered to be too distant to be affected.

The River Tigris is located 1.5 km from the warehouse, too far to be at significant risk from the chemicals left on site

Exposure pathways

Inside the warehouses the waste pesticides are present as powders. The floor and internal walls are coated with pesticide containing dusts. The most important exposure pathway is considered to be inhalation of the dusts, followed by direct contact with the skin and accidental ingestion.

Dispersion of the chemicals is expected to be limited. Most of the compounds present will breakdown over time with contact with water, oxygen and heat. Soil analyses to date indicate only limited migration of compounds from chemical wastes into the soil and surface water. Migration as dust is only relevant for short distances outside the warehouses.

Risk summary

In summary, the Al Suwaira site is currently considered to represent a **low risk** to human health, due to the site controls in place. Site neighbours are not considered to be at risk. Site workers are at **severe risk** if they enter the warehouses without protection.

8.7 Findings

The key findings for the site are:

- The site in its current state represents a **low** human health risk, but only due to security preventing access to the contaminated warehouses;
- Approximately 100m^3 of waste pesticides are present in the warehouses;
- The contaminated warehouses are unsafe to use or even enter and will remain in that condition unless decontaminated;
- The soil inside the compound could be classed as slightly contaminated by pesticides, but the levels detected to date do not warrant urgent action.

8.8 Recommendations

Summary

1. In the medium term (1 – 5 years), to allow the facility to be used, the hazardous pesticide wastes need to be collected and securely contained and the warehouses need to be decontaminated;

2. In the medium term, the hazardous wastes collected need to be treated or permanently disposed to an appropriate facility.

The floor, walls and ceiling of the warehouse need decontamination to allow it to be used again

Recommendation No.1 in detail

Title: Containment of hazardous waste and warehouse decontamination.

Responsible party: The responsible party for the work should be the site owners, the Ministry of Agriculture. As the Ministry does not have the skills or normally the need for this type of hazardous waste management, it should partner with other ministries such as the MoEn and the Ministry of Industry and Minerals. Note that specialist expertise is required for all this type of work due to its hazardous nature [78].

Scope of work: A more detailed assessment of the volume and types of the pesticide wastes is required as a first step, prior to any decontamination works[79].

The proposed methodology of waste containment is as follows:

- The pesticides in damaged sacks or drums are decanted or transferred into 50 litre resealable steel drums;
- The drums are stored on site in a secure, decontaminated warehouse.

The proposed methodology of warehouse decontamination is as follows:

- All containers of pesticide are safely removed;
- The ceiling, walls, floor and all fittings of the warehouses are vacuumed to remove dusts;
- The vacuum dust bags are treated as hazardous waste and contained in 50 litre resealable steel drums;
- The ceiling, walls, floor and all fittings of the warehouses are sprayed to remove traces of chemicals, first with a sodium hypochlorite solution and then with water.

Due the presence of calcium cyanide, it is very important that the pesticide wastes and collected dusts are kept away from water.

The first stage estimate of the volume of waste to be removed, including dusts, is 5 tonnes, equating to 1,000 barrels of 50 litre capacity. This volume can be easily contained in one of the existing warehouses.

The work can be done mainly using skilled manual labour with some light machinery. High-level Personal Protective Equipment (PPE) is needed, in the form of suitable masks, gloves, boots and suits. Additional worker safety equipment is needed such as decontamination units, emergencies showers and specialised first aid kits (with hydrogen cyanide antidote).

Timing. The project is anticipated to require four months for planning and implementation. Capacity building activities, if needed, are anticipated to require six months.

Cost estimate. Assuming containment of 5 tonnes of waste and decontamination of six warehouses, the project cost is estimated at US$ 110,000. This estimate assumes the predominant use of local staff, no additional capacity building and the use of existing equipment. The required equipment provision and capacity building is separately estimated at US$ 400,000.

9 Khan Dhari results and recommendations

9.1 Site introduction

The Khan Dhari chemicals warehousing site is located 35 km west of Baghdad, near the town of Abu Ghraib.

➤ Figure 9.1 Khan Dhari site setting

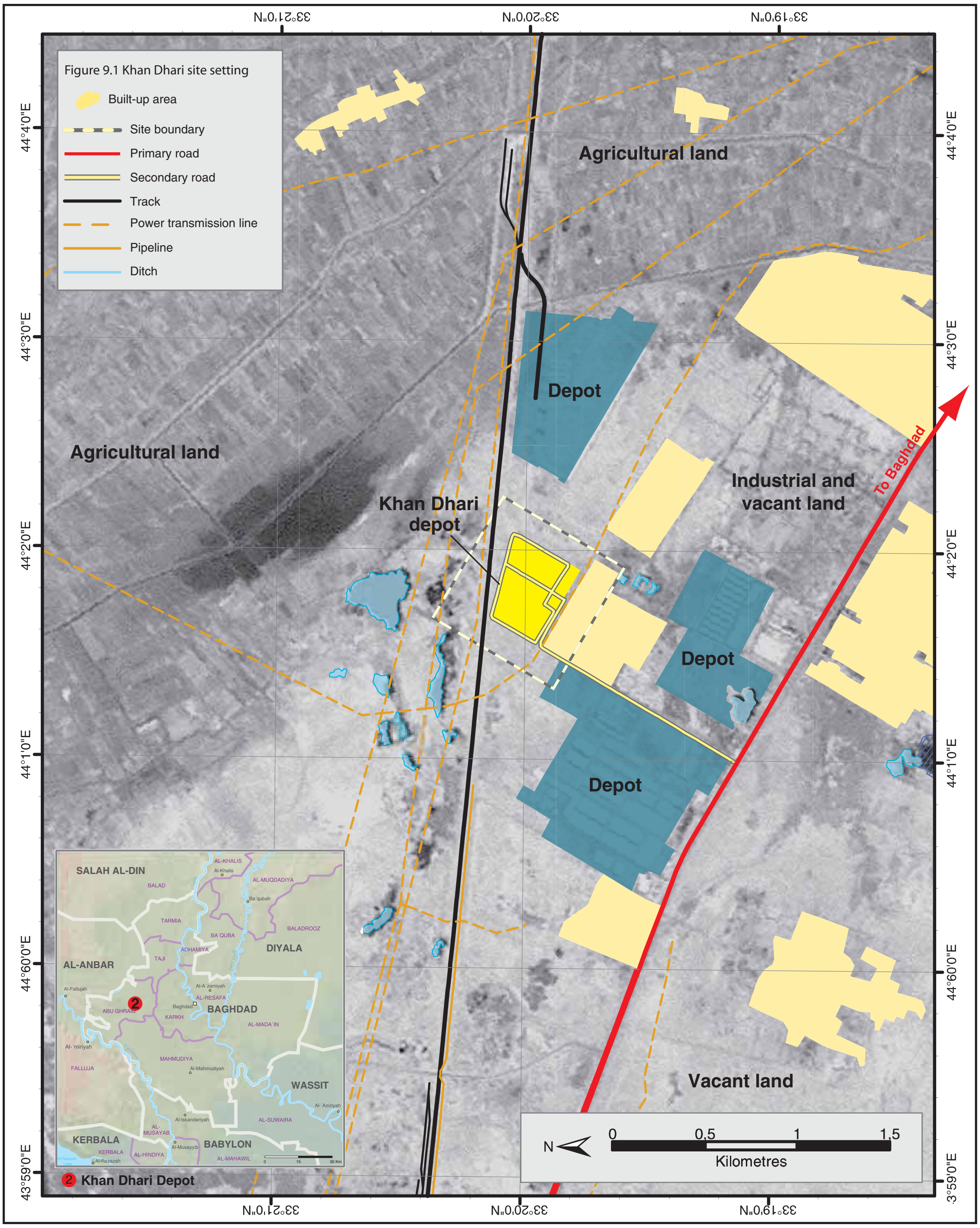
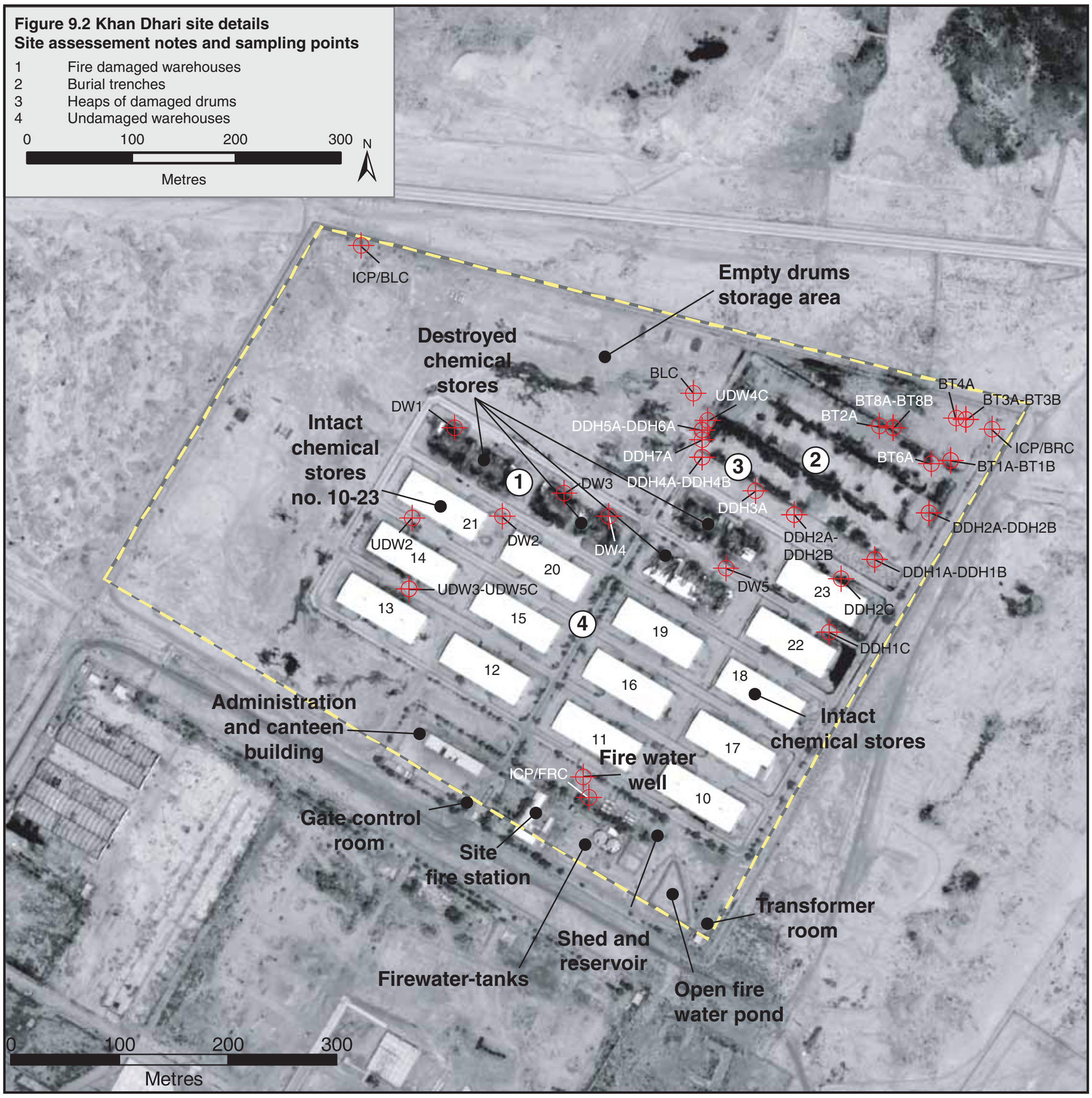


Figure 9.2 Khan Dhari site detail



The site is approximately 30 hectares in area and is located in the flat plain north of the River Tigris. The surrounding land uses are principally agriculture, warehousing and light industry with some vacant land. Figure 9.1 shows the site location and surrounding land uses.

The site is managed by the Al Doura Refinery Company but serviced all of the Iraqi refinery industry. It contains a complex of 18 warehouses and two support buildings. Four of the warehouses have been totally destroyed by fire. Figure 9.2 shows the current site layout, overlaid on a satellite image taken in January 2005.

The warehouse yard now contains over 1000 burnt drums and areas of spilled chemicals

The site is underlaid by gypsum rich, silty sands with saline groundwater estimated to be at 3m – 5m depth. Surface water drainage is to the River Tigris to the south. The site assessment team report that the shallow ground water is saline and not used for drinking water supplies.

The site was intact and in normal use up until March 2003. Immediately after the conflict, the site was looted of machinery, empty drums, fittings and some chemicals. In the process, containers full of chemicals were poured onto the ground. Site staff report that 6,000 empty barrels contaminated with chemicals were stolen from the site.

Looters also started a fire which destroyed the four warehouses and the stored chemicals inside and in the adjacent yard. At the time of the fire, residents reported a cloud of heavy, acrid smoke up to 2 km across, causing respiratory problems for local residents.

The site is currently secured but not in use. The burned warehouses remain untouched and the yard contains over 1,000 damaged and burned barrels piled in irregular rows. Spilled liquids and solids are visible in the damaged areas.

9.2 Site assessment activities

The Khan Dhari site was visited by UNEP in 2003 and by Ministry of the Environment staff twice in 2003 and 2004 for general fact finding, and once in 2005 for detailed sampling and monitoring. Table 9.1 details the sampling and monitoring activities of the March 2005 site visit.

Table 9.1 Site assessment activities at Khan Dhari

Sample type / activity	Number of samples or points
Soil	43
Waste chemicals	–
Surface water	–
Soil gas measurements	21
Groundwater	1
Total samples (for laboratory analysis)	44

Water was sampled from the site firewater well. No surface water was present. In addition to the sampling work, the MoEn took over 70 photographs, many of which are presented in this report.

9.3 Chemicals and toxicology

A detailed list of the chemicals, materials and volumes stored at Khan Dhari prior to the looting and fire has been supplied by the Al Doura refinery staff. The materials stored included process chemicals, catalysts, resins, detergents, filter clays, ceramics, acids, bases, corrosion inhibitors, petroleum additives and lubricants. Many of these materials are not hazardous. The most important hazardous chemicals noted in terms of toxicity and volume were:

- 130 tonnes of tetraethyl lead (TEL) liquid in 340 kg containers;
- 861 tonnes of furfural (furaladehyde) liquid in 240 kg containers;
- 257 tonnes of methyl ethyl ketone (MEK) in 165 kg containers;
- Sodium hydroxide (significant quantity).

Iraq still uses leaded petrol and imports tetra-ethyl lead

Tetraethyl lead (TEL)

In pure form, TEL is a clear, heavy (non-volatile) liquid that is commonly dyed red or orange[80]. It is an organic lead compound used as an anti-knock additive for petrol. It is highly toxic, causing nervous system and brain damage.

When burned it forms inorganic lead oxides and carbonates of lower toxicity.

The looting resulted in extensive spillage of furfural

Furfural

Furfural is a heavy, low volatility clear liquid that turns red-brown on contact with air[81]. It is used in refineries as a solvent in the production of lubricant oil and elsewhere as a fungicide and herbicide. It is moderately toxic [82, 83], with skin contact being the principal exposure route.

Partially oxidised furfural is spilled across the drum storage areas

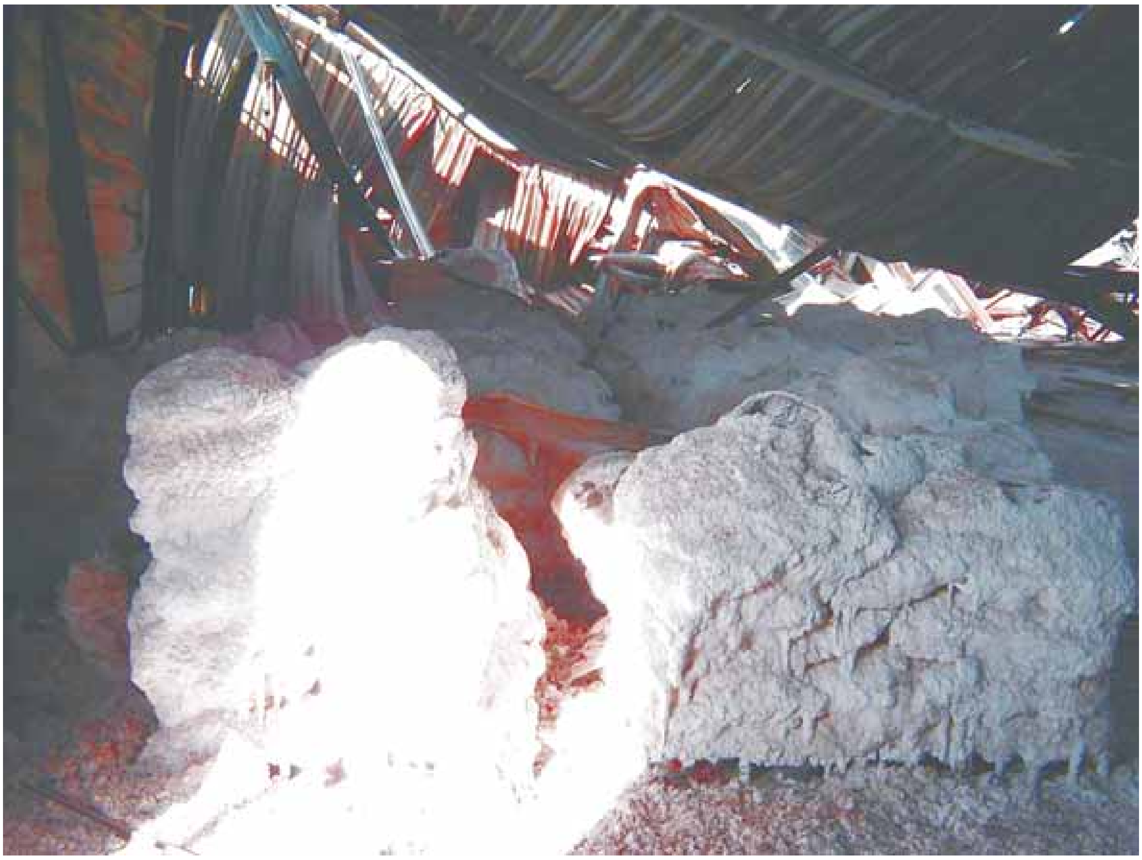
When burned completely, it forms carbon dioxide and water. Due to its moderate flammability, furfural in drums may not burn completely, resulting in unburned, partially oxidised viscous brown–black liquids. From photographs, it appears that extensive spillage of furfural occurred across the Khan Dhari site as a result of the 2003 looting and fire.

9

Methyl ethyl ketone (MEK)

MEK is a colourless, highly volatile organic chemical. In refineries it is used primarily as a solvent. It is moderately toxic and very mobile in water [84,85].

When burned completely, it forms carbon dioxide and water. Due to its high flammability and volatility, no MEK is expected to be still present in Khan Dhari in unsealed containers, although some may have infiltrated the soil and groundwater.



Damaged stocks of sodium hydroxide remain inside the burnt out warehouses

Sodium hydroxide

Sodium hydroxide is an alkaline (caustic) compound (high pH)[63]. In Khan Dhari, it is present as a white solid mass inside one of the burnt warehouses. It is used for chemical oxidation and neutralisation of spent refining wastewater and other treatment purposes. It is a powerful oxidising and corrosive agent, releasing chlorine gas if mixed with acids or burned.

Based on the photographs and descriptions provided by site staff, it is estimated that there was in excess of 20 tonnes of sodium hydroxide at Khan Dhari. If exposed to air, water and soil over time sodium hydroxide decays to sodium salts and water through reduction with a wide range of other compounds.

9.4 Hazardous wastes

From photographic and laboratory evidence, it is clear that there is a significant volume of hazardous waste dispersed across the Khan Dhari site. It is present in the form of the contents of fire damaged drums, spilled heavy liquids and burnt residues. However, it is also clear from the photographs that the intensity of the fire has destroyed most of the organic chemicals, leaving behind inorganic residues.

Accurate estimates of the volume of hazardous waste have yet to be obtained

Chemical analysis of the soil around the waste piles indicates heavy metals are dispersed throughout the site, but volatile and semi-volatile chemicals are not present in significant quantities.

As a result, the waste is generally considered to be only moderately hazardous, with the greatest hazard presented by the inorganic lead dispersed as dust and ash in the compound and burnt warehouses.

Without a detailed survey, only broad estimates can be given for the volumes involved. It is estimated that up to 200 tonnes of moderately hazardous waste is present on site. However, this is mixed in with over 1,000 damaged drums and building rubble, so the volume involved is expected to be in the order of 2,000m^3 or more.

The hazardous waste is mixed in with burnt building debris

9

9.5 Land and water contamination

Laboratory analysis of the shallow soil inside the compound indicates isolated heavy contamination by lead and isolated marginal contamination with a range of semi-volatile organic compounds (SVOCs). The lead concentration in the surface soil is generally below 100 mg/kg but in one location it was detected at 16,990 mg/kg. Only marginal contamination was detected at on location of 0.85m depth, indicating limited penetration of contaminants.

The SVOCs detected are considered to be representative of the partially burnt or oxidised mineral oil, and organic chemicals such as furfural and were all found at shallow depths.

Laboratory analysis of the firewater well indicates that it is uncontaminated by organic chemicals or heavy metals. As reported by site staff, it is highly saline with a chloride concentration of 3,748 mg/litre.

In summary, land contamination of the site is considered to be overall moderate, relatively limited in extent and shallow.

9.6 Risk assessment

The qualitative assessment of the risk to human health and the environment at Khan Dhari is based upon the RBCA framework and a review of the site-specific sources (including hazardous wastes), pathways and receptors. The key points for Khan Dhari are described below and on the next pages.

Sources – areas and chemicals of concern

There are multiple sources of acute and chronic toxicity on the site, however the great majority are of moderate to low toxicity. The lead (both organic and inorganic) and the furfural are considered to be the most important sources, given their volume, acute toxicity and distribution.

The penetration of the contaminants into the soil has probably been limited by factors such as concrete and low rainfall

Receptors - human health

The site is currently non-operational, fenced and guarded. Entry into the warehouses is restricted. The levels of contaminants detected outside the burnt warehouse and drum areas are relatively low. Groundwater is not used and there is no permanent surface water. Thus, the most important receptors are limited to staff who enter these areas.

