Conflict Pollution Hotspots in Iraq

Land Remediation for Livelihoods Restoration

صندوق الإصلاح والتعافي وإعادة إعمار العراق

IRAQ REFORM, RECOVERY & RECONSTRUCTION FUND

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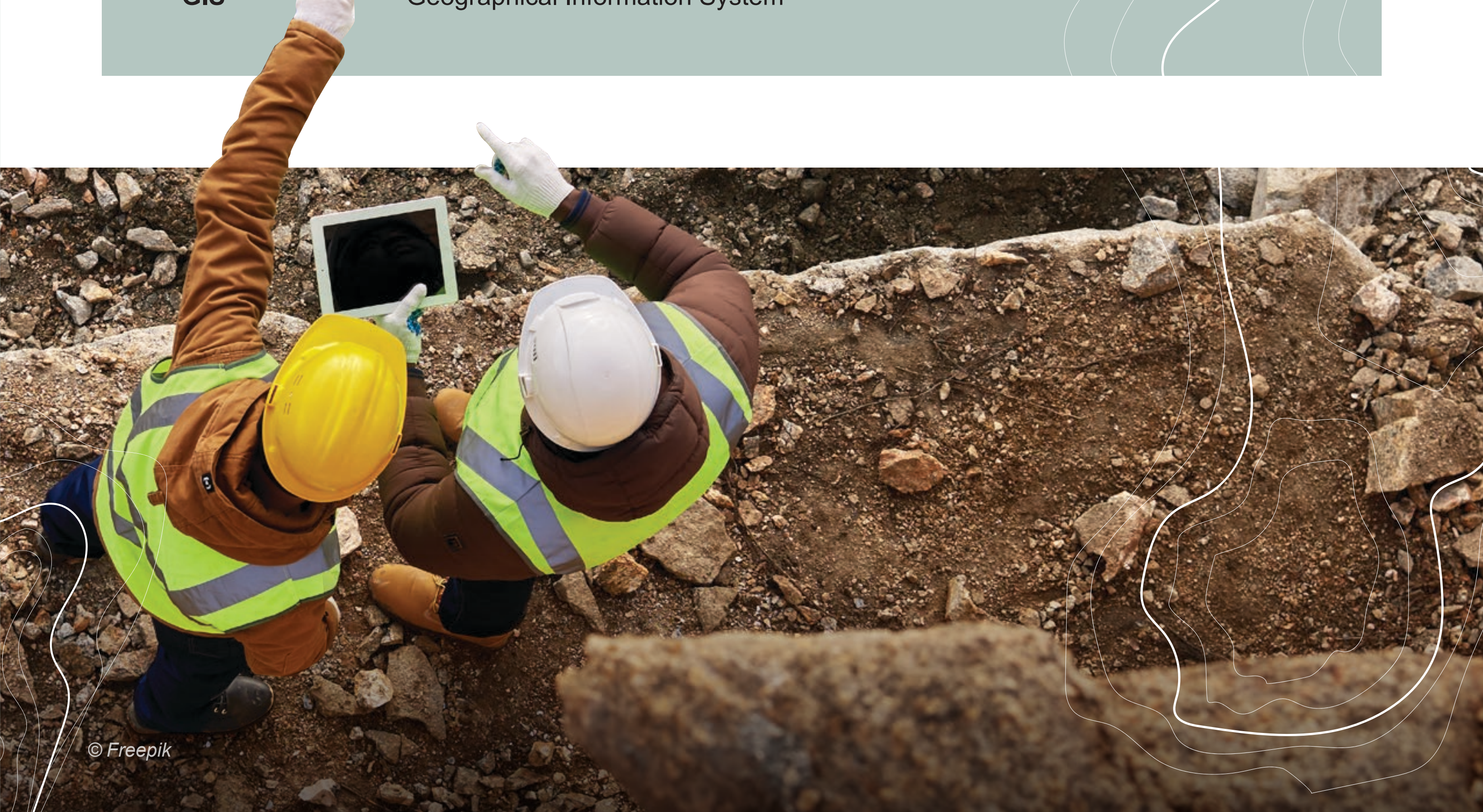
LIST OF ACRONYMS