The site has a secure boundary and is guarded

Environmental receptors and habitats

The site is in a generally built-up area. There are no relevant environmental receptors on or immediately surrounding the site. The River Tigris is considered to be too distant to be significantly affected.

Exposure pathways

The remaining inorganic lead is mixed in with ash and other burnt residues which range in composition from powder to a hard crust or cohesive mass. The furfural is present as a waxy, tarry mass spread thinly on the ground and in damaged containers. The most important exposure pathway is considered to be inhalation of the dusts, followed by direct contact with the skin and accidental ingestion. Lead dust is considered to represent the greatest hazard.

Transport of the contamination beyond the site is expected to be limited. Soil analyses to date indicate only limited migration of compounds from chemical wastes into the soil and surface water. Migration as dust is only relevant for short distances outside the burnt warehouse and drum area.

Risk summary

In summary, Khan Dhari is currently considered to represent a **low risk** to human health, due to the site controls in place. Site neighbours are not considered to be at risk. Site workers are at **moderate risk**, if they enter the burnt warehouse and drum area.

9

9.7 Findings

The key findings for the site are:

- Overall the site is considered to represent a **low risk**, mainly due to the site controls in place;
- Large parts of the site in its current state represent a **moderate risk** to the health of site workers. The site is therefore unfit for normal use;
- The principal threat is from direct contact with and inhalation of the lead dusts and oxidised organic chemicals;
- In the absence of corrective action, the hazard levels will remain constant for decades.

9.8 Recommendations

Summary

1. In the medium term (1 – 5 years), all of the hazardous waste on site is contained and removed;
2. In the medium term, the hazardous wastes collected need to be treated or permanently disposed to an appropriate facility;

Both the spilled chemicals and the damaged drums will need to be removed

Recommendation No.1 in detail

Title: Containment and removal of the hazardous wastes.

Responsible party: The responsible party for the work should be the site owners, the Al Doura Refinery Company, part of the Ministry of Oil. Note that specialist expertise is required for all this type of work due to its hazardous nature.

Scope of work: A more detailed assessment of the volume and precise location of the most hazardous wastes is required as a first step. These wastes can be identified and marked out for containment and disposal.

The proposed methodology of containment and disposal is as follows:

- The damaged drums are sorted into two categories – recyclable and not-recyclable – based upon the presence of adhesive compounds;.
- Recyclable drums are emptied, brushed out, triple rinsed and crushed, then sent offsite as normal scrap metal;
- Non-recyclable drums are crushed to reduce volumes and treated as hazardous waste;
- Loose chemical dusts and solids are collected into 200 litre steel drums;
- The fire-damaged warehouses are demolished and wastes separated into hazardous and non-hazardous grades;
- The sealed waste drums and crushed drums are stored on site in a secure warehouse;
- Laboratory analysis samples are taken for each drum, pending decisions on the final method of treatment or disposal.

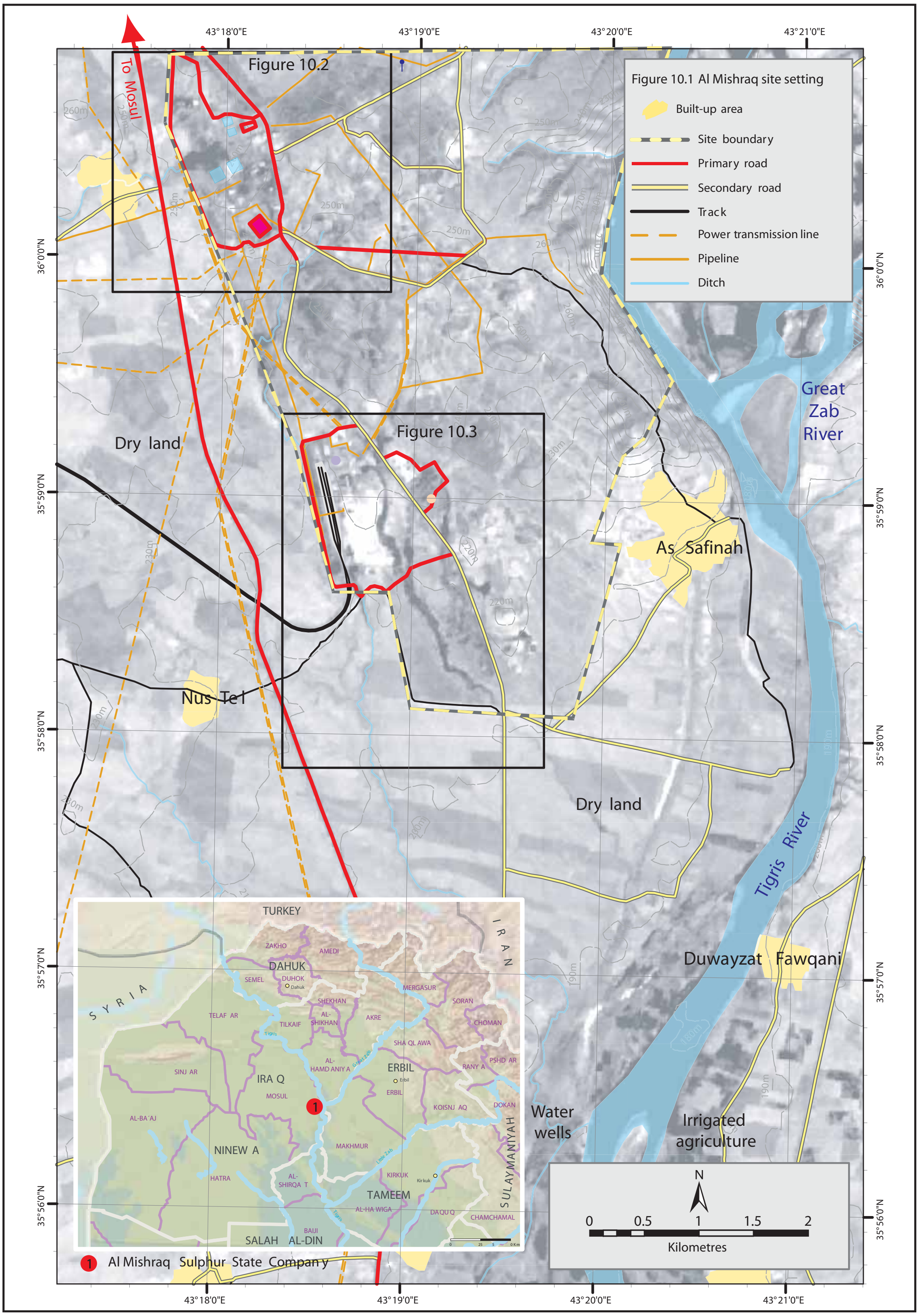
The hazardous waste collection work can be done mainly using manual labour with some light machinery. The warehouse demolition work will require heavy machinery. High-level Personal Protective Equipment (PPE) is needed, in the form of suitable masks, gloves, boots and suits. Additional worker safety equipment is needed such as decontamination units, emergencies showers and specialised first aid kits.

Timing. The project is anticipated to require 12 months for planning and implementation. Capacity building activities, if needed, are anticipated to require six months.

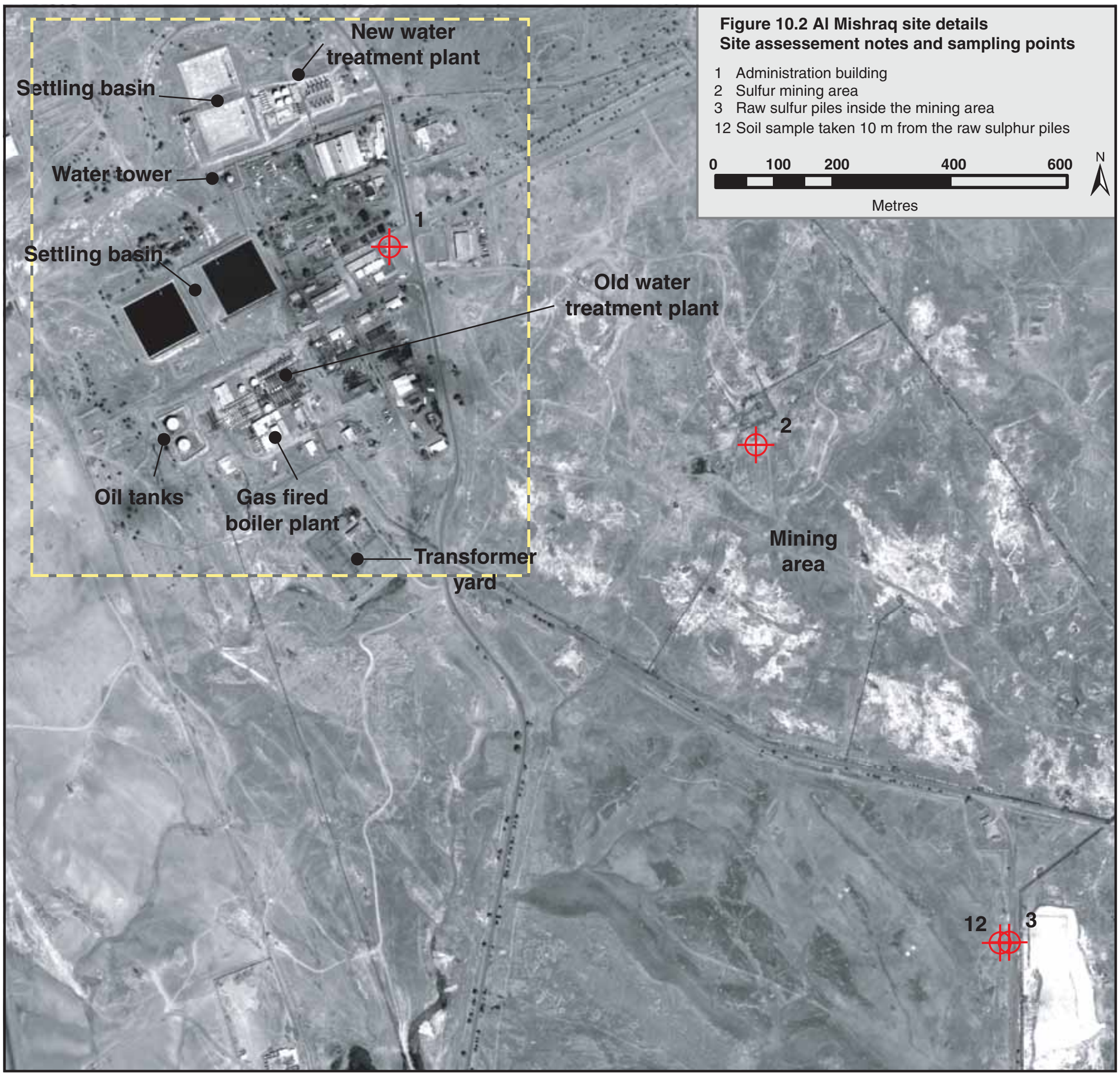
Cost estimate. Based on containment of 2,000 m^3 of waste and the demolition of three warehouses the project cost is estimated at US$ 250,000. This estimate assumes the predominant use of local staff, no additional capacity building and the use of existing equipment. The required specialised hazardous waste equipment provision and capacity building is separately estimated at US$ 400,000.

10 Al Mishraq results and recommendations

➤ Figure 10.1 Al Mishraq site setting



➤ Figure 10.2 Al Mishraq North site details

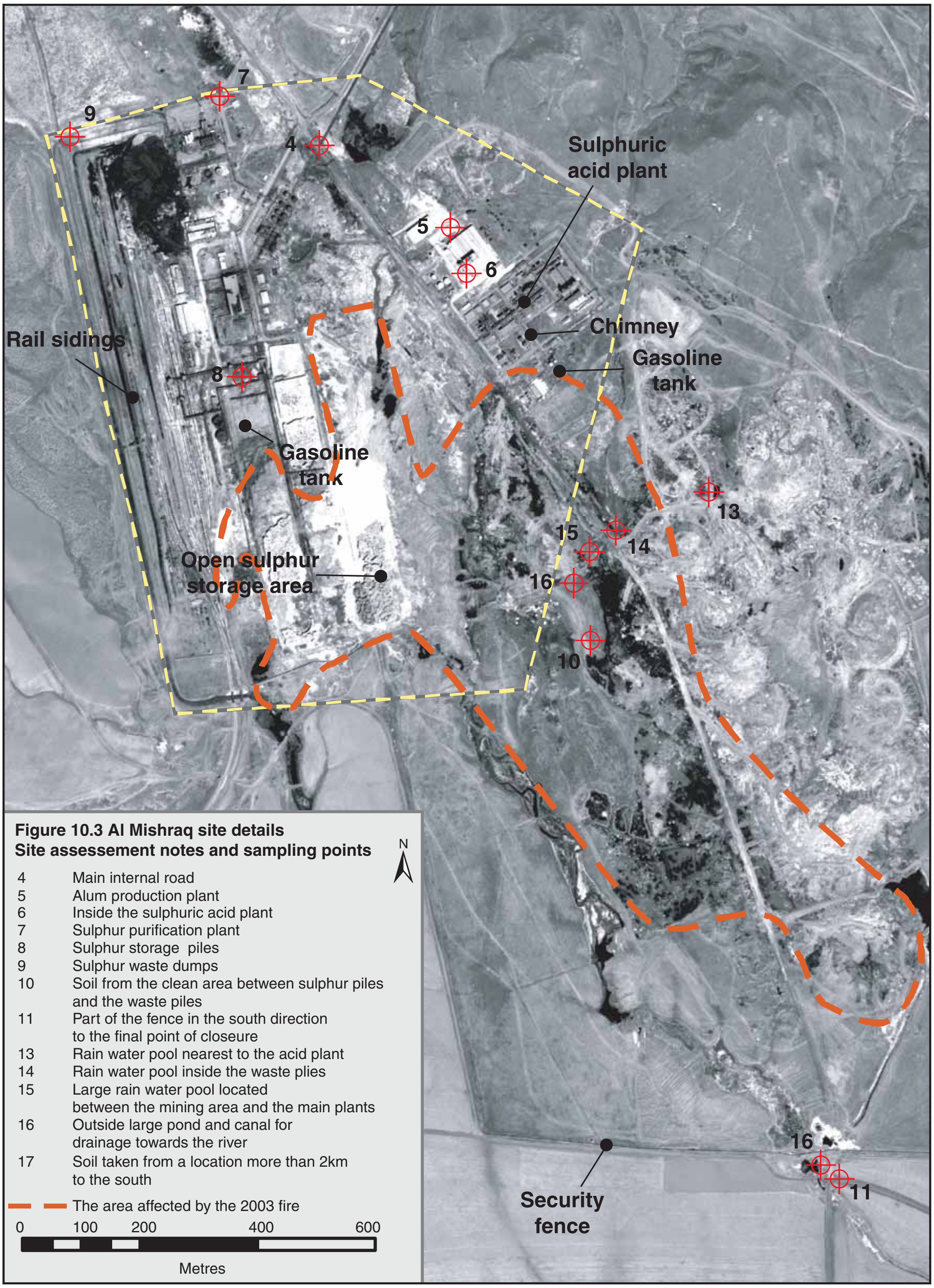


10.1 Site introduction

The Al Mishraq sulphur mining and processing complex is located 50 km south of Mosul, close to the west bank of the River Tigris. The complex is spread over a 17 km^2 area and consists of a sulphur mine, a sulphuric acid plant, an alum (aluminium sulphate) plant and associated facilities for power generation, water treatment and injection, administration and engineering. The plant operated from 1972 to April 2003 and is currently idle and partly derelict. Figures 10.1, 10.2 and 10.3 show the site setting and details of the power generation and mining areas.

Purified sulphur stored ready for sale

➤ Figure 10.3 Al Mishraq South site details



The sulphur was mined by the Frasch process, whereby superheated water, steam and compressed air are injected into a sulphur-bearing deposit and sulphur is stripped from the return water. Sulphuric acid and heat treatment was used to clean bitumen and other minerals from the sulphur and the resultant waste solids and liquids were deposited on-site to form large mounds dispersed in an area of more than 1 km^2. The waste piles contained up to 70% sulphur in various mineral forms.

Asphalt containing waste piles in front of the sulphur purification plant

The purified sulphur was stockpiled next to a rail yard for export. In March 2003, the stockpile volume was approximately 500,000 m^3. Production effectively ceased in March 2003 and the site was comprehensively looted over the period April to July 2003. In June 2003, a fire started by looters destroyed a large volume of the purified stockpile and the adjacent waste piles (see on the next page).

In 2004, the alum plant operated intermittently using up existing stocks of raw materials before closing down. As of July 2005, the entire site was shut down and secured. As a result of the looting and under-investment the facility is semi-derelict.

The sulphuric acid plant is in poor condition

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10.2 Mining geology and hydrogeology

High concentrations of minerals occur naturally in the Al Mishraq area and any assessment of chemical contamination and wastes needs to take this into account.

The ore body – the area of commercial mineralization – is over 10 km^2 in area and located at a depth of 50 – 300m [86]. It is composed of a mixture of sulphur, limestone, gypsum and bitumen and is below the groundwater table. The groundwater flows through the ore body from the hills to the north west into the River Tigris. Natural hydrogen sulphide springs were observed in the river prior to the start of mining.

During the mining operations a portion of the superheated water mixture was not recovered and instead leaked laterally underground and into the river as sulphur springs, thereby polluting the river. In a 1983 report, the sulphur springs were reported as fountains springing from the riverbank and reaching a height of up to 50m, indicating very high flow rates and pollution loads[87]. Later changes in mining methods and the installation of subsurface cut-off walls reduced but did not eliminate the flow of sulphurous water into the Tigris.

The area of mineral extraction is somewhat disturbed but still retains vegetation and supports grazing

10.3 2003 sulphur fire

The Al Mishraq sulphur fire in 2003 was a major environmental disaster and the site assessment covered the aftermath of this event.

The fire was started by arsonists on 25th June 2003 and burned continuously for a month, although it was largely under control by 8th July[88]. Reports of the sulphur volumes burnt range from 300,000 to 400,000 tonnes. The fire was eventually contained by a combination of isolation by earth berms – man-made embankments – burial with earth and foam smothering. The state of the sulphur stockpile before and after the fire is presented as Figures 10.4 and 10.5 respectively, indicating approximately a 70% loss in area.

➤ Figure 10.4 Sulphur stockpile 17th June 2003

IKONOS–2, 17 June 2003 Image courtesy of European Space Imaging GmbH

➤ Figure 10.5 Sulphur stockpile 29th April 2005

Quickbird, 29 April 2005 Image courtesy of Digital Globe

Burning of pure sulphur produces sulphur dioxide gas, which is corrosive and toxic. At the high concentrations generated by the fire it was present as an aerosol (white smoke/fumes). When dispersed in the atmosphere it reacts with water, other gases and dusts to form sulphuric acid and sulphates. The sulphuric acid is contained in water vapour and droplets and forms acid rain.

Figures 10.6 and 10.7 cover both the sulphur stockpile and mining waste areas. The imagery indicates that the western edge of the waste area was also partly burned and/or disturbed by firefighting activities. The waste sulphur piles include bitumen, the burning of which would have generated particulates and incomplete combustion products such as polyaromatic hydrocarbons.

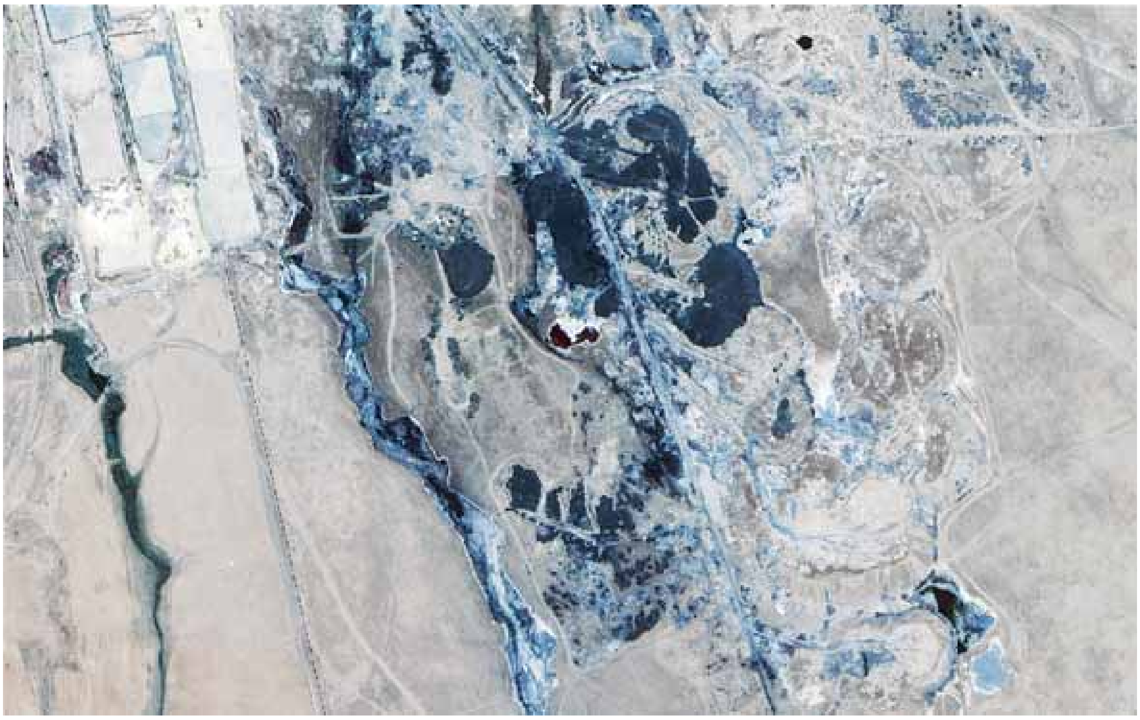
Satellite image tracking of the smoke plume [89, 90,91] showed the sulphur dioxide (SO_2) cloud dispersing generally to the south east, however on some days it was also dispersed northwards. Elevated SO_2 concentrations were detected over 200 km distant. Figure 10.8 shows the smoke plume emanating from the sulphur waste area site and trending southeast. Figure 10.9 shows the plume dispersing to the south east and south, clearly discernible for more than 100 km.

At the local level, 25 villages and three towns were badly affected, with many hospital reports of respiratory problems and at least two deaths. At the time of the fires a large part of the local population evacuated their villages. Media reports at the time of the fire indicate that extensive damage occurred to wheat crops in the vicinity of the fire. It is believed that this was a result of acute acid burns to the exposed plants, resulting in plant death and stunted growth.

An important question is whether the fire caused any long term environmental damage. The potential longer term impacts of concentrated sulphur dioxide fumes are well known from studies of fumes from mines and smelters. The most common impact is vegetation dieback, particularly trees. In the absence of vegetation, erosion rates are significantly increased and, dependent upon topography, the area can become stripped of topsoil and effectively barren.

Facilities such as smelters are a chronic source of pollution for periods of years, whilst the fire was an intense but short-term source. Rapid vegetation dieback was recorded, but there has been no scientific study done to date regarding the long-term effects.

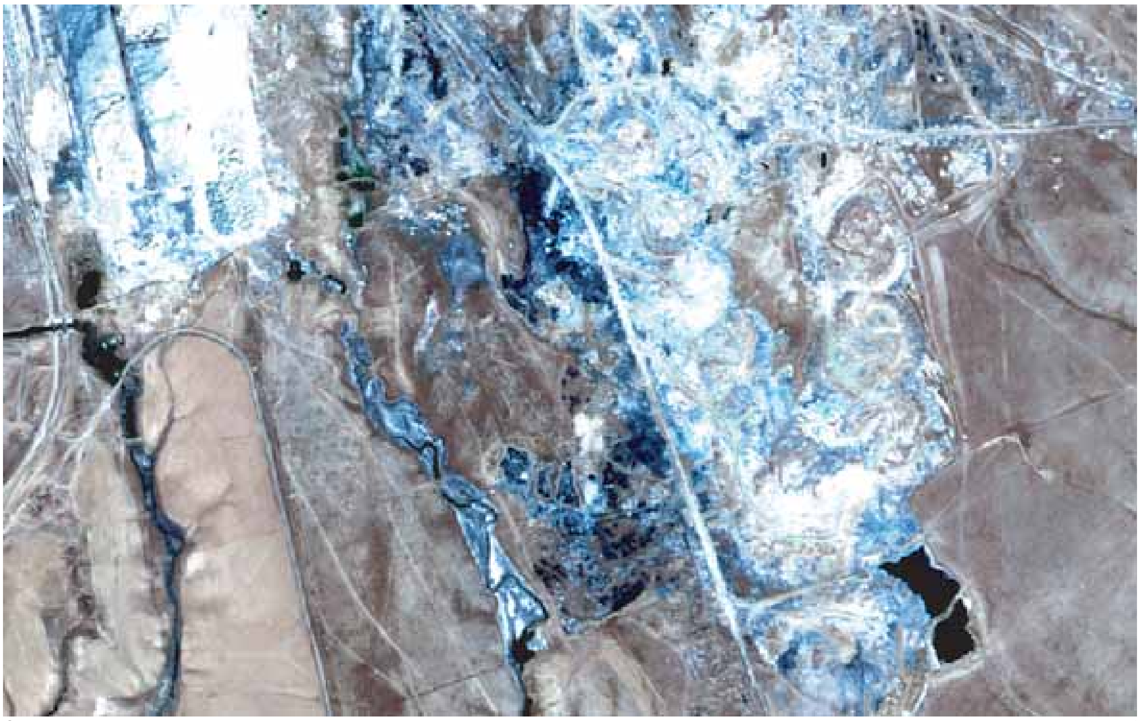
➤ Figure 10.6 Mining waste area 17th June 2003



IKONOS–2, 17 June 2003
Band combination: Red, Green, Blue

Image courtesy of
European Space Imaging GmbH

➤ Figure 10.7 Mining waste area 29th April 2005

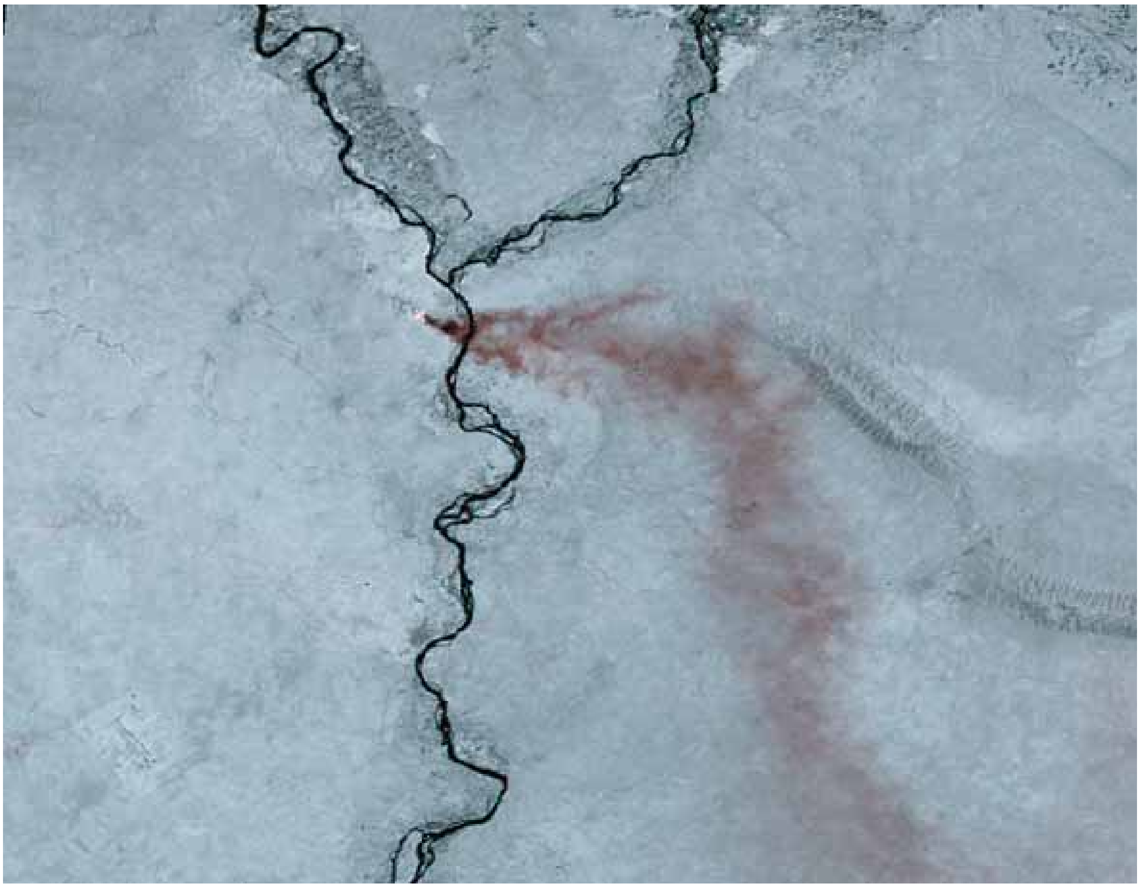


Quickbird, 29 April 2005
Band combination: Red, Green, Blue

Image courtesy of
Digital Globe

Figure 10.7 from 2005 shows the extent of the fire in the stockpile and waste areas. Approximately 1 –2 km^2 has been stripped of vegetation, covered in ash or otherwise disturbed. Much of the damage outside of the area of the fire was done by firefighting equipment including bulldozers and heavy earthmovers which stripped soil and dug pits to obtain material for fire suppression.

Figure 10.8 Smoke from the Al Mishraq sulphur and waste fire



Aster, 14 July 2003
Band combination: 10, 11, 13

Image courtesy of
UNEP / DEWA / GRID – Sioux Falls

Figure 10.9 Regional SE dispersion of smoke and SO_2 plume

Aster, 14 July 2003
Band combination: Near IR, Red, Blue

Image courtesy of
UNEP / DEWA / GRID – Sioux Falls

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➤ Figure 10.10 Drainage gullies leading SE from waste area to River Tigris

Quickbird

Image courtesy of Digital Globe, 2005

➤ Figure 10.11 Detail on mine sediments in Tigris riverine flats

Quickbird

Image courtesy of Digital Globe, 2005

Local erosion and sedimentation can be seen in the immediate vicinity of the fire area. Much of this land, however, was expected to have already been in a degraded state as a result of mine operations. Figures 10.10 and 10.11 are undated but are clearly from before the fire (based on reference features). The image shows highly reflective mine sediments in the river flats, downstream of the mining waste areas.

The area affected by the 2003 fire shows zones of ash but also substantial revegetation by spring 2005

The ash-vegetation border is relatively abrupt with ash indicating areas of complete plant loss including roots and seedstock

A visit to the site by the MoEn team in April 2005 included an inspection and soil sampling in the vicinity of the fire. Healthy annual vegetation and grasses can be seen immediately adjacent to the burnt areas.

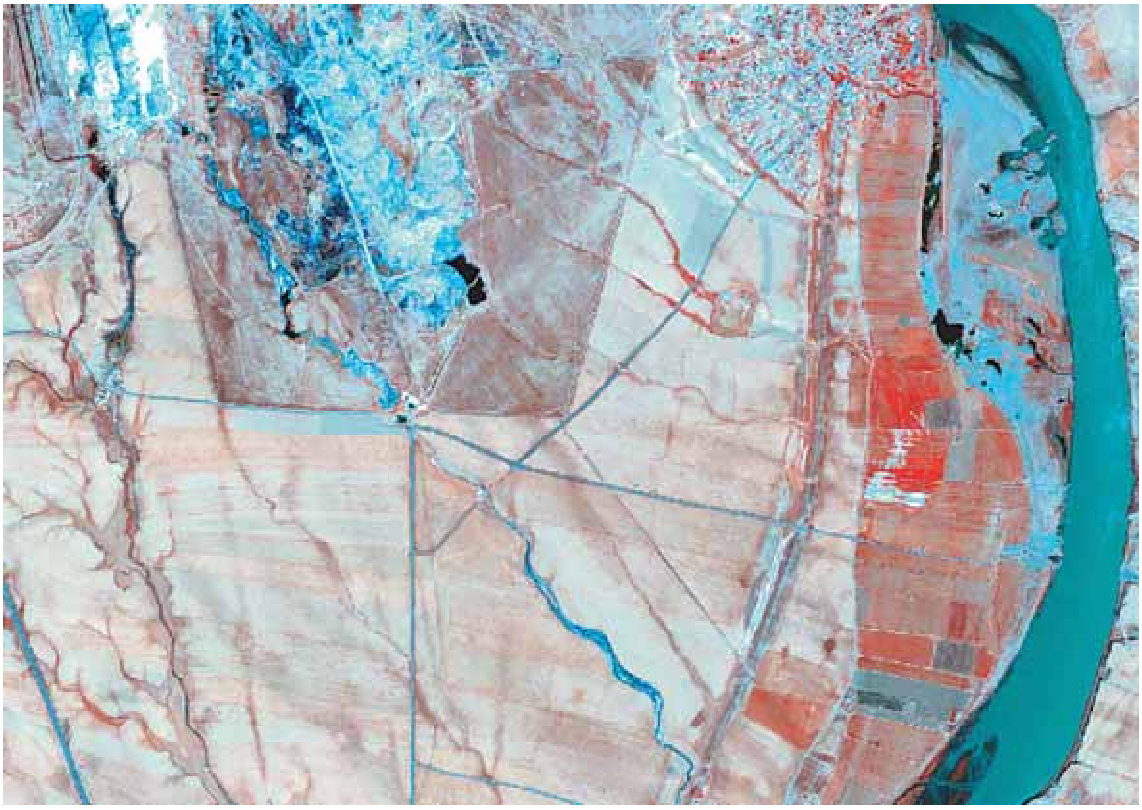
A limited comparison of satellite images also indicates no major permanent damage. Figures 10.12 and 10.13 show cropped areas adjacent to the River Tigris 5 km east of the fire site on 17th June 2003 and 29th April 2005. Whilst there are seasonal differences, there is no apparent large-scale change in the intensity or areas under irrigation.

➤ Figure 10.12 Mishraq SE region agriculture 17th June 2003

IKONOS–2, 17 June 2003
Band combination: Red, Green, Blue

Image courtesy of
European Space Imaging GmbH

➤ Figure 10.13 Mishraq SE region agriculture 29th April 2005



Quickbird, 29 April 2005
Band combination: Near IR, Green, Blue

Image courtesy of
Digital Globe

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In summary, the work done in this study is not considered extensive enough to provide firm evidence and conclusions, however, the early indications are that the damage to the environment from the Al Mishraq fire was not permanent and natural recovery is very well advanced after two years.

The temporary nature of the damage is probably due to the soil buffering capacity which can neutralise episodic acidic rain and surface water and thereby protect plant root systems from permanent damage. Leaves and stems exposed to the acidic aerosols will have been damaged at the time of the fire, but plants can survive and grow back whilst future crops planted or sown will be largely unaffected.

10.4 Site assessment activities

The Al Mishraq site was visited by Ministry of the Environment staff twice in 2003 and 2004 for general fact finding, and once in 2005 for detailed sampling and monitoring. Table 10.1 details the sampling and monitoring activities of the March 2005 site visit.

Table 10.1 Site assessment activities at Al Mishraq

Sample type / activity	Number of samples or points
Soil	26
Waste chemicals	–
Surface water	5
Groundwater wells	5
Total samples	36

In addition to the sampling work, the MoEn staff toured the site with a video camera and took over 60 photographs, many of which are presented in this report.

The Al Mishraq site is over 17km^2 in area and so was not examined in detail. The work focused on the area of the 2003 fire and the sulphur storage and waste areas. Groundwater wells outside the site were sampled and monitored with a portable instrument.

The general industrial facilities and the core processing plant such as the power station, boilers and sulphur process trains were not examined in any detail. It is believed that these facilities would have the normal range of hazardous waste and contamination, however, this was beyond the scope of this study.

10.5 Site chemicals and toxicology

The most important chemicals and material present at the Al Mishraq complex are;

- Pure sulphur;
- Aluminium sulphate;
- Asphaltenes (bitumen);
- Sulphuric acid;
- Hydrogen sulphide (in groundwater).

Sulphur, aluminium sulphate and bitumen have relatively low toxicity to humans. Sulphur is present naturally in food and in low concentrations it is an important element for human health. Aluminium sulphate is used in food preservatives, cooking and water clarification and purification. Bitumen, whilst toxic to ingest, is used universally in road construction.

Drainage ponds close to the acid plant contain dilute sulphuric acid

Sulphuric acid is of concern primarily due to its corrosive affects. The acid plant is expected to contain significant quantities of residual acid in pipes, tanks and basins. Acid may also be present in surface water drainage and leachate from the sulphur waste piles

Hydrogen sulphide is a toxic gas, which is naturally present in the groundwater of Al Mishraq. The site assessment team reported that at least four local village wells are no longer used due to elevated hydrogen sulphide levels. Hydrogen sulphide may also be present in the waste sulphur piles if anaerobic conditions prevail.

10.6 Hazardous wastes and soil contamination

The soil in the Al Mishraq area contains naturally high levels of native sulphur and sulphate, primarily gypsum. In the mine area, elevated concentrations of bituminous compounds are also found naturally. Accordingly, it would be wrong to conclude that the site is contaminated because of these compounds are present.

The area has naturally high levels of sulphate which apparently do not seriously impact the vegetation

Laboratory analysis of soil indicates levels of sulphate of up to 26%. This is thought to indicate that the soils or the waste contain a high percentage of gypsum. Elevated concentration of chromium and nickel were also detected in one sample.

The large piles and areas of sulphur mining and process wastes are definitely waste materials. However, they are not considered to represent hazardous wastes in the normal sense.

10.7 Land degradation

Approximately 10% of the site is mining waste dumps, which could be classed as degraded land. The degradation is caused not so much by the concentrations of contaminants as by the disruption of the land surface by dumping, topsoil stripping, dipping of pits, the erosion of waste piles and downstream sedimentation.

Other undeveloped areas of the mining complex appear to be slightly degraded but still supporting vegetation and in 2005 were supporting livestock (small herds of cattle).

Satellite image analysis indicates no large scale land degradation outside the mining complex boundary which could be directly related to the site. Small scale deposition of mineral salts is detectable on the north riparian flat of the Tigris, although the actual impact of this material on the river or the riparian ecology is unknown.

Land degradation in the mining and processing areas is caused by a combination of excavation, spoil dumping, erosion and mineral concentrations killing off vegetation

10.8 Surface water contamination

Laboratory analysis of surface water indicated high levels of sulphates and carbonates. Water contamination by sulphur compounds is also a natural process in the Al Mishraq area. Sulphur compounds known to exist naturally include sulphates and hydrogen sulphide. Much of what was analysed could therefore have occurred naturally.

Sulphur and mineral deposits lining the drainage canal indicate water pollution has been ongoing for many years

The natural and induced contamination was differentiated on the basis of pH. What is not expected naturally is strongly acid water, i.e. pH 4 or below. The natural baseline for surface waters for the River Tigris was recorded as pH 8.4. In contrast, four surface water ponds and channels in the vicinity of the sulphuric acid plant and

Surface water near the sulphuric acid plant is very acidic

waste piles had pH values of 0.6, 0.7, 2.2 and 4.1 indicating highly acidic sources. The sample with a pH of 0.6 also had elevated levels of metals including copper, lead, arsenic, chromium and beryllium. This is to be expected in such an acidic sample as metals are liberated from soil minerals under acidic conditions [92].

The worst affected ponds have a pH of less than 1, indicating highly acidic conditions

As the plant had been shut down for two years, the surface water sampled is not effluent from ongoing operations. The acid is therefore either residual effluent mixed with rainwater or ongoing acid drainage due to sulphide decomposition. In either case the surface water in the vicinity of the sulphur treatment complex is unlikely to regain a balanced pH in the short to medium term.

The area of acidic surface water is located approximately 4 km from the River Tigris and is connected to the river by two steep sided gullies. The gullies appear to be mainly dry and the drainage rate during March 2005 visit was limited (less than 0.1m^3/second). Significant short term flows could however be expected during the rare rainy periods.

10.9 Groundwater contamination

The MoEn team sampled five local village wells outside the site at a distance of 1 - 5 km from the site boundary and interviewed residents regarding their use and history. Four out of five wells were reported by the local population as unusable due to high sulphate or hydrogen sulphide levels.

10

The results of the field monitoring are summarised in Table 10.2 and the detailed analyses are in the report Annex.

In summary of the analysis, the pH levels appear to be within normal limits, but total dissolved solids concentrations are high. In the absence of historical data it is impossible to interpret whether the wells became unusable due to the mining operations or natural conditions. What is clear, however, is that much of the groundwater in the region of the site is currently not of potable quality due to its mineral content.

The local well W2 is no longer in use due to sulphate levels

Table 10.2 Al Mishraq region groundwater field monitoring results

Sample	General sample location	Depth to water metres	On-site monitoring results			
			Temp °C	pH	EC m/s	TDS g/l
W 1	5 km from the S complex boundary in the south direction. Nasser village, unusable well, the location was affected by the 2003 fire.	10	19.8	8.2	2.47	1.23
W 2	2 km from the complex boundary in the east. Al-Safina village, unusable well.	1.5	19.5	7.0	3.4	1.70
W 3	2 km from the complex boundary in the south west direction. Nastil village, well usable for irrigation.	20	23.8	6.7	7.01	3.46
W 4	>3.5 km from the complex boundary in the west direction. Zahra village, well unusable for eight years.	5.7	19.1	7.7	11.23	5.6
W 5	>1 km from the complex boundary in the west direction. Nina'a village, a new well unusable till now due to the high sulphur content and H2S gas.	>50	23.7	7.6	6.06	3.02

10.10 Risk assessment

The qualitative assessment of the risk to human health and the environment is based upon a review of the site-specific sources, pathways and receptors. The key points of each factor for Al Mishraq are listed below and on the next page:

Sources – areas and chemicals of concern

The most important source of risk on the Al Mishraq site is considered to be the sulphuric acid detected in the surface water. The source of this acid is anticipated to be either residual process effluent or decomposing sulphides in the waste piles.

The raw sulphur and sulphate are not considered to be important sources in terms of toxicity.

The acidic ponds although hazardous are fenced off from public entry

Receptors – human health

The site is currently non-operational, fenced and guarded. The hazardous areas are limited to surface water ponds and gullies in a limited part of the site. Thus, the most important receptors are limited to staff and trespassers entering these areas.

Dependent upon the pH of the surface water and groundwater draining offsite and into the River Tigris, site neighbours could also be classed as potential receptors.

Environmental receptors and habitats

The River Tigris, which borders the site, is an obvious and significant environmental receptor. Previous reports indicate that the ore body is directly linked to the river and that significant pollution by heated sulphurous water had already occurred.

The Great Zab River joins the Tigris opposite the main area of sulphurous water discharge. It is therefore probable that this area was also affected during production. The river junction is upstream of the current acid drainage zone so it is not considered to be a key receptor (unless operations restart).

Exposure pathways

For the site workers, the principal pathway to exposure to the acid would be direct contact with the contaminated surface water. This is not considered to present a significant risk, provided that workers are aware of the risks.

The acid drainage would present a risk to any one attempting to use it for irrigation. However, it is understood that in general the agriculture in the region is either rain fed or irrigated with water from the Tigris.

Acid drainage into the Tigris may affect local water quality but the scale of the river flow compared to the drainage gullies indicates that the impacts would be localised due to dilution and the buffering capacity of the river water.

10

Risk summary

In summary, the Al Mishraq site is considered to represent a **low risk** to human health, principally site staff and trespassers. Site neighbours may be at moderate risk if they attempt to utilise the runoff water from two of the gullies. River Tigris ecology may be at **low risk** from ongoing acid mine drainage. This is expected to be a chronic issue, but also limited in severity and extent.

10.11 Findings

The key findings for the site are:

- Desk-based research indicates that surface water and groundwater pollution from the Al Mishraq site was significant at the time of its operation. The principal receptor was the River Tigris. The primary pollution source was the superheated water injection process. Now that the plant is idle, this source is absent;
- Following the June 2003 sulphur fire, initial investigations indicate that short term damage to vegetation was severe close to the plant but there is no evidence of widespread or significant long term damage;
- A large area inside the complex contains sulphur and bitumen contaminated waste spoil piles and this areas is regarded as degraded land but not hazardous waste;
- Rainwater and drainage ponds and gullies close to the sulphur processing and acid plants contain hazardous levels of acid. Runoff from these areas may be affecting local river water quality;
- There is regional moderate groundwater contamination by sulphate and hydrogen sulphide, but much of this may be naturally sourced;
- The site in its current state represents a **low risk** to human health and the environment, principally due to the acidic surface water ponds. Maintenance of site security can minimise this hazard;
- In the absence of corrective action, the hazard levels will remain high for decades.

The untreated effluent issuing from the alum plant

10.12 Recommendations

Summary

No short-term recommendations are provided, as the situation at Al Mishraq is considered as poor but stable and therefore not warranting urgent corrective action.

In the long term, environmental issues should be thoroughly addressed in any proposal to demolish or instead upgrade and re-start the plant.

Details

In the long term, the facilities will either be demolished or upgraded and re-started.

Demolition of the facilities will present a range of hazards which can be best assessed and managed at that time. Disposal of residual effluents and the rehabilitation of acid ponds and waste areas will be the key environmental issues.

Upgrading the Al Mishraq plant to meet modern environmental standards is expected to be costly

Environmental issues should be thoroughly addressed in any proposal to upgrade and re-start the plant. These issues are significant enough potentially to affect the economic viability of any renewed operation. The overall environmental performance of previous operations was well below acceptable international standards and at the time probably caused regional scale damage to the River Tigris' ecology and lowered the intake quality for downstream town water supplies.

Bringing the plant up to modern standards and rehabilitating the worst of the existing damage would probably entail the following:

- Installation of a wastewater treatment plant;
- Installation of process and boiler stack treatment units;
- Extensive subterranean cut-off, drainage and water injection works to protect the river from further lateral leakage of the superheated mining solutions;
- Extensive environmental monitoring;
- Rehabilitation of the acid water ponds and drainage zones by pH buffering with limestone and other forms of neutralisation.
- Partial rehabilitation of the waste areas by cut and fill landscaping, filling in the ponds, providing topsoil coverage and re-vegetation;

These potential works have not been costed in detail but are estimated to exceed US$ 50 million in capital costs alone.

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Ouireej results and recommendations

11.1 Site introduction

The Ouireej scrap yard is located 15 km south of Baghdad, in the flat alluvial plain southwest of the River Tigris.

Figure 11.1 Oiureej site setting

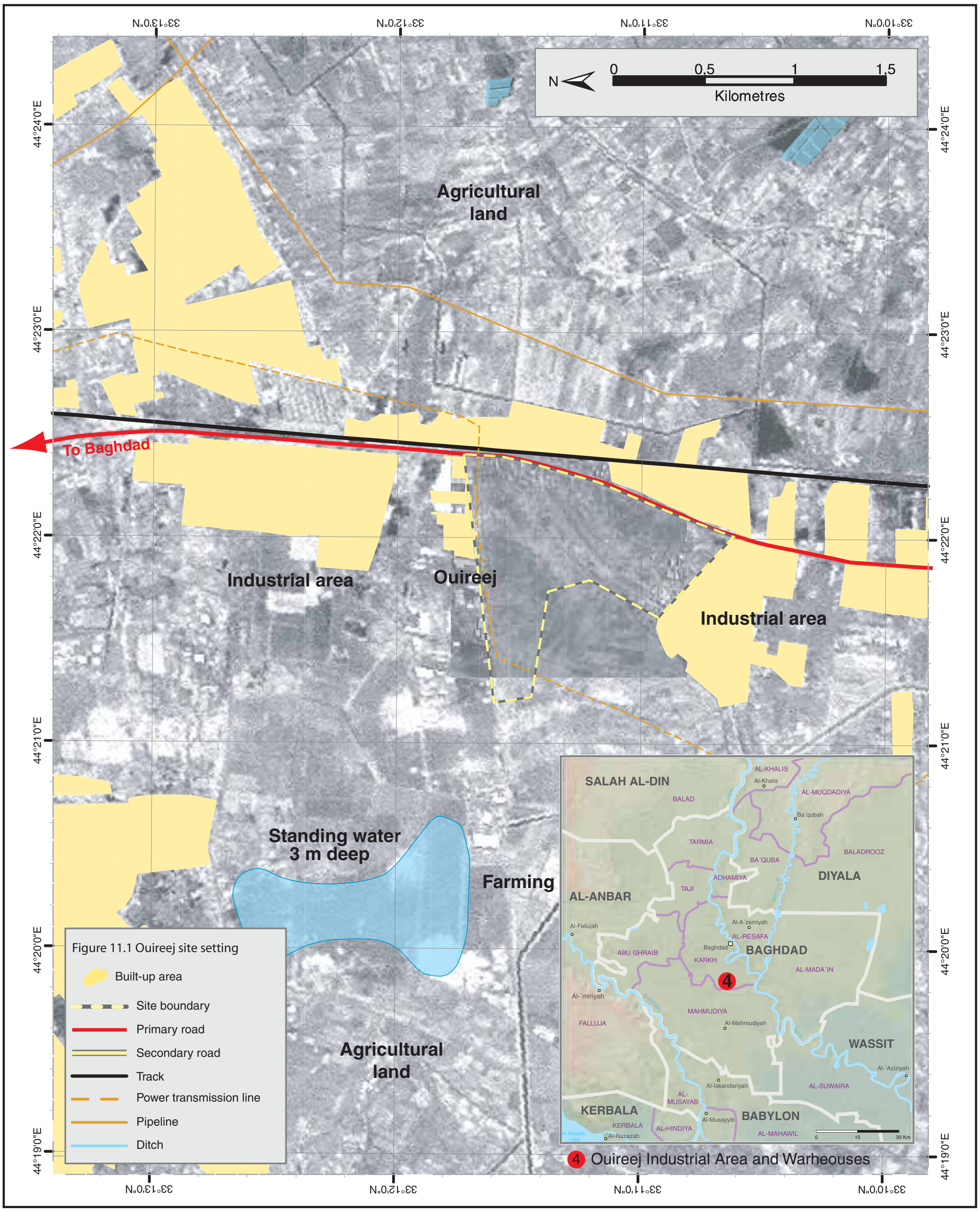
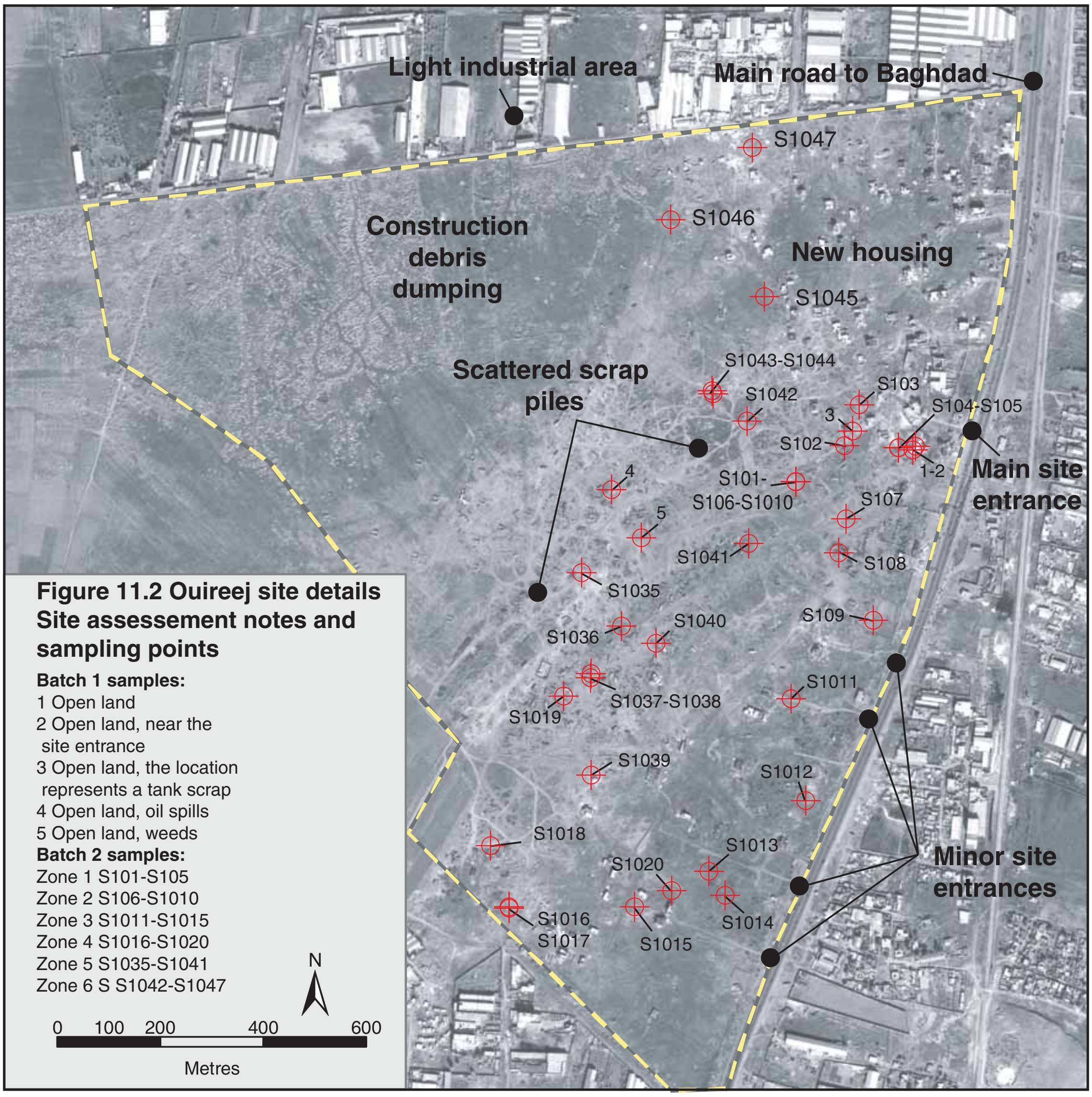


Figure 11.2 Oiureej site detail



The site is approximately 60 hectares in size and contains a range of military and civilian scrapped vehicles and machinery. The site was used as a storage and active scrap recovery facility in 2003 - 2004, but is now effectively idle. The activities noted on site during its operating period include:

Ouireej contains a mixture of civilian and military scrap

- Cutting and dismantling vehicles and machinery into manageable sizes;
- Sorting and separating scrap into different metals and non-metallic components;
- Crushing to reduce volumes;
- Burning of cables etc, to remove plastic coatings from metal.

The surrounding land use is a mixture of industrial residential and agricultural. There are some houses on and adjacent to the site. The margins of the site also appear to be used for dumping of construction debris.

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The site is very sparsely occupied and there is a great deal of vacant or unused land. Figures 11.1 and 11.2 show the site and surrounding land uses.

Assessment of satellite images indicates that the site was vacant land prior to 2003. The site was apparently originally marked as residential and titles were given out for many housing plots prior to 2003, each of approximately 300m^2 in area. From mid 2003 onwards, the site was nominated by the Baghdad municipality as one of the dumping grounds for damaged and redundant Iraqi military vehicles and equipment.

MoEn staff report that the scrap operations on the site reached a peak in late 2003 and throughout 2004 and that the amount of scrap on site at present (June 2005) represents only 25% of the original volume. The scrapping operations apparently closed down due to a combination of dwindling economic returns and pressure from the municipalities.

The cutting up and removal of scrap at Ouireej was largely uncontrolled

MoEn staff reported that two site workers were killed during the operating period, one from an explosion and one from poisoning (no further details available). There were also anecdotal reports of multiple complaints of skin problems from the scrap workers, particularly skin lesions and irritation.

11.2 The military scrap industry in Iraq

Scrap metal recovery and export is one of the few industries currently thriving in Iraq. As military equipment commonly contains significant quantities of steel and other metals, it is one of the preferred targets for the scrap industry. Prior to 2003, the Iraqi army had a large number of armoured and heavy pieces of equipment. Very approximate numbers of the key items are as follows[38]:

- 2,000 main battle tanks (types T55s, T62s and T72s);
- 2,000 armoured personnel carriers (APCs);
- 4,000 artillery, anti-tank and anti-aircraft guns.

It is assumed that the majority of this equipment has already been scrapped or is in the process of being scrapped, as it is either damaged, redundant or obsolete.

Scrap metal recovery in general is well known worldwide as a potential source of environmental and human health problems because of the uncontrolled way in which the metals may be collected, stored and processed. Common problems include:

- Hazardous working conditions;
- Chemical spillages;
- Land and water contamination;
- Inappropriate disposal of hazardous wastes;
- Fumes from burning waste.

The scrapping of military equipment presents additional issues and hazards when compared to the civilian scrap industry. These are related to the contents and condition of the military equipment when it enters the site, rather than the way it is scrapped. The most severe hazards

Discarded military hardware litters the site

arise from the scrapping of equipment destroyed or damaged in combat operations, as is the situation in Iraq.

The additional hazards for the scrapping of military equipment in Iraq are considered to be:

- Unexploded ordnance (UXO);
- Depleted uranium (DU) rounds;
- Polychlorinated biphenyls;
- Asbestos;
- Halons;
- Mineral oils.

These materials and the associated issues are explained in more detail below and on the next page.

Unexploded ordnance

Unexploded ordnance (UXO) is commonly found in destroyed or damaged military vehicles and particularly in tanks. A T62 tank can contain up to 52 rounds of 100mm shells, representing up to 200 kilograms of explosives and propellants.

When a tank is partly destroyed or damaged by gunfire, mines or other means, it may explode, burn or simply cease to function. Very commonly the ammunition is not all destroyed and remains inside the tank body, often trapped within twisted and burnt wreckage.

The fire and explosion hazard presented by cutting up scrap metal containing UXO is clear. In addition explosives are generally highly toxic.

Depleted uranium (DU) rounds

Multi-national forces used depleted armour piercing DU ammunition in the 2003 conflict; as 30mm shells in A10 ground attack aircraft and as 100 and 120mm anti-tank rounds used in American and British tanks.

DU is used in military operations as its very high density makes it suitable for use as penetrators which destroy armoured vehicles by punching a hole in solid steel walls and breaking up inside the vehicle.

Many of the destroyed Iraqi tanks and APCs were hit by DU rounds, normally 2 -7 times per armoured vehicle. These vehicles are therefore expected to have extensive DU contamination in the form of dust and large fragments. Over time, DU corrodes to uranium oxide powder, causing further dispersion.

DU presents a chemical hazard as it is moderately toxic (approximately the same as other heavy metals such as lead). It also presents a low-level radioactive hazard[10].

If DU is included in tanks taken away for scrap metal recovery, its fate can vary according to its form and the type of processing:

– DU and uranium oxide dust and fragments will be distributed on the ground surface around the original combat area and the scrap yard storage and processing areas;
– Whole DU rounds or pieces may stay intact and be exported with other scrap;
– The uranium may be smelted with the steel scrap and be incorporated in the ingots;
– Some of the uranium may burn during smelting, releasing uranium oxide dust.

By these processes, the original DU contamination may spread widely, causing additional problems and increasing the difficulty of future clean-up work.

Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) are extremely stable, non-flammable, non-corrosive, non-reactive fluids with the appearance of engine oils. They were used worldwide in industry in the 1960s and 1970s but are being progressively phased out, due to their toxicity, resistance to degradation and bioaccumulative effect[93,94] .

The T72 tank uses between 30-200 kilogrammes of pure PCB as hydraulic fluid to move the tank turret and main gun, and as an engine heat exchange fluid. The PCB is found in two pressurized storage tanks in the turret and in many hydraulic units, pumps and lines.

During scrap cutting and dismantling it is expected that virtually all of the PCB liquid will be spilled onto the ground and the site personnel will be exposed to high concentrations through direct skin contact.

PCBs are acutely toxic in large doses, but the most important hazard is the longer term risk of PCB-induced cancer from relatively low doses.

Asbestos

Asbestos is a naturally occurring mineral fibre that is widely used for insulation, fire protection and building. When processed, it can take many forms, such as loose cotton wool-like filling, woven cloth, or fibres in a solid mass, such as concrete. Asbestos is a human health hazard due to the damage that very small asbestos fibres can do lung tissue. The most important long term hazards are fibrosis (lung scarring) and asbestos-induced lung cancer[95].

T-72 tanks and APCs utilize asbestos to coat hydraulic lines and as a heat shield. Over time, and when damaged, the lines release asbestos dust. During scrap cutting and dismantling asbestos material and dust can be spread widely and dumped indiscriminately.

Halons

Halon is the generic term for halogenated organic compounds and, more specifically, a group of compounds containing chlorine, fluorine and hydrocarbons, otherwise known as chlorofluorocarbons (CFCs). CFCs were widely used internationally as refrigerants and fire fighting agents but they are being phased out as they are powerful ozone depleters[95]. Halon is used in T-72 tanks and armoured personnel carriers as a fire suppressant. It is contained in pressurized bottles and lines in the crew and engine compartments.

Mineral oils

Damaged military vehicles can be expected to contain significant mineral oils used as fuel, hydraulic oil and lubricants. As an example, the Iraqi T62 tanks have diesel fuel tanks with a total capacity of 600 litres.

11.3 Site assessment activities

The Ouireej site was visited by MoEn staff twice in 2003 and 2004 for general fact finding, and five times in 2005 for detailed sampling and monitoring. Table 11.1 details the sampling and monitoring activities of the April and May 2005 site visits.

Table 11.1 Site assessment activities at Ouireej

Sample type / activity	Number of samples or points
Soil	50
Waste chemicals	–
Surface water	3
Groundwater	–

In addition to the sampling work, the MoEn took over 80 photographs, many of which are presented in this report. Several video movies were made of the site inspections.

11.4 Hazardous wastes

The intensity of the assessment work was insufficient to provide any volume estimate for such a large site. However, it is clear that although hazardous wastes are present on the site, they are not present as large discrete stockpiles, but scattered as fragments, barrels and small piles. The most common type of waste appears to be scattered burnt residues from uncontrolled burning of the non-metallic parts of the scrapped vehicles.

Although unattractive, most civilian scrap materials are not classed as hazardous waste and can be recycled

Decayed and unstable UXO is exposed on the ground surface – suspected artillery/tank round

11.5 Unexploded ordnance

The site has not been assessed by a UXO expert, so any findings at this stage must be regarded as tentative. Photographic evidence does indicate UXO is present, however. One photograph shows what appears to be a partly buried artillery round with a white-phosphorous/tracer shell, whilst partly buried small arms ammunition is scattered across the site.

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Other ordnance sighted includes complete surface-to-surface missile bodies, although no investigation was made of the contents. Previous sight visits by UN staff in 2003 noted complete and damaged tanks, which were no longer present at the time of the latest visit by MoEn staff.

11.6 Land and water contamination

Shallow soil contamination is present at numerous points throughout the site, as evidenced by encrustations of metal oxides, oil stains and discoloured ground.

Laboratory analysis of shallow soil detected contamination by PCBs, mineral oil and heavy metals, principally copper, lead, antimony and zinc. The detected levels of all contaminants were relatively low. PCB contamination was relatively widespread, being detected in eight soil samples with a maximum concentration of 23 µg/kg.

Surface soil contamination by metal compounds is clearly visible in parts of the site

Laboratory analysis of rainwater ponds on the site indicated marginal contamination by heavy metals and mineral oils.

In summary, the limited sampling to date indicates that the site is **slightly contaminated** with the compounds and elements anticipated from scrap metal recovery operations.

Analysis of surface water on the site indicates contamination by oils and metals

11.7 Risk assessment

The qualitative assessment of the risk to human health and the environment is based on the RBCA framework and a review of the site-specific sources, pathways and receptors. The key points of each factor for Ouireej are listed below and on the next page.

Sources – areas and chemicals of concern

There are multiple potential sources of risk on the Ouireej site, including PCBs, heavy metals and hydrocarbons. Contaminants anticipated but not detected to date include asbestos and depleted uranium. The presence of UXO is a real but unquantifiable risk.

The most toxic source materials detected to date are PCBs. The detected concentration, however, is very low (23 µg/kg) just 2.3 times the Australian screening value of 10µg/kg. Given that the likely source of the PCBs (tank hydraulic lines) contained pure PCBs, the detected concentration is very likely not the maximum concentration present on site. The detected concentrations of 1 – 23 µg/kg are more indicative of contamination spread thinly across the site by traffic driving across isolated hotspots of high concentration.

Receptors – human health

The site is currently operational and open to the public. New housing is encroaching onto the site on the eastern and southern sides, and in some cases houses are nearly surrounded by scrap piles.

The most vulnerable receptors with respect to human health are considered to be site workers and the housing residents, particularly children.

Children playing on the Ouireej site are the most likely group to be affected by the toxins and UXO still present

11

Environmental receptors and habitats

The site is in a generally built-up area. There are no relevant environmental receptors on or immediately surrounding the site. The River Tigris is considered too distant to be affected.

Exposure pathways

The majority of the contaminants detected and anticipated on the Ouireej site have relatively low mobility but are persistent in the environment. Widespread migration outside the site is not expected, with the exception of material inside exported scrap and adhered to vehicle tyres.

Within the site, the most important exposure pathway for human health is considered to be direct contact, followed by accidental ingestion. Inhalation of contaminated dust is also an important pathway, particularly for asbestos and DU.

Risk summary

In summary, the Ouireej site is considered to represent a **moderate risk** to human health, however this hazard is largely confined to site workers and site residents. The presence of both military scrap and site residents raises the overall hazard level beyond that normally found and accepted in scrap metal yards worldwide.

11.8 Findings

The key findings for the site are:

- The site in its current state represents a **moderate risk** to human health, primarily to site workers, but also to site residents;
- The principal toxicity risk is from direct contact with and inhalation of chemicals in the process of transporting, cutting, sorting and burning the scrap;
- Explosion and fire risks from UXO present on the site are expected but cannot be quantified;
- The mixing of civilian and military scrapping activities is increasing the scale of the problem;
- The observed house building on a working military scrap yard site with UXO risks is creating new risks and issues.

11.9 Recommendations

Summary

In the short term;

1. The local municipality, in partnership with the MoEn and on-site contractors, re-organises the site to separate the military scrap activities, civilian scrap and dumping activities and residential housing;
2. UXO risks are investigated and eliminated at the time of the re-organisation.

In the longer term:

Construction of new houses in a military scrapyard area will result in more people being exposed to unnecessary risks

1. Hazardous waste in all areas is collected and disposed offsite to an appropriate treatment or disposal facility.

2. Surface soil is removed across the site to a depth of 10cm and disposed to landfill in order to remove the widespread traces of PCBs and other chemicals of concern.

Recommendation No.1 in detail

Military scrap storage and recovery is a subset of the scrap recovery occurring at Oiureej. Much of the military scrap does not present an unusual hazard, whilst a portion, such as tanks and UXO, clearly presents an elevated hazard.

Separation of the hazardous military scrap from other material by relocation and secure fencing would be a simple and cost effective method for reducing the risk of exposure for most site workers and all of the nearby residents.

Maintenance of this separation would need to be enforced by commercial means, e.g. only one contractor is allowed to deal with military scrap and is paid to manage the issue.

Basic capacity building and awareness raising to improve environmental practices for military scrap management is best achieved if there is only one licensed operator.

The current building of new houses in the scrap yard area should be stopped or managed to include land re-zoning and site cleanup prior to redevelopment. It must be acknowledged that this measure may be difficult to enforce or finance at this time.

No scope of work, cost estimate or timing is provided for these recommendations as the main issues are considered to be licensing controls and operations. In the absence of effective licensing and controls, any funds expended on site clean up would probably be wasted, as ongoing scrap activities would re-contaminate the area.

12

General findings and recommendations

12.1 Introduction

In addition to the specific findings for the five sites assessed to date, the project has uncovered a range of general problems in Iraq related to land contamination and hazardous wastes. These findings are discussed in this chapter.

Given the current security situation in Iraq and the wide range of development priorities, any recommendations provided by UNEP regarding land contamination or hazardous waste management must be realistic in scale. Recommendations also have limited value in the absence of a robust mechanism for their implementation. Therefore, not all findings are accompanied by specific recommendations.

The recommendations provided are presented in a concise format and include a summary, a nominated responsible party, outline scope of work, estimated time and cost. More detailed explanations of the recommendations including cross-linkages, prioritisation and the underlying rationale can be obtained directly from UNEP on request.

The general findings are:

- **Priority site identification and corrective action**. The serious problem of highly hazardous wastes on derelict industrial and military sites needs to be addressed with a programme of site identification, rapid assessment, local capacity building and appropriate corrective action;

- **Hazardous waste facilities**. A central hazardous waste management facility for Iraq is needed to enable proposed work and avoid future problems;

- **Oil industry sites**. Oil industry sites and ongoing pipeline breaks are undoubtedly a current major source of contamination and hazardous waste and need addressing in the medium to long term, by the oil industry;

- **Mining industry sites**. Mining industry sites have caused land degradation and in some cases extensive water pollution. Most sites contain quantities of mining waste which include hazardous compounds. Costly intervention measures are probably not justified unless the mines re-start or are permanently closed;

- **Military scrap yards**. The military scrap industry is an ongoing preventable source of human health and environmental hazards that could benefit from some simple reforms;

- **Munitions disposal sites**. Munitions disposal work is believed to be creating new contaminated sites which need to be drawn into the larger programme of priority site management;

- **Policy and legislation**. In the longer term, national strategies, policies, legislation and enforcement are needed for hazardous waste management and contaminated land.

Findings and recommendations are described on the next pages. Recommendations are also summarised in Tables 13.1 – 13.3.

12.2 Priority site identification

Finding summary. UNEP estimates that there are at least 20 and potentially up to 100 contaminated sites in Iraq where rapid corrective action is required to remove or secure highly hazardous wastes. As a first step such sites need to be identified and assessed.

Discussion. UNEP estimates that there are several thousand contaminated sites in Iraq, with several hundred among them rated as significant in terms of the scale and toxicity of chemicals involved. The international experience is that the site-specific human health and environmental risks from land contamination are generally relatively low but can be very high for a minority of sites. The same pattern is anticipated for Iraq, indicating that there are likely to be anything up to a hundred sites where quick corrective action is absolutely essential.

The sites of concern are nearly all derelict industrial facilities with uncontrolled public access. The principal source of hazards is the open dumping of highly toxic chemical wastes and the dispersal of such wastes by looting, demolition or weather. The quantities on site are expected to vary from less than a tonne to potentially hundreds of tonnes. Anticipated chemicals include hydrocarbons, cyanides, solvents, pesticides, heavy metals, explosives, acids and caustics.

There is insufficient information currently available to adequately plan a corrective action programme covering more than the sites assessed to date. A larger scale programme of site identification and rapid assessment would be needed to obtain this information.

The MoEn already has the technical capabilities to carry out this work as a result of the site assessment and capacity building work done to date with UNEP. They would need funding and logistical support to help them implement such a major project.

Recommendation. The MoEn, in partnership with other government departments and aid agencies, should lead a programme of site identification and rapid assessment to find and document sites where quick corrective action is required.

Responsible party. Ministry of the Environment. Partners – Ministry of Industry and Minerals, ex- MIC departments, aid agencies.

Scope. The structure and scope of the project depends upon the extent of involvement of other ministries. Ideally, each ministry should lead assessment of their own portfolio of sites, with the MoEn providing guidance and specialist resources, such as the central analytical laboratory. As a minimum, MoEn staff from each governorate plus a MoEn headquarters specialist should address each major site.

The list of sites in Tables 5.1 and 5.2 should be reviewed and other sites added, if known. A rapid assessment should be undertaken at each site, the scope of which should include:

- Desk study work on the history, chemicals and processes involved;
- Site visits to look for hazardous wastes, inspect facilities and take photographs;
- Limited sampling of wastes, water and soil and analysis of samples at the new MoEn laboratory;
- Concise reporting and ranking for risk – High, Medium, Low.

The list of sites ranked High will be scheduled for quick corrective action.

Timing. Rapid assessment is expected to take 2-3 months per site including reporting. Assessment of approximately 100 sites is expected to take 12 months, depending upon resources.

Cost. Estimated at US$ 400,000 based on MoEn local costs and US$ 4,000 per site to cover logistics, security, laboratory analysis, reporting, UN technical support and oversight.

12.3 Priority site corrective action

Findings summary. Iraq has a significant legacy of highly hazardous waste, including a number of sites where the risk to human health is so severe that rapid corrective action is required.

Discussion. Sites such as Al Qadissiya are indicative of the hazardous waste legacy that is now facing Iraq. Literally tonnes of highly toxic chemicals are dispersed on sites with uncontrolled public access. Deaths or injuries from exposure may have already occurred.

In the absence of corrective action, these wastes will continue to present a ongoing severe hazard. The chemical decay period for some materials noted is in the order of decades. Time, weather and further disturbance by looting or demolition will result in the dispersion and mixing of the material, potentially increasing the risk of exposure.

The experience from assessment of Al Qadissiya and other sites is that only a small fraction of the total waste volume can be classed as highly hazardous. Quick corrective action is only warranted for the most hazardous material, so prior assessment and targeting work can minimise the volumes requiring treatment.

The options for corrective action include the provision of on-site security (fencing etc), on-site treatment, on-site encapsulation and off-site treatment and disposal. The action selected needs to take into technical factors such as the waste form (solid, liquid), volume, toxicity and treatability, as well as local factors such as site location, accessibility and security status. In the short to medium term, the activities need to be very clearly scoped and limited, to ensure that costs remain proportionate to other development priorities.

Recommendation. A programme of hazardous waste cleanup and storage should commence, starting with the Al Qadissiya, Suwaira and Khan Dhari sites and scoped to include up to 20 equivalent sites to be identified at a later date.

Responsible parties. MoEn to act as coordinator and regulator, site owners (Ministries of Industry and Minerals, Finance, Agriculture and others) to implement.

Scope. Detailed scopes of work are listed in the recommendations for each assessed site. The general scope of work proposed includes:

- Volume and chemical survey of highly hazardous wastes only;
- Repackaging spilled and open wastes into drums;
- Cleaning, crushing and scrapping of damaged drums;
- Cleaning chemical dusts from buildings;
- Storing packaged wastes on site if secure. If not, transport to a secure site;
- Final disposal and treatment to await construction of a hazardous waste facility.

The majority of the work would be manual with limited machinery requirements and completely portable equipment. A capacity-building programme would be required for the work to be done by Iraqi national staff, companies or ministries.

A different option for final disposal would be the export of the wastes to another country with the necessary facilities to deal with them safely. At this stage this option is not addressed further due to the likely high costs.

Timing. The work could be completed for the first site in nine months and in three years for up to 20 sites, including time for site assessment and capacity building.

Cost. Without a volume and chemical survey, any estimate is highly speculative. Based on the costing of US$ 100,000 for Al Qadissiya and US$ 110,000 for Al Suwaira, 20 sites could cost in the order of US$ 2 million. This scale of expenditure excludes a thorough clean-up of all wastes and focuses only on the expected small volume of the most hazardous wastes.

12.4 Capacity building

Finding summary. There is currently no specialist technical capacity in Iraq to take any quick corrective action on highly hazardous waste. This would need to be developed prior to conducting any such works.

Discussion. Highly hazardous wastes identified to date include sodium cyanide and hexavalent chromium and mercury compounds. Explosives, chlorine and chlorinated solvents are also likely to be present. The management of such materials when in the form of uncontained wastes requires specialist expertise and equipment for materials handling and personal protection.

To the best knowledge of UNEP, such capacity does not currently exist in the Iraqi government or industry. Extensive technical knowledge on the industrial sites, chemicals and processes involved is however retained by the original operating staff and management. As a result, it is anticipated that the training aspects of capacity building would be relatively straight-forward if the right people were selected.

Recommendation. A specialised unit for taking rapid corrective action on highly hazardous wastes should be formed within the Iraqi government. The host organisation requires a mandate, resources and expertise. Potential hosts could include the Ministries of Environment, Technology or Industry and Minerals. It is recommended that the organisation includes staff sourced from the ex-MIC and Ministry of Industries engineering, scientific and project management departments.

Specialist equipment and training is needed to safely clean up chemical spills and chemical fire sites – Khan Dhari yard area

Responsible party. To be decided. Partners – Aid agencies.

Scope. The management structure of the project depends upon selection of the lead ministry. Ideally the lead ministry should a) be responsible for the majority of sites where the work will be carried out and b) employ the majority of staff trained and paid to do the work. The MoEn should retain the role of regulator and coordinator.

The scope of work should cover comprehensive capacity building for the works predicted, including training, provision of equipment and consumables and funding of initial operating expenses in Iraq.

Timing. Capacity building is expected to take eight months.

Cost. Estimated at US$ 400,000, based upon training 20 staff and equipping two site teams for initial work on two medium-sized sites.

12.5 Hazardous waste facilities

Findings summary. Iraq has no national or government controlled hazardous waste management facilities capable of handling hazardous wastes and no adequate system to identify, store, collate and transport such wastes.

Discussion. Desk studies and interviews have provided no evidence of an adequate large scale hazardous waste management facility anywhere in Iraq. Historically, the trend for hazardous waste disposal appears to have been on-site dumps for large facilities and co-mingling with municipal wastes for other facilities. The on-site facilities are typically unlined and uncovered pits and mounds with no environmental protective features.

Dedicated hazardous waste management facilities are required to permanently dispose of this type of material – Al Qadissiya

On a national scale, the responsible management of hazardous wastes requires one or more modern, adequately sized hazardous waste management facilities. Without some form of appropriate offsite treatment and disposal option, the current legacy will be difficult and overly expensive to clean up and new problems will arise.

Recommendation. A new hazardous waste treatment and disposal facility should be built for mainly inorganic wastes with most organic chemical wastes being incinerated in a nominated cement plant furnace.

Responsible parties. The Ministry of Industry and Minerals should be the lead sponsor of such a project. The MoEn should act in a regulatory capacity. The local municipality for the facility will also have an important role. The private sector has the capacity (internationally) to build and manage such facilities. However, privatisation of hazardous waste management needs to be carried out under tight control to avoid the creation of new problems.

Scope. Building a hazardous waste treatment and disposal facility is a complex and sensitive engineering project. The normal development process includes data collection on waste inputs, site selection work, technical studies, design, permitting, securing of funds and procurement.

The actual scope of the facility or facilities would depend upon the results of the development work. A conceptual model has been developed by UNEP as a starting point. The outline details of the model are:

- One centralised facility for safe management and final disposal of the majority of Iraq's highly hazardous inorganic wastes and some organic wastes;
- The majority of organic chemical wastes are incinerated as part of the fuel stream for a selected cement plant furnace;
- A minority of difficult organic chemical wastes are exported for treatment;
- The Ministry of Oil has its own specialist facilities geared to crude oil-based wastes only;
- The centralised facility has waste treatment units for oxidation, neutralisation, solidification and scrap recycling as well as two grades of landfill disposal cells and a highly secure aboveground storage unit;
- The centralised facility runs on a semi-commercial basis for cost recovery purposes;
- The facility is located on one of the large military industrial estates, which are already very heavily contaminated and no longer in use.

Timing. Development work including securing of funding is expected to require two years. Construction of the central facility would require one year.

Cost. The development work, including data collection on waste inputs, site selection work, technical studies, design, permitting, securing of funds and procurement is estimated to cost US$ 1.6 million.

It is expected that substantial development work would be required in order to provide a valid cost estimate for a central facility. The capital cost is expected to be in the order of US$20 million, assuming the land is provided free.

Costs for the incineration of organic chemical wastes and any Ministry of Oil facilities are excluded.

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12.6 Military industrial sites

Findings summary. The numerous derelict military industrial sites represent the most chemically hazardous areas in Iraq. Prospects for improvement are limited in the short to medium term.

Discussion. Sites in Iraq previously used for arms production and storage consist of 38 main facilities and dozens of smaller ones. The estimated total area of these sites is in excess of 100 km^2.

Engineers previously employed by the Ministry of Military Industrialisation (MIC) have reported to UNEP that the majority of ex-MIC manufacturing sites are in a similar condition to Al Qadissiya, i.e. derelict, looted and unsecured.

Table 5.2, provided by the ex-MIC engineers, shows the majority of contained chemicals and processes that could be expected to cause land contamination and generate highly hazardous waste. The extent of the problem will vary from site to site, but it is clear that the ex-MIC sites collectively represent a significant risk to human health and the environment.

Based on the Al Qadissiya findings and the experience with military sites worldwide, the full scale cleanup of the ex-MIC portfolio would cost in excess of US$ 1 billion and take up to 10 years, if implemented.

The future use of the sites is uncertain. In some urban areas, they will probably be redeveloped, whilst in remote areas they will probably remain vacant and derelict. In the absence of controls, it is likely that redevelopment will result in risks to the new site users from the existing hazardous waste and land contamination. The uncontrolled demolition of Al Qadissiya is a case study illustrating the current lack of controls.

Many of the abandoned military manufacturing sites are reported to be in a similar condition to Al Qadissiya

Recommendations. – none specifically for military industrial sites. The recommendation for rapid assessment and corrective action to address deposits of hazardous waste is discussed elsewhere. However, it applies especially to the closed military industrial sites.

12.7 Oil industry sites

Findings summary. Oil industry sites and ongoing pipeline breaks are undoubtedly a current major source of contamination and hazardous waste and need addressing in the medium to long term, by the industry itself.

Discussion. The number of oil-contaminated sites in Iraq is probably in excess of 1,000 based on the number of oil production, exportation and refining facilities, oil fire trenches and reported oil pipeline attacks. The great majority of such sites will be contaminated by surface spills of crude oil.

Under the prevailing climatic conditions, crude oil spilled to the land surface will mainly evaporate, but some will sink into the soil or remain on the surface until covered by blown dust or sediment from runoff. The result is a shallow layer of oily, tarry soil that remains for years to decades and is technically difficult to remediate. Oil that has penetrated the subsoil may also eventually infiltrate to the groundwater table causing localised pollution of the aquifer.

The toxicity risk from weathered crude oil is relatively low, so the overall acute toxic risk to human health is normally not significant. The odour, stickiness and smothering properties of large quantities of oil can, however, have a significant impact on-site users and neighbours. In high concentrations it will also kill vegetation and suppress re-growth.

Remediation of oil spills on land is expensive, with costs ranging from US$ 10/tonne to over US$ 100/tonne dependent upon location, concentration and technology. A large trunk pipeline spill can contaminate in excess of 10,000 tonnes of soil. Accordingly, a full cleanup the current list of oil contaminated sites in Iraq could cost hundreds of millions of dollars.

The approach taken to oil spill cleanup worldwide is normally based on three concepts:

Net Environmental Benefit Analysis (NEBA), Risk Based Corrective Action (RBCA) and cost-benefit. Application of these three concepts can help focus efforts on priority areas and control unwarranted expenditure, however it is clear that Iraq is faced with a potentially high cost for the remediation of these spills.

Unlike the remainder of Iraq industry, the oil and gas sector has a high future capacity for self management of environmental issues including oil spills, contaminated land and hazardous waste. The sector is very large and it has secure funding, relatively secure assets, strong growth prospects, a skilled workforce and some degree of environmental awareness. In future, the sound management of environmental issues will depend largely on awareness raising, capacity building and budget priorities within the oil industry itself.

Recommendation. There is considered to be limited need for a MoEn managed, aid-funded programme on oil industry sites. Instead, the MoEn should act as regulator to the oil industry, prompting it to improve performance and to clean up legacies.

Responsible parties. MoEn to take the initiative. Ministry of Oil to take responsibility and implement corrective action programmes.

Scope. The environmental problems and legacies related to Iraq's oil industry could take up to a decade to resolve. The potential scope includes oil spill cleanup and improvements on effluent treatment, waste management and emergency response,

Timing. Optimal management of the ongoing oil spills is a top priority. All other work is considered a medium priority. Remedial work could be carried out concurrently with the anticipated production and facility upgrades over the next 10 years.

Cost. The MoEn - Ministry of Oil liaison process would have a negligible cost. If general compliance with best international standards is the target, the cost of environment-related works for the oil industry is likely to be well in excess of US$ 100 million over the next decade.

12.8 Mining sites

Findings summary. Mining at sites such as Al Mishraq has resulted in local land degradation, however the cessation of mining activities throughout Iraq has greatly reduced the ongoing pollution load to soil, water and air.

Discussion. The operation of major mines such as at Al Mishraq and Akashat has resulted in severe but localised damage to vegetation cover, soil and water resources. Closure of the mines has put an end to the damage caused by operations such as effluent discharge. Thus, the situation has stabilised, although stockpiles, processing and tailings areas remain contaminated and present a residual risk to human health and the environment.

The rehabilitation of degraded land at the major mining sites in Iraq is considered too costly to justify at present

Mine site rehabilitation can be very expensive and is not considered a priority at this stage. In the event of the mines re-opening, the new operations will need to adopt modern environmental management techniques and standards, and possibly also address the legacies of prior operations.

Recommendations. None specifically for mining sites.

12.9 Munitions disposal sites

Findings summary. Munitions disposal work is believed to be creating new contaminated sites which need to be drawn into the larger programme of priority site management.

Discussion. The urgent need for the safe disposal of the current vast stockpile of redundant weaponry and munitions is not disputed. The methods used (controlled explosions, in place and in multiple control points) are also considered appropriate for the unstable materials of concern in the current security situation.

The primary concern relating to munitions disposal is the long-term risk to human health the disposal sites represent once the work is completed and the military have left. Such sites normally need a surface and shallow soil cleanup to remove remaining scrap, unexploded ordnance (UXO) and chemical contamination caused by toxic explosive compounds such as TNT.

In the absence of such work, Iraq will be faced with either a future high cost or the need to quarantine potentially large areas of land for the foreseeable future.

Recommendations. MoEn to commence a dialogue with the Ministry of Defence on this subject as a first step to site identification and assessment.

12.10 Military scrap yards

Findings summary. The military scrap industry is a preventable source of human health and environmental hazards that could benefit from some simple reforms.

Discussion. The recycling of scrap metals and other materials in Iraq is a beneficial industry that should be encouraged. However, the lack of any form of control on the military scrap industry is causing avoidable land contamination and human health hazards. The mixing of civilian and military scrapping operations such as that occurring at Ouireej is exacerbating the problem.

Scrap metal industries worldwide are recognised as both a source of environmental problems and difficult to control. The situation is particularly difficult for Iraq, given the rapid growth of the scrap industry and the lack of security.

In view of the current difficulties, the focus should be on practical short to medium term improvements such as controlling access to sites, land use zoning, licensing and export controls. The wholesale reform of the scrap metal industry to improve environmental practices, whilst desirable, is also probably not feasible in the short to medium term. The remediation of working scrap yard sites, such as Ouireej is also probably unfeasible at present.

Separation of military and civilian scrap operations could reduce the scale of the problem. The great majority of scrap metal generated is linked to civilian vehicles and derelict industries. Within the military scrap category, a large amount (e.g. trucks, building materials) also does not represent any additional hazard over civilian scrap. These materials could be left to the civilian scrap industry.

The small percentage of additionally hazardous military sourced materials does, however, present specialised problems and needs to be addressed separately.

Recommendation. The industry is re-organised and licensed on a commercial buy-back basis to separate and store hazardous military scrap.

Responsible party. MoEn working with municipalities, Ministry of Defence and multi-national forces.

Scope. A list of hazardous military scrap items should be developed and subject to special licensing and oversight. Examples of items that present special hazards include spent or empty munitions, missiles, rockets, artillery, tanks and armoured personnel carriers. Objects struck by depleted uranium rounds also present additional hazards.

The licensing should cover particular operators and sites permitted to transport, store and scrap the hazardous items. Where items cannot be safely scrapped, operators should be paid for the transport and storage until longer term disposal sites are found. Thus, the most hazardous material would be effectively bought back out of the market and controlled.

Timing. Modifications to the existing licensing regime should take no more than six months.

Cost. The additional cost of implementation and monitoring of the licensing regime would not be significant. The principal cost would be the buy-back of hazardous items for their equivalent scrap value and ongoing storage cost. Without details of scrap tonnages any estimate is speculative, but could be expected to be in the order of several million US$ across all of Iraq.

12.11 National strategy, policy and legislation

Finding summary. In the longer term, national strategies, policies, legislation and enforcement are needed for hazardous waste management and contaminated land.

Discussion. Current and pressing issues such as the highly hazardous waste identified on the priority sites can be managed with ad hoc project plans and without any new legislation. In the longer term, a national strategy and legislation are needed for hazardous waste management and contaminated land.

For hazardous waste management, the strategy should cover issues such as waste reduction, waste classification, transport, storage, treatment and facility licensing.

For contaminated land, the strategy should cover issues such as prioritisation, risk based corrective action, property redevelopment and pollution liability.

In both cases the strategy must be Iraq-specific in order to ensure that inappropriate and overly expensive solutions are not adopted from other countries without modification.

Recommendation. The topics of hazardous waste management and contaminated land are included in the medium to long term plans of the MoEn under their programme of environmental legislation development.

Responsible party. MoEn in liaison with the Ministries of Finance and Planning and Development.

Scope. Strategies for both hazardous waste management and contaminated land need to be developed, approved, funded and implemented. This will require strategy development, consultation, issuing of guidance material and finally development of legislation and statutory guidance.

Timing. 2 –5 years.

Cost. Minimal if development work is done mainly by the MoEn. Potentially up to US$ 300,000 over several years for assistance from UNEP and/or international consultants.

13

Conclusions

13.1 Project performance review

Completion of the scope of work

The Environmental Site Assessment (ESA) project was focused on the topic of chemically contaminated sites in Iraq. The project was scoped to include activities at both a high level (policy) and low level (individual sites). As of August 2005, all the scoped activities had been delivered and completed with no significant changes from plan.

Achievement of objectives

The two principal objectives of the project were:

1. The short-term objective of conducting priority site assessment work on the chemically contaminated sites identified as potentially presenting serious risks to human health and the environment;

2. The longer term objective of building institutional knowledge and capacity for the very much larger programme of site assessment, remediation and improvements in hazardous waste management that is foreseen for Iraq as part of its overall development.

These two objectives have been largely met, with the following limitations:

Priority site assessment. Initial work selected and focused on five priority sites. The initial screening work has revealed, however, that there are likely to be up to 100 sites requiring similar priority assessment.

Capacity building. Extensive capacity building has been achieved in the areas of site assessment fieldwork and data collection. This has enabled the assessment work to occur. Feedback from MoEn staff highlights the need for further capacity building in the subjects of data interpretation and development of solutions.

Additional achievements

In addition to the formal objectives, the priority site selection and assessment work provided sufficient information to form an overview of the situation in Iraq regarding contaminated sites and hazardous waste. This in turn has facilitated the development of recommendations and plans to begin to address these issues at the national level.

Impact of security

The ongoing security issues in Iraq significantly impacted the project, but did not prevent achievement of the project objectives. Key impacts included limitations on the extent and type of fieldwork, prevention of access by international experts to the sites and increased costs for capacity building due to course-related international travel.

Lessons learned

Planning for work in a conflict setting. The project was originally designed to operate in a post-conflict, but moderately secure environment. The deterioration in the security situation forced a change in strategy. The fact that the project objectives were met, despite the security issues, illustrates that it is possible to find practical solutions which strike the appropriate balance between security, cost and quality. Nonetheless, if the project were designed again, based on current security conditions, several important changes would be made to the capacity-building work to allow for the necessary and increased level of autonomy of the MoEn staff for the fieldwork and reporting stages.

Focus on hazardous waste. The original scope of work addressed both land contamination and hazardous waste aspects of site assessment. Findings to date clearly indicate that hazardous waste is the more serious issue for Iraq, so this subject could have been addressed in greater depth.

13.2 Summarised findings

The assessment of the five sites combined with general desk-based research provided sufficient information to form an overview of the situation for contaminated sites and hazardous waste across Iraq.

Findings have therefore been developed at both the national level and for each site assessed. The national level findings cover the following topics:

- Priority site identification and corrective action;
- Hazardous waste facilities;
- Oil industry sites;
- Mining industry sites;
- Military scrap yards;
- Munitions disposal sites;
- Policy and legislation.

The main national level findings are:

Industrial and military legacy of contamination and hazardous waste. Iraq is faced with a legacy of contaminated and derelict industrial and military sites. Most of the sites are unlikely to re-start operations, and a portion of the sites in urban areas may be redeveloped for residential or other uses. These sites have major problems with hazardous waste and variable but generally lesser problems with contaminated soil and water. In a minority of cases, the sites represent a severe risk to human health, specifically to site workers and trespassers.

Reduction in industrially sourced pollution. The closure of many of the sites has resulted in a net reduction in waste production and pollution loading of the air and water, as many large-scale polluting processes have now ceased.

Special case post-conflict sites – military scrap yards and munitions disposal. The ongoing destruction of Iraq's military arsenal is creating isolated cases of new contamination and hazardous wastes. Although this cannot currently be adequately addressed due to the security situation, some basic improvements in practices and forward planning could reduce the risks to human health and the environment, as well as reduce the cost of any future cleanup work.

Oil industry. The oil industry is a major source of land contamination and hazardous wastes, but is expected to have the resources to tackle this issue in the longer term. Pollution from pipeline ruptures due to sabotage is probably the most pressing but problematic environmental issue facing the industry at present.

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Policy and legislation. In the longer term, national strategies, policies, legislation and enforcement are needed for hazardous waste management and contaminated land.

The main the findings for the five priority sites are:

Al Qadissiya metal plating facility. This demolished site represents a **severe** risk to human health, due to cyanide containing hazardous waste.

Al Suwaira pesticides warehouse complex. The site in its current state represents a **low** human health risk, but only due to security preventing access to the contaminated warehouses. The warehouses are unsafe to use or even enter.

Khan Dhari petrochemicals warehouse site. Large parts of the site in its current state represent a **moderate** risk to the health of site workers. The site is therefore unfit for normal use.

Al Mishraq sulphur mining complex. Surface water and groundwater pollution from the Al Mishraq site was significant at the time of its operation but has now largely ceased. Preliminary work in relation to the 2003 sulphur fire indicates that the permanent effects on the environment are localised and limited. The site in its current state represents a **low** risk to human health and the environment, principally due to acidic surface water ponds.

Ouireej military scrap yard site. The site in its current state represents a **moderate** risk to human health, principally to site workers, but also to site residents. The mixing of civilian and military scrapping activities is increasing the scale of the problem.

13.3 Summarised recommendations

Recommendations have been developed for the national level and for each of the five sites and are summarised in Tables 13.1 and 13.2.

Table 13.1 National scale recommendations

Recommendations	Responsible party & partners	Timing (months)	Cost estimate US$ million
1. Identification of sites warranting quick corrective action. A programme of identification and rapid assessment of approximately 100 sites.	MoEn, site owners	12	0.4
2. Corrective action programme on priority sites. Hazardous waste cleanup and storage on up to 20 sites not yet assessed.	MIM, MoEn, MoO, ex-MIC, MoAg	36	2.0
3. Capacity building for corrective action. Training, provision of equipment and consumables and funding of initial operating expenses.	MoEn, MT, MIM, MF/ex-MIC	8	0.4
4. Hazardous waste treatment and disposal facility. Development work.	MIM, MT, MoEn, municipality	24	1.6
5. Hazardous waste treatment and disposal facility. Construction and equipment.	MIM, MT, MoEn, municipality	12	20
6. Oil industry sites. The MoEn redefines its relationship with the MoO and prompts the oil industry to start a programme of environmental improvements.	MoEn, MoO	Ongoing	Over 10 million (MoO)
7. Military scrap industry. The industry is re-organised and licensed on a commercial buy-back basis to separate and store hazardous military scrap.	MoEn, MoD, municipalities	Ongoing	Several million (Scrap industry)
8. Strategy, policy and legislation. The topics of hazardous waste management and contaminated land are included in the medium to long term plans of the MoEn for environmental legislation.	MoEn	24 -60	0.3

Table 13.2 Recommendations for the 5 sites

Site	Site Owner	Recommendations	Priority	Cost estimate US$
Al Qadissiya	MF/ex-MIC	Containment and removal of the most hazardous wastes.	High	100,000
Al Suwaira	Ministry of Agriculture	Containment of hazardous waste and warehouse decontamination.	Medium	110,000
Khan Dhari	MoO	Containment of hazardous waste and warehouse demolition	Medium	250,000
Al Mishraq	MIM	No short-term recommendations. Long-term recommendations for overall improvement in environmental management for the site if re-started.	Low	Not costed – Long-term issue
Ouireej	Municipality / private	The site is re-organised to separate the military scrap activities, civilian scrap and dumping activities and residential housing.	Medium	Not costed – civil issue
Total		Sum of short-term recommendations with costings		460,000

13.4 Implementation of recommendations

Recommendations have limited value in the absence of a robust implementation mechanism in Iraq. In addition, given the current security situation in Iraq and the wide range of development priorities, recommendations need to be prioritised.

The Government of Iraq holds ultimate responsibility for accepting and implementing the recommendations of this report as it considers appropriate. The government, represented in this case by the Ministry of the Environment, has made it clear, however, that assistance from the international community in the implementation phase would be welcome and beneficial.

A conceptual plan for implementation of the recommendations is set out below on the assumption that it would be organised as a partnership between the Iraqi government and one more national or international development agencies and that all of the recommendations will be funded and implemented.

Preparation – up to 12 months

Identification of and initial agreement with the partner national/international development agency or agencies;
Confirmation of funding, based upon review of the cost estimates provided for specific recommendations;
Detailed planning and mobilisation.

First phase - 24 months

Identification of sites requiring rapid corrective action;
Capacity building for corrective action on hazardous wastes;
Corrective action on Al Qadissiya, Al Suwaira and Khan Dhari sites;
Implementation of recommendations for Ouireej;
Development work for the hazardous waste treatment and disposal facility.

Second phase – 24 months

Corrective action on up to 20 other industrial military sites;
Construction and start-up of the hazardous waste treatment and disposal facility.

A

Annex A

List of Acronyms, Abbreviations and Units

Acronyms

APC	Armoured Personnel Carrier
EIA	Environmental Impact Assessment
ESA	Environmental Site Assessment
CFCs	Chlorofluorocarbons
CIS	Commonwealth of Independent States
CN	Cyanide
Cr(III)	Trivalent Chromium
Cr(VI)	Hexavalent Chromium
DRO	Diesel Range Organics
DU	Depleted Uranium
EPID	Environmental Protection and Improvement Directorate (Iraq)
GC MS	Gas Chromatograph Mass Spectrometer
GDP	Gross Domestic Product
GPS	Global Positioning System
H_2S	Hydrogen sulfide
ICP OES	Induction Coupled Plasma Optical Emission Spectroscopy
MCERTS	Monitoring Certification Scheme
MEK	Methyl Ethyl Ketone
MIC	Ministry of Military Industrialisation
MIM	Ministry of Industry and Minerals
MoF	Ministry of Finance
MoAg	Ministry of Agriculture
MoEn	Ministry of Environment
MoO	Ministry of Oil
MoT	Ministry of Technology (& Science)
NEBA	Net Environmental Benefit Analysis
OC	Organo Chlorine (pesticides)
OP	Organo Phosphorous (pesticides)
PC	Personal Computer
PCBs	Polychlorinated biphenyls
PCoB	UNEP Post-Conflict Branch
PAH	Polyaromtic Hydrocarbons
PID	PhotoIonisation Detector
PPE	Personal Protective Equipment
PRO	Petrol Range Organics
RBCA	Risk Based Corrective Action
SO_2	Sulphur dioxide
SVOCs	SemiVolatile Organic Compounds
TEL	Tetra Ethyl Lead
TNT	Trinitrotoluene
UKAS	United Kingdom Accreditation Service
UN	United Nations
UNEP	United Nations Environment Programme
US	United States of America
USD	United States Dollar
UXO	Unexploded Ordnance
VOCs	Volatile Organic Compounds
WMD	Weapons of Mass Destruction
XRF	X-Ray Fluorescence Spectroscopy
XRD	X-Ray Diffraction

Abbreviations

Allied	Allied Forces during the 1991 Gulf War
Gulf War	The 1991 war in Kuwait, Iraq and Saudi Arabia
UN Trust Fund	The United Nations Development Group International Reconstruction Fund Facility for Iraq
C6 – C10	Compounds with carbon numbers from 6 to 10.
DDT	Organochlorine pesticide of composition $C_{14}H_9Cl_5$

Units

kg	Kilogrammes
mg/kg	Milligrams per litre or kilogramme
µg/kg	Micrograms per litre or kilogramme
km	kilometre
km^2	Square kilometres
m^3	cubic metres
Ha	Hectares

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C

Annex C

List of Site Assessment Equipment Provided

Item	Number	Description
Health and Safety Equipment		
Footwear	25 pairs	Steel toe capped safety boots
Footwear	5 pairs	Rubber waterproof boots
Coveralls	25	Lightweight coveralls
Disposable coveralls	10 - 20	Single use coveralls and boot covers
Disposable masks	50	Single use half face dust masks
Gloves	40 packs	Disposable nitrile or rubber gloves, high strength re-usable gloves
Eyewear	25	Safety glasses
Helmets	25	Construction safety helmets
Respiratory protection masks	5 and 10	Half face and full face particulate, acid and gas protection masks with detachable filter units
First aid	5	Basic first aid kits and emergency eyewash kits
Computers, cameras and navigation equipment		
Laptop computers and software	5	Laptop Toshiba, model No. Sa-50-503 plus Norton Antivirus software
Digital still cameras	5	Digital Camera Sony, model Cybershot DSC-P73
Digital video cameras	5	Video Camera Canon
Global Positioning Satellite Receiving units (GPS)	5	Global Positioning System, model GRAMIN eTrex legend
Soil, water, gas and dust sampling and monitoring equipment		
Water Monitoring device	2	In-situ inc Troll 9000 multi-parameter sensors and logging unit
Photo ionisation Detectors	2	IonScience DL 102
Landfill gas analysers	2	Bacharach GA2000 Infrared analyzer
Toxic gas detectors	5	Oldham MX2100
Oil-water interface meters	3	Bacharach IM1.1.20 20m
Water level meters	5	Bacharach SP5 30m
Water sampling bailers	200	Disposable plastic bailers 90cm long
Soil auger kits	1	Eijelkamp hand auger set + additional auger piece
Atmospheric dust personal sampling kits	5	SKC pumps and sampling kits plus accessories
Hazardous material sampling equipment	2 sets	Solid waste sampler, liquid waste samplers, push tubes, drum pry bar
Portable chemical testing kits		
Acute toxicity testing	3	Deltatox – Microtox portable testing units and consumables
Petroleum hydrocarbon testing	2	Petroflag – portable test units and consumables
PCB testing	5	Ensys PCB in soil test units
Halogenated organic compound testing kits	2	Ensys PCE/TCE in soil test kits

Annex D1

Summary of Laboratory Analyses for Soils – Al Qadissiya

Summary Results of Chemical Analysis for Soils – Al Qadissiya	Number of Samples Analysed	Number Detected above MDL	Minimum Detected Concentration	Maximum Detected Concentration
Metals (all results in mg/kg)				
Arsenic	22	21	4	41
Beryllium	22	1	<	1
Cadmium	22	0	<	<
Chromium	22	22	7	362
Copper	22	4	1	12050
Mercury	22	0	<	<
Nickel	22	4	6	605
Lead	22	4	2	33860
Antimony	22	21	5	12920
Selenium	22	0	<	<
Silver	22	0	<	<
Thallium	22	1	<	4
Zinc	22	22	5	1295
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40)	22	8	265	1692
GRO (C4-C10)	9	0	<	<
GRO (C10-C12)	9	0	<	<
Benzene	9	0	<	<
Toluene	9	0	<	<
Ethyl Benzene	9	0	<	<
m & p Xylene (ug/kg)	9	0	<	<
o Xylene	9	0	<	<
MTBE	9	0	<	<
SVOCs (all results in µg/kg)**				
Anthracene	12	1	<	207
Benzo(a)anthracene	12	2	127	1271
Benzo(a)pyrene	12	1	<	1316
Benzo(ghi)perylene	12	1	<	885
Benzo(k)fluoranthene	12	1	<	1662
Chrysene	12	2	201	1422
Fluoranthene	12	2	156	2198
Indeno(1/2/3-cd)pyrene	12	1	<	687
Napthalene	12	1	<	624
Phenanthrene	12	2	113	929
Pyrene	12	2	140	2344
Bis(2-ethylhexyl)phthlate	12	2	724	829
Dibenzofuran	12	1	<	165
SVOC TICs (all < MDL)	12	0	<	<
PCBs (all results in µg/kg)				
Total of 7 congener PCBs	4	1	<	50
Other Parameters (mg/kg unless stated)				
Calcium	8	8	5306	59890
Magnesium	8	8	751	14300
Potassium	8	8	2257	4395
Sodium	8	8	424	1500
Bicarbonate alkalinity as CaCO3	8	8	82	257
Sulphate SO4	8	8	1725	14570
Chloride (soluble)	10	10	74	6380
Acid soluble carbonate (%)	8	8	10.81	41.62
Total cyanide	22	8	1	48
Free cyanide	22	2	1	8
pH	10	10	7.62	8.34
Asbestos	9	0	<	<

KEY:
**A further 62 VOC compounds were below the method levels of detection (<1µg/l)*
***A further 47 SVOC compounds were below the method levels of detection (generally <100ug/kg)*

Annex D2

Summary of Laboratory Analyses for Waters – Al Qadissiya

Summary Results of Chemical Analysis for Waters – Al Qadissiya	Number of Samples Analysed	Number Detected above MDL	Minimum Detected Concentration	Maximum Detected Concentration
Metals (all results in mg/kg)				
Arsenic	7	1	<	3
Beryllium	7	1	<	1
Cadmium	7	0	<	<
Chromium	7	7	15	2368
Copper	7	6	1	6
Mercury	7	0	<	<
Nickel	7	7	1	200
Lead	7	0	<	<
Antimony	7	0	<	<
Selenium	7	2	1	3
Silver	7	4	2	13
Thallium	7	0	<	<
Zinc	7	7	32	44
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40)	16	2	324	912
GRO (C4-C10)	7	0	<	<
GRO (C10-C12)	7	0	<	<
Benzene	7	0	<	<
Toluene	7	0	<	<
Ethyl Benzene	7	0	<	<
m & p Xylene (ug/kg)	7	0	<	<
o Xylene	7	0	<	<
MTBE	7	0	<	<
SVOCs (all results in µg/kg)**				
Anthracene	5	0	<	<
Benzo(a)anthracene	5	0	<	<
Benzo(a)pyrene	5	0	<	<
Benzo(ghi)perylene	5	0	<	<
Benzo(k)fluoranthene	5	0	<	<
Chrysene	5	0	<	<
Fluoranthene	5	0	<	<
Indeno(1/2/3-cd)pyrene	5	0	<	<
Napthalene	5	0	<	<
Phenanthrene	5	0	<	<
Other Parameters (mg/kg unless stated)				
Calcium	5	5	38330	223900
Magnesium	5	5	5944	158200
Potassium	5	5	0.5	20.3
Sodium	5	5	20.3	472.5
Carbonate Alkalinity	5	0	<	<
Bicarbonate Alkalinity as CaCO3	5	5	14	220
Sulphate SO4	11	11	33	1553
Sulphide	11	0	<	<
Chloride (soluble)	5	5	32	445
Total cyanide	10	0	<	<
Free cyanide	12	0	<	<
pH	5	5	6.94	8.17

KEY:
**A further 56 VOC compounds were below the method levels of detection (<1µg/l)*
***A further 50 SVOC compounds were below the method levels of detection (generally <100ug/kg)*

Annex D3

Summary of Data from the Tier 1 Screening Process for Soils – Al Qadissiya

Summary of Data from the Tier 1 Screening Process for Soils – Al Qadissiya	Dutch1* Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Dutch Tier 1 Criteria	Australian** Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Australian Tier 1 Criteria
Metals (all results in mg/kg)				
Arsenic	55	0	100	0
Beryllium	30	0	20	0
Cadmium	12	0	20	0
Chromium	380	0	nc	0
Copper	190	1	1000	1
Mercury	10	0	15	0
Nickel	210	4	600	1
Lead	530	3	300	3
Antimony	15	6	nc	0
Selenium	100	0	nc	0
Silver	15	0	nc	0
Thallium	15	0	nc	0
Zinc	720	1	7000	0
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40) (mg/kg)	5000	0	5600	0
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	1	0	nc	0
Toluene	130	0	nc	0
Ethyl Benzene	50	0	nc	0
m & p Xylene	25	0	nc	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
SVOCs (all results in µg/kg)**				
PAH sum of 10	40	0	nc	0
Phthalates	60	0	nc	0
PCBs (all results in µg/kg)				
Total of 7 congener PCBs	1	1	10	1
Other Parameters (mg/kg unless stated)				
Sulphate SO4	nc	0	2000***	7
Total cyanide	50	0	500	0
Free cyanide	20	0	250	0
Asbestos	nc	0	nc	0

KEY:
**A further 62 VOC compounds were below the method levels of detection (<1µg/l)*
***A further 47 SVOC compounds were below the method levels of detection (generally <100ug/kg)*
****Australian Ecological Investigation Level*

Table: Tier 1 Exceedances for Soil

Chemical Parameter	Tier 1 Dutch (No., Sample, Ref, Depth)	Tier 1 Australian (No., Sample, Ref, Depth)
Copper	**1:** Storegate surface	**1:** Storegate surface
Nickel	**4:** Storegate surface; AH29 1.2m; AH30 0.9-1m; AH40 3m	**1:** AH40 3m
Lead	**3:** Storegate surface; AH27 0.2m; H33 0.0m	3: Storegate surface; AH27 0.2m; H33 0.0m
Antimony	**6:** Storegate surface; AH31 0.6-0.7m; H33 0.0m; AH34 0.3m; AH37 2.5m; AH40 3m	0
Zinc	**1:** Storegate surface	0
PCBs	**1:** End of Street 0-0.2m	**1:** End of Street 0-0.2m
Sulphate		**7:** End of Street; Storegate surface; AH27; AH30; H33; AH37; H43

D

Annex D4

Summary of Data from the Tier 1 Screening Process for Waters – Al Qadissiya

Summary of Data from the Tier 1 Screening Process for Waters – Al Qadissiya	**Dutch* Tier 1 Screening Criteria for Ground-water**	**Numbers of Samples Exceeding Dutch Tier 1 Criteria**	**Australian** Tier 1 Screening Criteria for Ground-water**	**Numbers of Samples Exceeding Australian Tier 1 Criteria**
Metals (all results in mg/kg)				
Arsenic	60	0	7	0
Beryllium	15	0	nc	0
Cadmium	6	0	2	0
Chromium	30	1	nc	0
Copper	75	0	2000	0
Mercury	0.3	0	1	0
Nickel	75	1	20	1
Lead	75	0	10	0
Antimony	20	0	3	0
Selenium	160	0	10	0
Silver	40	0	100	0
Thallium	7	0	nc	0
Zinc	800	0	3000	0
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40)	600**	1	nc	0
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	30	0	1	0
Toluene	1000	0	800	0
Ethyl Benzene	150	0	300	0
m & p Xylene (ug/kg)	70	0	600	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
SVOCs (all results in µg/kg)**				
Anthracene	5	0	nc	0
Benzo(a)anthracene	0.5	0	nc	0
Benzo(a)pyrene	0.05	0	nc	0
Benzo(ghi)perylene	0.05	0	nc	0
Benzo(k)fluoranthene	0.05	0	nc	0
Chrysene	0.2	0	nc	0
Fluoranthene	1	0	nc	0
Indeno(1/2/3-cd)pyrene	0.05	0	nc	0
Napthalene	70	0	nc	0
Phenanthrene	5	0	nc	0
Other Parameters (mg/kg unless stated)				
Total cyanide	1.5	0	nc	0
Free cyanide	1.5	0	nc	0

KEY:
**A further 56 VOC compounds were below the method levels of detection (<1µg/l)*
***A further 50 SVOC compounds were below the method levels of detection (generally <100ug/kg)*

Table: Tier 1 Exceedances for Water

Chemical Parameter	**Tier 1 Dutch** (**No.,** Sample, Ref, Depth)	**Tier 1 Australian** (**No.,** Sample, Ref, Depth)
Chromium	1: AH56	
Nickel	1: AH61	1: AH61
EPH	1: AH56	

Annex E1

Summary of Laboratory Analyses for Soils – Al Suwaira

Summary Results of Chemical Analysis for Soils – Al Suwaira	Number of Samples Analysed	Number Detected above MDL	Minimum Detected Concen-tration	Maximum Detected Concen-tration
Metals (all results in mg/kg)				
Arsenic	20	20	3	11
Beryllium	20	0	<	<
Cadmium	20	1	<	1
Chromium	20	20	34	111
Copper	20	20	8	438
Mercury	20	3	59	77
Nickel	20	20	29	149
Lead	20	20	4	142
Antimony	20	20	2	5
Selenium	20	0	<	<
Silver	20	0	<	<
Thallium	20	0	<	<
Zinc	20	20	58	4320
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40) (mg/kg)	20	20	12	65755
GRO (C4-C10)	20	5	525	13611
GRO (C10-C12)	20	1	<	463
Benzene	20	2	28	30
Toluene	20	4	65	192
Ethyl Benzene	20	4	45	2414
m & p Xylene	20	5	64	6559
o Xylene	20	5	40	4524
MTBE	20	1	<	328
SVOCs (all results in µg/kg)**				
Anthracene	20	2	152	188
Napthalene	20	3	506	1279
Phenanthrene	20	2	294	323
2-Chlorophenol	20	1	<	1627
2-Methylphenol	20	1	<	6877
2,4-Dichlorophenol	20	3	5543	33698
2,4-Dimethylphenol	20	1	<	1976
Bis(2-ethylhexyl)phthalate	20	10	582	168870
Butylbenzyl phthalate	20	1	<	743
Di-n-butyl phthalate	20	2	14573	43390
2-Methylnaphthalene	20	3	242	1759
1,2,4-Trichlorobenzene	20	1	<	325
SVOC TICs (all results in mg/kg)**				
C16-C24 hydrocarbons: 20% acids	20	16	82.1	458.8
Benzothiazole	20	13	0.8	3
Bibenzothiazole	20	13	0.95	6.09
Dichlorofop Methyl	20	12	1.3	9596.8
C8-C18 Acids	20	2	891	1199.8
Tetradifon	20	6	5.9	67
OCP/OPP Pesticides (all results in µg/kg)				
Dichlorvos	20	0	<	<
Mevinphos	20	0	<	<
Alpha-BHC (Lindane)	20	0	<	<
Beta-BHC (Lindane)	20	1	<	196
Gamma-BHC (Lindane)	20	0	<	<
Diazinon	20	4	4	17959
Methyl Parathion	20	0	<	<
Heptachlor	20	1	<	109
Fenitrothion	20	8	2	35793
Malathion	20	4	2	1360
Aldrin	20	3	9	99
Parathion	20	0	<	<
Heptachlor Epoxide	20	3	2	28
Endosulphan I	20	7	3	3880
p,p'-DDE	20	13	1	29332
Dieldrin	20	12	2	5461
Endrin	20	4	72	10653
Endosulphan II	20	4	7	812
p,p'-TDE(DDD)	20	3	2	318
Ethion	20	0	<	<
p,p'-DDT	20	8	2	7076
Endosulphan sulphate	20	0	<	<
p,p'-Methoxychlor	20	4	103	4898
Azinphos methyl	20	0	<	<
Other Parameters (mg/kg unless stated)				
Calcium	2	2	71940	75390
Magnesium	2	2	15530	18650
Potassium	2	2	4773	4815
Sodium	2	2	6648	12222
Bicarbonate alkalinity as CaCO3	2	2	124	193
Sulphate SO4 (mg/l)	2	2	7634	33490
Chloride (soluble)	20	20	962	49972
Acid soluble carbonate (%)	2	2	34.48	34.54
pH	20	20	5.68	8.31
Asbestos	20	nfd	<	<
Man-made mineral fibre	2	0	<	<
Organic fibre (% by volume)	2	1	<	31-100

KEY:
**A further 39 SVOC compounds were below the method levels of detection (generally <100ug/kg)*
***A further 11 complex SVOC compounds were detected and 18 Unknowns*
nfd = no fibres detected
< = below level of detection

E

Annex E2

Summary of Data from the Tier 1 Screening Process for Soils – Al Suwaira

Summary of Data from the Tier 1 Screening Process for Soils – Al Suwaira	Dutch1* Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Dutch Tier 1 Criteria	Australian** Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Australian Tier 1 Criteria
Metals (all results in mg/kg)				
Arsenic	55	0	100	0
Beryllium	30	0	20	0
Cadmium	12	0	20	0
Chromium	380	0	nc	0
Copper	190	2	1000	0
Mercury	10	3	15	3
Nickel	210	0	600	0
Lead	530	0	300	0
Antimony	15	0	nc	0
Selenium	100	0	nc	0
Silver	15	0	nc	0
Thallium	15	0	nc	0
Zinc	720	3	7000	0
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40) (mg/kg)	5000	3	5600	3
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	1	0	nc	0
Toluene	130	0	nc	0
Ethyl Benzene	50	0	nc	0
m & p Xylene	25	0	nc	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
SVOCs (all results in µg/kg)**				
PAH sum of 10	40	0	nc	0
Chlorophenols	10	1	nc	0
Chlorobenzenes	30	0	nc	0
Phthalates	60	3	nc	0
SVOC TICs (all results in mg/kg)**				
C16-C24 hydrocarbons: 20% acids	nc	0	nc	0
Benzothiazole	nc	0	nc	0
Bibenzothiazole	nc	0	nc	0
Dichlorofop Methyl	nc	0	nc	0
C8-C18 Acids	nc	0	nc	0
Tetradifon	nc	0	nc	0
OCP/OPP Pesticides (all results in mg/kg)				
DDT/ DDE/ DDD	4	3	200	0
Drins**	4	2	10	2
Other Parameters (mg/kg unless stated)				
Bicarbonate alkalinity as CaCO3	nc	0	nc	0
Sulphate SO4 (mg/l)	nc	0	2000	2
Asbestos	nc	0	nc	0

KEY:
**A further 39 SVOC compounds were below the method levels of detection (generally <100ug/kg)*
***Dutch = Aldrin, Dieldrin, Endrin: Australian = Aldrin, Dieldrin*

Table: Tier 1 Exceedances for Soil

Chemical Parameter	Tier 1 Dutch (No., Sample, Ref, Depth)	Tier 1 Australian (No., Sample, Ref, Depth)
Copper	**2:** 2 surface; 4 surface	0
Mercury	**3:** sediment T5; 2 surface; 4 surface	**3:** sediment T5; 2 surface; 4 surface
Zinc	**3:** sediment T5; 2 surface; 4 surface	0
EPH	**3:** sediment T5; 2 surface; 4 surface	**3:** sediment T5; 2 surface; 4 surface
Chlorophenols	**1:** sediment T5	0
Phthalates	**3:** sediment T5; 2 surface; 4 surface	0
DDT/DDE/DDD	**3:** sediment T5; 2 surface; 4 surface	0
Drins	**3:** sediment T5; 2 surface	**2:** 2 surface; 4 surface
Sulphate	0	**2:** 15 surface; 22 surface

Annex F1

Summary of Laboratory Analyses for Soils – Khan Dhari

Summary Results of Chemical Analysis for Soils – Khan Dhari	Number of Samples Analysed	Number Detected above MDL	Minimum Detected Concentration	Maximum Detected Concentration
Metals (all results in mg/kg)				
Arsenic	42	41	5	15
Beryllium	42	0	<	<
Cadmium	42	2	1	2
Chromium	42	41	20	106
Copper	42	41	5	46
Mercury	42	0	<	<
Nickel	42	41	8	135
Lead	42	39	2	16990
Antimony	42	41	2	7
Selenium	42	0	<	<
Silver	42	0	<	<
Thallium	42	0	<	<
Zinc	42	41	9	5072
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40) (mg/kg)	42	33	24	44956
GRO (C4-C10)	42	20	94	55791
GRO (C10-C12)	42	14	403	78522
Benzene	42	0	<	<
Toluene	42	0	<	<
Ethyl Benzene	42	0	<	<
m & p Xylene	42	0	<	<
o Xylene	42	0	<	<
MTBE	42	0	<	<
SVOCs (all results in µg/kg)**				
Anthracene	43	3	183	239
Benzo(a)anthracene	43	3	198	861
Benzo(a)pyrene	43	2	172	331
Benzo(ghi)perylene	43	1	<	533
Benzo(k)fluoranthene	43	2	221	493
Chrysene	43	2	195	2712
Fluoranthene	43	1	<	147
Indeno(1/2/3-cd)pyrene	43	1	<	203
Napthalene	43	7	119	4841
Phenanthrene	43	6	142	2126
Bis(2-ethylhexyl)phthalate	43	3	619	33068
Dimethyl phthalate	43	1	<	93161
SVOC TICs (all results in mg/kg)				
C10-C12 & C10-C16 Aromatics	42	6	16.5	3684.4
C12-C16 Hydrocarbons	42	9	21	822
C14-C20 & C16-C20 Hydrocarbons	42	4	63.1	36814
C12-C24 Hydrocarbons	42	4	1476	53434.2
C18-C26 Hydrocarbons	42	7	1202.8	111925
C16-C20 Acid Esters	42	21	50.6	2250.9
Do-, Tri-, Tetra-, Penta- & Hexadecane	42	2	163.1	242.5
Methyl furfural	42	3	10.55	37.8
C14-C24 Alkenes	42	3	104.5	644.4
Other Parameters (mg/kg unless stated)				
Calcium	11	11	42440	66310
Magnesium	11	11	4141	9592
Potassium	11	11	938	12717
Sodium	11	11	581	85514
Bicarbonate alkalinity as CaCO3	11	11	59	608
Sulphate SO4 (mg/l)****	11	11	17090	250400
Chloride (soluble)	12	12	42	2222
Acid soluble carbonate (%)	11	11	7.5	60
pH	13	13	7.41	9.81
Asbestos	13	nfd	<	<

KEY:
**A further 56 VOC compounds were below the method levels of detection (<1µg/l)*
***A further 48 SVOC compounds were below the method levels of detection (generally <100ug/kg)*
nfd - no fibres detected
< = below level of detection

F

Annex F2

Summary of Laboratory Analyses for Waters – Khan Dhari

Summary Results of Chemical Analysis for Soils – Khan Dhari		All concentrations (µg/l) (except where stated)		
	Number of Samples Analysed	Number Detected above MDL	Minimum Detected Concen-tration	Maximum Detected Concen-tration
Metals				
Arsenic	1	1	na	9
Beryllium	1	0	na	<
Cadmium	1	0	na	<
Chromium	1	0	na	<
Copper	1	1	na	2
Mercury	1	0	na	<
Nickel	1	1	na	6
Lead	1	0	na	<
Antimony	1	0	na	<
Selenium	1	1	na	47
Silver	1	0	na	<
Thallium	1	0	na	<
Zinc	1	1	na	504
VOCs*				
EPH (DRO) (C10-C40)	1	1	na	647
GRO (C4-C10)	1	0	na	<
GRO (C10-C12)	1	0	na	<
Benzene	1	0	na	<
Toluene	1	0	na	<
Ethyl Benzene	1	0	na	<
m & p Xylene (ug/kg)	1	0	na	<
o Xylene	1	0	na	<
MTBE	1	0	na	<
SVOCs**				
Anthracene	1	<	na	<
Benzo(a)anthracene	1	<	na	<
Benzo(a)pyrene	1	<	na	<
Benzo(k)fluoranthene	1	<	na	<
Benzo(ghi)perylene	1	<	na	<
Chrysene	1	<	na	<
Fluoranthene	1	<	na	<
Indeno(1/2/3-cd)pyrene	1	<	na	<
Napthalene	1	<	na	<
Phenanthrene	1	<	na	<
Other Parameters (mg/kg unless stated)				
Calcium (mg/l)	1	1	na	527.2
Magnesium (mg/l)	1	1	na	346.8
Potassium (mg/l)	1	1	na	12.9
Sodium (mg/l)	1	1	na	1500
Bicarbonate alkalinity as CaCO3 (mg/l)	1	1	na	95
Sulphate (mg/l)	1	1	na	4342
Chloride (soluble) (mg/l)	1	1	na	3748
pH	1	1	na	7.88

KEY:
**A further 56 VOC compounds were below the method levels of detection (<1µg/l)*
***A further 48 SVOC compounds were below the method levels of detection (generally <100ug/kg)*
< = below level of detection

Annex F3

Summary of Data from the Tier 1 Screening Process for Soils – Khan Dhari

Summary of Data from the Tier 1 Screening Process for Soils – Khan Dhari	All concentrations (mg/kg) (except where stated)			
	Dutch1* Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Dutch Tier 1 Criteria	Australian** Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Australian Tier 1 Criteria
Metals				
Arsenic	55	0	100	0
Beryllium	30	0	20	0
Cadmium	12	0	20	0
Chromium	380	0	nc	0
Copper	190	0	1000	0
Mercury	10	0	15	0
Nickel	210	0	600	0
Lead	530	3	300	4
Antimony	15	0	nc	0
Selenium	100	0	nc	0
Silver	15	0	nc	0
Thallium	15	0	nc	0
Zinc	720	3	7000	0
Hydrocarbons and VOCs				
EPH (DRO) (C10-C40)	5000	8	5600	6
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	1	0	nc	0
Toluene	130	0	nc	0
Ethyl Benzene	50	0	nc	0
m & p Xylene	25	0	nc	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
SVOCs				
Polycyclic Aromatic Hydrocarbons****	40	0	20	1
Benzo(a)pyrene	nc	0	1	0
SVOC TICs	nc	0	nc	0
Other Parameters				
Sulphate***	nc	0	2000	9
Asbestos	nc	0	nc	0

KEY:
**Intervention Values (Feb 2000)*
***Investigation Levels Standard Residential mand Use (1999)*
****Dutch IV for mineral oil is used: Australian C16-C35 aliphatics value used*
*****Dutch is sum of 10: Australian is sum of 18*
nc = no criteria
TICs = tentatively identified compounds

Table: Tier 1 Exceedances for Soil

Chemical Parameter	**Tier 1 Dutch** (**No.,** Sample, Ref, Depth)	**Tier 1 Australian** (**No.,** Sample, Ref, Depth)
Lead	**3:** BT5A 0.1m; ICP/BRC 0.15m; BT1 0.15m	**4:** BT5A 0.1m; ICP/BRC 0.15m; BT5B0.85m; BT1 0.15m
Zinc	**3:** DDH1A 0.2m; DDH4A 0.2m; DW5 0.2m	0
EPH	**8:** DDH1A 0.2m; DDH1B 0.85m; DDH2C 0.05m; DDH4A 0.2m; DW5 0.2m; DDH1 0.1m; DW10.1m; UDW1 0.05m	**6:** DDH1A 0.2m; DDH1B 0.85m; DDH2C 0.05m; DW5 0.2m; DDH1 0.1m; UDW1 0.05m
PAH	0	**1:** DD1C 0.05m
Sulphate	0	**9:** BT1B 0.1m; BT3B 0.85m; BT5A 0.1m; DDH1A 0.2m; DDH2B 0.85m; DDH5B 0.8m; DW2 0.2m; DW4 0.2m; ICP/BLC 0.15m

F

Annex F4

Summary of Data from the Tier 1 Screening Process for Waters – Khan Dhari

Summary of Data from the Tier 1 Screening Process for Waters – Khan Dhari	All concentrations (µg/l) (except where stated)			
	Dutch* Tier 1 Screening Criteria for Ground-water	Numbers of Samples Exceeding Dutch Tier 1 Criteria	Australian** Tier 1 Screening Criteria for Ground-water	Numbers of Samples Exceeding Australian Tier 1 Criteria
Metals				
Arsenic	60	0	7	0
Beryllium	15	0	nc	0
Cadmium	6	0	2	0
Chromium	30	0	nc	0
Copper	75	0	2000	0
Mercury	0.3	0	1	0
Nickel	75	0	20	0
Lead	75	0	10	0
Antimony	20	0	3	0
Selenium	160	0	10	1
Silver	40	0	100	0
Thallium	7	0	nc	0
Zinc	800	0	3000	0
VOCs				
EPH (DRO) (C10-C40)	600**	1	nc	0
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	30	0	1	0
Toluene	1000	0	800	0
Ethyl Benzene	150	0	300	0
m & p Xylene	70	0	600	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
SVOCs*				
Anthracene	5	0	nc	0
Benzo(a)anthracene	0.5	0	nc	0
Benzo(a)pyrene	0.05	0	nc	0
Benzo(k)fluoranthene	0.05	0	nc	0
Benzo(ghi)perylene	0.05	0	nc	0
Chrysene	0.2	0	nc	0
Fluoranthene	1	0	nc	0
Indeno(1/2/3-cd)pyrene	0.05	0	nc	0
Napthalene	70	0	nc	0
Phenanthrene	5	0	nc	0
Other Parameters				
Sulphate (mg/l)	nc	0	nc	0
Chloride (soluble)	nc	0	250000	0

KEY:
**A further 50 SVOC compounds were below the method levels of detection (generally <10ug/l)*

Table: Tier 1 Exceedances for Water

Chemical Parameter	Tier 1 Dutch (No., Sample, Ref, Depth)	Tier 1 Australian (No., Sample, Ref, Depth)
Selenium	0	**1:** Firewell Water
EPH	**1:** Firewell Water	0

Annex G1

Summary of Laboratory Analyses for Soils – Al Mishraq

Summary Results of Chemical Analysis for Soils – Al Mishraq	Number of Samples Analysed	Number Detected above MDL	Minimum Detected Concen-tration	Maximum Detected Concen-tration
Metals (all results in mg/kg)				
Arsenic	26	26	2	9
Beryllium	26	0	<	<
Cadmium	26	0	<	<
Chromium	26	26	47	1082
Copper	26	26	12	44
Mercury	26	0	<	<
Nickel	26	26	23	310
Lead	26	21	2	7
Antimony	26	26	2	6
Selenium	26	0	<	<
Silver	26	0	<	<
Thallium	26	0	<	<
Zinc	26	26	22	76
Hydrocarbons and VOCs (µg/kg unless stated)				
EPH (DRO) (C10-C40) (mg/kg)	26	22	18	124
GRO (C4-C10)	26	1	<	24
GRO (C10-C12)	26	0	<	<
Benzene	26	0	<	<
Toluene	26	0	<	<
Ethyl Benzene	26	0	<	<
m & p Xylene (ug/kg)	26	1	<	24
o Xylene	26	0	<	<
MTBE	26	0	<	<
Other Parameters (mg/kg unless stated)				
Calcium	2	2	85440	46180
Magnesium	2	2	8504	10920
Potassium	2	2	2208	8571
Sodium	2	2	396	545
Bicarbonate alkalinity as $CaCO_3$	2	2	14	34
Conductivity (at 25 deg.C)(mS/cm)	26	26	2.29	5.53
Nitrate (soluble) as NO_3	26	16	1	118
Nitrite (soluble as NO_2)	26	21	0.1	5
Sulphate	26	26	1377	265800
Water soluble Sulphate SO_4 (mg/l)	26	26	63	8803
Acid soluble Sulphide	26	1	<	215
Chloride (soluble)	26	26	14	202
Fluoride (soluble)	26	1	<	6
Phosphate (ortho as PO_4)	26	1	<	2
Acid soluble carbonate (%)	26	26	11.11	52.6
pH	26	NA	2.44	8.05
Total sulphur (%)	26	26	0.02	19.72

KEY:
< = below level of detection

Annex G2

Summary of Laboratory Analyses for Waters – Al Mishraq

Summary Results of Chemical Analysis for Waters – Al Mishraq	Number of Samples Analysed	All concentrations (µg/l) (except where stated) Number Detected above MDL	Minimum Detected Concen-tration	Maximum Detected Concen-tration
Metals				
Arsenic	10	5	1	143
Beryllium	10	1	<	84
Cadmium	10	1	<	21.5
Chromium	10	6	2	7287
Copper	10	9	2	2704
Mercury	10	0	<	<
Nickel	10	9	1	11470
Lead	10	1	<	123
Antimony	10	0	<	<
Selenium	10	4	2	32
Silver	10	0	<	<
Thallium	10	1	<	5
Zinc	10	10	15	10320
Hydrocarbons and VOCs				
EPH (DRO) (C10-C40)	10	1	<	3349
GRO (C4-C10)	10	0	<	<
GRO (C10-C12)	10	1	<	1201
Benzene	10	0	<	<
Toluene	10	0	<	<
Ethyl Benzene	10	0	<	<
m & p Xylene (ug/kg)	10	0	<	<
o Xylene	10	0	<	<
MTBE	10	0	<	<
Other Parameters (mg/kg unless stated)				
Calcium	2	2	208.2	467.7
Magnesium	2	2	104	848.1
Potassium	2	2	3.9	28.5
Sodium	2	2	90	300
Total Alkalinity as CaCO3	7	7	9	430
Hardness	10	10	196	10368
Bicarbonate alkalinity as CaCO3	2	2	125	310
Conductivity (at 25 deg.C)(mS/cm)	7	7	0.47	11.68
Nitrate (soluble) as NO3	10	4	2.1	7.4
Nitrite (soluble as NO2)	10	2	0.21	0.26
Sulphate	5	5	6702.1	400361.7
Sulphide	10	0	<	<
Chloride (soluble)	10	10	13	627
Fluoride (soluble)	10	8	0.9	538.4
Phosphate (ortho as PO4)	10	3	0.09	22.15
pH	10	10	<1	8.35
Free sulphur	10	2	0.05	53
Total suspended solids	10	8	13	1057

KEY:
< = below level of detection

G

Annex G3

Summary of Data from the Tier 1 Screening Process for Soils – Al Mishraq

Summary of Data from the Tier 1 Screening Process for Soils – Al Mishraq	All concentrations (mg/kg) (except where stated)			
	Dutch1* Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Dutch Tier 1 Criteria	Australian** Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Australian Tier 1 Criteria
Metals				
Arsenic	55	0	100	0
Beryllium	30	0	20	0
Cadmium	12	0	20	0
Chromium	380	1	nc	0
Copper	190	0	1000	0
Mercury (inorganic)	10	0	15	0
Nickel	210	2	600	0
Lead	530	0	300	0
Antimony	15	0	nc	0
Selenium	100	0	nc	0
Silver	15	0	nc	0
Thallium	15	0	nc	0
Zinc	720	0	7000	0
Hydrocarbons and VOCs				
EPH (DRO) (C10-C40)***(mg/kg)	5000	0	5600	0
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	1	0	nc	0
Toluene	130	0	nc	0
Ethyl Benzene	50	0	nc	0
m & p Xylene (ug/kg)	25	0	nc	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
Other Parameters				
Sulphate SO4 (mg/l)****	nc	0	2000	21
Acid soluble sulphide	nc	0	nc	0
Chloride (soluble)	nc	0	nc	0
Total sulphur (%)	nc	0	nc	0

KEY:
**Intervention Values (Feb 2000)*
***Investigation Levels Standard Residential mand Use (1999)*
****Dutch IV for mineral oil is used: Australian C16-C35 aliphatics value used*
*****Australian Ecological Investigation Level*

Table: Tier 1 Exceedances for Soil

Chemical Parameter	Tier 1 Dutch (**No.,** Sample, Ref, Depth)	Tier 1 Australian (**No.,** Sample, Ref, Depth)
Chromium	**1:** 6 0.1m	0
Nickel	**2:** 7 0.1m; 19 0.15m	0
Sulphate	nc	**21:** 1; 2; 4 -17; 19-22; 24

G

Annex G4

Summary of Data from the Tier 1 Screening Process for Waters – Al Mishraq

Summary of Data from the Tier 1 Screening Process for Waters – Khan Dhari	All concentrations (µg/l) (except where stated)			
	Dutch* Tier 1 Screening Criteria for Ground-water	Numbers of Samples Exceeding Dutch Tier 1 Criteria	Australian** Tier 1 Screening Criteria for Ground-water	Numbers of Samples Exceeding Australian Tier 1 Criteria
Metals				
Arsenic	60	1	7	1
Beryllium	15	1	nc	0
Cadmium	6	1	2	1
Chromium	30	1	nc	0
Copper	75	1	2000	1
Mercury	0.3	0	1	0
Nickel	75	1	20	1
Lead	75	1	10	1
Antimony	20	0	3	0
Selenium	160	0	10	0
Silver	40	0	100	0
Thallium	7	0	nc	0
Zinc	800	1	3000	1
Hydrocarbons and VOCs				
EPH (DRO) (C10-C40)	600**	0	nc	0
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	30	0	1	0
Toluene	1000	0	800	0
Ethyl Benzene	150	0	nc	0
m & p Xylene	70	0	600	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
Other Parameters				
Nitrate (soluble) as NO3 (mg/l)	nc	0	50000	0
Nitrite (soluble as NO2) (mg/l)	nc		3000	0
Sulphate (mg/l)	nc	0	nc	0
Acid soluble sulphide	nc	0	nc	0
Chloride (soluble)	nc	0	250000	0
Fluoride (soluble)	nc	0	1500	0
Free sulphur (mg/l)	nc	0	nc	0

KEY:
nc = no criteria
***Investigation Levels Standard Residential Land Use (1999)*
****IV for mineral oil is used*

Table: Tier 1 Exceedances for Water		
Chemical Parameter	**Tier 1 Dutch** (**No.**, Sample, Ref, Depth)	**Tier 1 Australian** (**No.**, Sample, Ref, Depth)
Arsenic	**1:** S1	**1:** S1
Beryllium	**1:** S1	0
Cadmium	**1:** S1	**1:** S1
Chromium	**1:** S1	0
Nickel	**1:** S1	**1:** S1
Lead	**1:** S1	**1:** S1
Zinc	**1:** S1	**1:** S1

Annex H1

Summary of Laboratory Analyses for Soils – Ouireej

Summary Results of Chemical Analysis for Soils – Ouireej	Number of Samples Analysed	Number Detected above MDL	All concentrations mg/kg	
			Minimum Detected Concen-tration	Maximum Detected Concen-tration
Metals (all results in mg/kg)				
Arsenic	50	50	4	19
Beryllium	50	0	<	<
Cadmium	50	3	3	11
Chromium	50	50	49	138
Copper	50	50	13	1738
Mercury	50	0	<	<
Nickel	50	50	65	209
Lead	50	50	6	1291
Antimony	50	50	3	55
Selenium	50	0	<	<
Silver	50	0	<	<
Thallium	50	0	<	<
Zinc	50	50	41	1381
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40) (mg/kg)	49	42**	7	118679
GRO (C4-C10)	13	1	<	44
GRO (C10-C12)	13	0	<	<
Benzene	13	0	<	<
Toluene	13	2	4	44
Ethyl Benzene	13	1	<	2
m & p Xylene (ug/kg)	13	1	<	10
o Xylene	13	1	<	3
MTBE	13	0	<	<
PCBs (all results in µg/kg)				
Total of 7 Congener PCBs	29	8	1	23
SVOCs* (all results in µg/kg)**				
Anthracene	18	2	121	352
Benzo(a)anthracene	18	1	<	326
Benzo(a)pyrene	18	0	<	<
Benzo(ghi)perylene	18	0	<	<
Benzo(k)fluoranthene	18	0	<	<
Chrysene	18	1	<	1841
Fluoranthene	18	2	185	233
Indeno(1/2/3-cd)pyrene	18	0	<	<
Napthalene	18	2	215	1400
Phenanthrene	18	4	271	2096
Pyrene	18	3	145	890
2-Methlynaphthalene	18	1	<	2025
Bis(2-ehtylhexyl)phthalate	18	6	919	13118
DÑn-butyl phthalate	18	2	3192	7209
SVOC TICs (all results in mg/kg)				
C14-C24 Hydrocarbons	5	3	13.2	93.3
C12-C30 Hydrocarbons	5	1	<	60778.4
C14-C30 Hydrocarbons	5	1	<	6341.5
Other Parameters (mg/kg unless stated)				
Calcium	14	14	37530	66630
Magnesium	14	14	9330	16300
Potassium	14	14	1579	10619
Sodium	14	14	3614	22317
Bicarbonate alkalinity as CaCO3	14	14	89	874
Sulphate SO4 (mg/l)****	14	14	3126	115500
Acid soluble sulphide	5	0	<	<
Chloride	13	13	2100	43908
Acid soluble carbonate (%)	14	14	18.47	35.23
pH	17	17	7.21	8.38
Total sulphur (%)	5	5	0.12	1.38
Asbestos	17	0	<	<

KEY:
**A further 60 VOC compounds were below the method levels of detection (<1µg/l)*
***All used engine oil*
****A further 48 SVOC compounds were below the method levels of detection (generally <100ug/kg)*

Annex H2

Summary of Laboratory Analyses for Waters – Ouireej

Summary Results of Chemical Analysis for Waters – Ouireej	Number of Samples Analysed	Number Detected above MDL	Minimum Detected Concen-tration	Maximum Detected Concen-tration
Metals (all results in µg/l)				
Arsenic	3	3	20	83
Beryllium	3	0	<	<
Cadmium	3	1	<	6.3
Chromium	3	3	3	11
Copper	3	3	4	27
Mercury	3	0	<	<
Nickel	3	3	17	62
Lead	3	2	3	38
Antimony	3	2	13	13
Selenium	3	3	38	203
Silver	3	0	<	<
Thallium	3	1	<	2
Zinc	3	3	21	7258
VOCs (all results in µg/l)				
EPH (DRO) (C10-C40)	3	2	898	1950
GRO (C4-C10)	2	0	<	<
GRO (C10-C12)	2	0	<	<
Benzene	2	0	<	<
Toluene	2	0	<	<
Ethyl Benzene	2	0	<	<
m & p Xylene	2	0	<	<
o Xylene	2	0	<	<
MTBE	2	0	<	<
SVOCs* (all results in µg/l)				
Anthracene	3	0	<	<
Benzo(a)anthracene	3	0	<	<
Benzo(a)pyrene	3	0	<	<
Benzo(ghi)perlene	3	0	<	<
Benzo(k)fluoranthene	3	0	<	<
Chrysene	3	0	<	<
Fluoranthene	3	0	<	<
Indeno(1/2/3-cd)pyrene	3	0	<	<
Napthalene	3	0	<	<
Phenanthrene	3	0	<	<
Other Parameters (mg/l unless stated)				
Calcium	3	3	852	1868
Magnesium	3	3	1051	5869
Potassium	3	3	93	690
Sodium	3	3	12188	18375
Carbonate alkalinity as CaCO3	3	0	<	<
Bicarbonate alkalinity as CaCO3	3	3	160	370
Sulphate	3	3	4307	15019
Chloride (soluble)	3	3	6489	>40000
pH	3	3	7.73	8.14

KEY:
**A further 50 SVOC compounds were below the method levels of detection (generally <100ug/kg)*

Annex H3

Summary of Data from the Tier 1 Screening Process for Soils – Ouireej

Summary of Data from the Tier 1 Screening Process for Soils –Ouireej	Dutch1* Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Dutch Tier 1 Criteria	Australian** Tier 1 Screening Criteria for Soils	Numbers of Samples Exceeding Australian Tier 1 Criteria
Metals (all results in mg/kg)				
Arsenic	55	0	100	0
Beryllium	30	0	20	0
Cadmium	12	0	20	0
Chromium	380	0	nc	0
Copper	190	2	1000	1
Mercury	10	0	15	0
Nickel	210	0	600	0
Lead	530	3	300	2
Antimony	15	2	nc	0
Selenium	100	0	nc	0
Silver	15	0	nc	0
Thallium	15	0	nc	0
Zinc	720	3	7000	0
Hydrocarbons and VOCs* (µg/kg unless stated)				
EPH (DRO) (C10-C40) (mg/kg)	5000	5	5600	5
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	1	0	nc	0
Toluene	130	0	nc	0
Ethyl Benzene	50	0	nc	0
m & p Xylene (ug/kg)	25	0	nc	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
PCBs (mg/kg)				
Total of 7 Congener PCBs	1	8	10	3
SVOCs* (all results in µg/kg)**				
PAH sum of 10	40	0	nc	0
Chlorophenols	10	0	nc	0
Chlorobenzenes	30	0	nc	0
Phthalates	60	0	nc	0
SVOC TICs (all results in mg/kg)				
C14-C24 Hydrocarbons	nc	0	nc	0
C12-C30 Hydrocarbons	nc	0	nc	0
C14-C30 Hydrocarbons	nc	0	nc	0
Other Parameters				
Sulphate SO4 (mg/l)****	nc	0	2000	14
Acid soluble sulphide	nc	0	nc	0
Asbestos	nc	0	nc	0

KEY:
**A further 60 VOC compounds were below the method levels of detection (<1µg/l)*
***All used engine oil*
****A further 48 SVOC compounds were below the method levels of detection (generally <100ug/kg)*

Table: Tier 1 Exceedances for Soil

Chemical Parameter	Tier 1 Dutch (No., Sample, Ref, Depth)	Tier 1 Australian (No., Sample, Ref, Depth)
Copper	**2:** 4 0.25m; 5 0.25m	**1:** 4 0.25m
Lead	**3:** 4 0.25m; 5 0.25m; S1034	**2:** 4 0.25m; 5 0.25m
Zinc	**3:** 4 0.25m; 5 0.25m; S1034	0
EPH	**5:** 4 0.25m; S1010 0.25m; S1022 0.2; S1028 0.25m; S1044	**5:** 4 0.25m; S1010 0.25m; S1022 0.2; S1028 0.25m; S1044
PCBs	**8:** 2; S104; S107; S109; S1029; S1033; S1035; S1050	**8:** 2; S104; S107; S109; S1029; S1033; S1035; S1050
Sulphate		**14:** 1; 4; S103; S106; S108; S1011; S1016; S1020; S1028; S1034; S1040; S1043; S1048; S1075

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Annex H4

Summary of Data from the Tier 1 Screening Process for Waters – Ouireej

Summary of Data from the Tier 1 Screening Process for Waters – Ouireej	Dutch* Tier 1 Screening Criteria for Ground-water	Numbers of Samples Exceeding Dutch Tier 1 Criteria	Australian** Tier 1 Screening Criteria for Ground-water	Numbers of Samples Exceeding Australian Tier 1 Criteria
Metals (all results in µg/l)				
Arsenic	60	1	7	3
Beryllium	15	0	nc	0
Cadmium	6	1	2	1
Chromium	30	0	nc	0
Copper	75	0	2000	0
Mercury	0.3	0	1	0
Nickel	75	0	20	1
Lead	75	0	10	1
Antimony	20	0	3	2
Selenium	160	1	10	3
Silver	40	0	100	0
Thallium	7	0	nc	0
Zinc	800	1	3000	1
VOCs (all results in µg/l)				
EPH (DRO) (C10-C40)	600**	2	nc	0
GRO (C4-C10)	nc	0	nc	0
GRO (C10-C12)	nc	0	nc	0
Benzene	30	0	1	0
Toluene	1000	0	800	0
Ethyl Benzene	150	0	300	0
m & p Xylene	70	0	600	0
o Xylene	nc	0	nc	0
MTBE	nc	0	nc	0
SVOCs* (all results in µg/l)				
Anthracene	5	0	nc	0
Benzo(a)anthracene	0.5	0	nc	0
Benzo(a)pyrene	0.05	0	nc	0
Benzo(ghi)perlene	0.05	0	nc	0
Benzo(k)fluoranthene	0.05	0	nc	0
Chrysene	0.2	0	nc	0
Fluoranthene	1	0	nc	0
Indeno(1/2/3-cd)pyrene	0.05	0	nc	0
Napthalene	70	0	nc	0
Phenanthrene	5	0	nc	0
Other Parameters (mg/l unless stated)				
Chloride (soluble)	nc	0	250000	0

KEY:
**A further 50 SVOC compounds were below the method levels of detection (generally <100ug/kg)*

Table: Tier 1 Exceedances for Water

Chemical Parameter	Tier 1 Dutch (No., Sample, Ref, Depth)	Tier 1 Australian (No., Sample, Ref, Depth)
Arsenic	1: W102	3: W101; W102; W103
Cadmium	1: W103	1: W103
Nickel	0	1: W102
Lead	0	1: W103
Antimony	0	2: W102; W103
Selenium	1:W102	3: W101; W102; W103
Zinc	1: W103	1: W103
EPH	2: W102; W103	

Annex I

List of Contributors

Environmental Site Assessment Team Members

Abbas Balasem – MoEn, Project Manager
Abdul-Manaf Tawfeek Abul-Salam – MIM
Ahmed Jassim Ta'an – MoEn
Ahmed Raheem Khudaer – MoEn
Bandar Talal Fathi – MoEn
Dhahir Jabir Addawa – MoF
Fatin Soubhi Aziz – MoEn, Team leader
Firas Hassan – MoEn
Hanaa Thanoon Mohamed – MoEn, Team leader
Harith Muthanna Abdulrazzak – MoEn
Heval Ahmed Mohammed – MoEn
Hiyam Jabbor Abdulsaada – MoEn
Hussein Abid Omran, MoEn
Hussein Hassan Kharnoob – MoEn, Team leader
Ibrahim Jawad Shareef – MoEn
Ibrahim Mehdi Abid – MoEn
Jaffar Sadik Abdul-Hassan – Al Rasheed County Municipality
Jaleel Hussein Salman – MoEn
Jathwa Abdulkareem Ibrahim – MoEn, Team leader
Kareema Salman – MoEn
Kasim Tibin Bazzoon – MoEn
Lateef Bunni Hussein – MoEn
Luai Sadik Muhammed – MoEn
Mahmood Mahdi Barbooti – MoEn, Team leader
Muthanna Ibrahim Haydar – MoEn
Natek Muhsin Abud – MoEn
Rana Ghassan Ali – MoEn
Salema Karam – MoEn
Sattar Obaid Hmood – MoEn
Shabi Abdul-Kadir Habib – MoEn
Suha Khadum Jaffer – MoAg
Taghreed Khalaf Abdulrazzak – MoEn
Talat Natheer Mahmood – MoO
Wameedh Ahmed Wasmie – MoEn
Yousif Muayad Yousif – MoEn

Other Iraq Ministry Team Members

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Ministry of Environment
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Ministry of Finance
Ministry of Agriculture

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Mr. Pekka Haavisto – The EU Special Representative for Sudan
Dr. Muthanna Al Omar, Baghdad
Mr. Jon Godson – ESA Expert
Mr. Andrew Morton – ESA Expert
Mr. Robert Holmes – ESA Expert
Mr. Ola Nordbeck – GIS and Remote Sensing Expert
Mr. Per Bakken – Director, UNEP IETC
Ms. Mayumi Morita – UNEP IETC
Ms. Rie Tsutsumi – UNEP Regional Office for Europe
Mr. Jogchum Finnema – UNOPS, Geneva
United Nations Office for Project Services, Amman, Jordan
UNEP International Environment Technology Centre, Osaka and Shiga, Japan

UNEP Post-Conflict Branch

Mr. Henrik Slotte – Chief
Mr. Muralee Thummarukudy – Operations Manager
Mr. David Jensen – Policy and Planning Coordinator
Mr. Mario Burger – Senior Scientific Advisor
Mr. Grant Wroe-Street – Project Coordinator
Ms. Francesca Cenni – Programme Officer
Ms. Mijke Hertoghs – Programme Officer
Mr. Hassan Partow – Programme Officer
Mr. Gabriel Rocha – Systems Administrator
Ms. Maliza Van Eeden – Project Officer
Mr. Alain Wittig – Associate Programme Officer
Mr. Richard Wood – Technical Coordinator
Ms. Joanne Stutz – Programme Assistant
Ms. Céline Reichard – Project Assistant
Ms. Olena Orlyk – Project Assistant
Mr. Matija Potocnik – Project Assistant

UNEP Iraq Project Office in Amman, Jordan
Mr. Koen Toonen – Programme Manager
Mr. Nedal Al Ouran – EIA Specialist
Ms. Majeda Ismail – Administrative Assistant
Mr. Firas Abu Taeh – Operations Support

Consultants

Ms. Hazel Davidson – Laboratory Analysis
Ms. Jane Upperton – Report Editor
Mr. Massimo Massera – GIS and Remote Sensing
Ms. Junko Favre – Translator
Mr. Reda Chalaby – Translator

Further information

Copies of this report may be ordered from:
SMI (Distribution Services) Limited
P.O. Box 119
Stevenage
Hertfordshire SG1 4TP, UK
Tel: +44 1438 748111
Fax: +44 1438 748 844

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http://postconflict.unep.ch

www.unep.org

United Nations Environment Programme
P.O. Box 30552 Nairobi, Kenya
Tel: ++254-(0)20-62 1234
Fax: ++254-(0)20-62 3927
Email: cpiinfo@unep.org

UNEP

It is estimated that Iraq has several thousand contaminated sites resulting from a combination of general industrial activities, military activities, post-conflict damage and looting. Many of the sites are derelict and open to public access. They contain substantial quantities of hazardous waste and present a threat to human health and to the environment.

In partnership with the Iraq Ministry of Environment and with funding from the Government of Japan, UNEP implemented an Environmental Site Assessment project to assist Iraq in tackling this problem. The project combined practical capacity building for the Iraq partners with detailed assessment work on five priority sites. These included a demolished plating works, a looted pesticides warehouse, a fire damaged chemicals warehouse, a sulphur mining and processing complex, and a military equipment scrap yard.

All of the sites investigated had multiple environmental problems, however one site was found to present an immediate and severe health hazard due to the presence of highly toxic waste. At the national level, two priorities were identified; firstly the expansion of this first phase of work into a priority programme of site assessment and emergency intervention, and secondly the construction of a central hazardous waste treatment and disposal facility. A follow up UNEP and Ministry of Environment project to address the identified toxic waste on the worst of the first five sites has commenced.