ASA	Advisory Services and Analytics
ARAR	Applicable or Relevant and Appropriate Requirements
CCDC	Continuous Change Detection and Classification
CoED	Cost of Environmental Degradation
COLD	Continuous Monitoring of Land Disturbance
CSO	Civil Society Organizations
DEM	Digital Elevation Model
DIVs	Dutch Intervention Values
EO	Earth Observation
EPA	Environment Protection Agency
EPD	Environmental Protection Directorate
ER	Electrokinetic Remediation
ESA	European Space Agency
FCSAP	Federal Contaminated Sites Action Plan, Government of Canada
FRTR	Federal Remediation Technologies Roundtable, USA
GDP	Gross Domestic Product
GIS	Geographical Information System



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LIST OF ACRONYMS (CONTINUED)

GPS	Global Positioning System
ha	Hectares
HEAL	Health, Economic, Agriculture, and Livelihoods
I3RF	Iraq Reform, Recovery, and Reconstruction Fund
IQD	Iraqi Dinar
LNAPL	Light Non-Aqueous Phase Liquid
m	Meters
MoE	Ministry of Environment
MoO	Ministry of Oil
MPC	Marginal Propensity to Consume
NPCSM	National Program for Contaminated Sites Management
NSZD	Natural Source Zone Depletion
OSM	OpenStreetMap
SVOC	Semi Volatile Organic Compounds
TPH	Total Petroleum Hydrocarbons
UNEP	United Nations Environment Programme
UK	United Kingdom
US	United States
US$	United States Dollar
UTM	Universal Traverse Mercator
US EPA	United States Environmental Protection Agency
VHR	Very High Resolution
VOC	Volatile Organic Compounds

Acknowledgments

This report is an output of World Bank's Advisory Services and Analytics (ASA) work with co-operation from Ministry of Environment, Government of Iraq on "Support to the Management of Environmental Hotspots" financed by the Iraq Reform, Recovery, and Reconstruction Fund (I3RF) and was prepared by Environment, Natural Resource and Blue Economy (ENB) Global Practice of Middle East and North Africa (MENA) Region.

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The task team is grateful to His Excellency Engineer Nazar Amedi, Minister of Environment and His Excellency Dr. Jasim Abdulazeez Hammadi Alfalahy, Deputy Minister of Environment, Government of Iraq for their leadership. Mr. Yousif Muayad Yousif, Director, Directorate of Climate Change, Mrs. Sarab Wajaan Ajeel, Manager, International Relationships Department, Mr. Oday Haddawee, Assistant Manager, International Relationships Department, and the Chemicals Monitoring and Contaminated Sites Assessment Department and National Experts Team (listed in Appendix H) led by Mr. Waleed Ali Hussein, Senior Chief Engineer, Ministry of Environment, Government of Iraq and other government institutions for their excellent support and cooperation in carrying out this study.

The team would also like to thank the World Bank colleagues Saroj Kumar Jha (Global Director, Water), Ramzi Afif Neman (Senior Operations Officer, MENA Strategic Co-operation Department), Naila Ahmed (Program Manager, I3RF), Waseem Falih Kadhim Al Muqdadi (Deputy Program Manager, I3RF), Zeina Azar (Operations Officer, I3RF) for their support and inputs provided,

Katelijn Van den Berg (Senior Environmental Specialist, East Asia and Pacific Region), Sameer Akbar (Senior Environmental Specialist, Europe and Central Asia Region), and Tracy Hart (Global Lead, Fragile and Conflict States) served as peer reviewers.

Jean-Christophe Carret (Country Director, Middle East Department), Meskerem Brhane (Regional Director, Sustainable Development, MENA Region), Lia Carol Sieghart (Practice Manager, ENB Global Practice, MENA Region), Richard Abdulnour (Country Manager, Iraq), Lemya Izzet Ayub (Operations Officer, World Bank Office, Baghdad), Salim Rouhana (Sector Leader, Sustainable Development) provided guidance in carrying out this work. Victoria Bruce-Goga (Senior Program Assistant) and Hasan Jamal Mohsin (Program Assistant) provided logistical support. The report was edited by Jennifer Stastny and designed by Brett Jefferson Stott.

Executive Summary

1. Introduction

Successive conflicts in Iraq were characterised by tactics to damage its oil and industrial assets that not only led to huge economic loss, but pollution of environmental resources (air, land and water) on an unprecedented scale. The Damage and Needs Assessment (DNA)[1] carried out by the World Bank Group (WBG) in 2017, estimated damages to the environmental resources at IQD85 billion (US$73 million) and sectoral losses as a result of the conflict at IQD3.5 trillion (US$3 billion). Further, this assessment estimated that up to 47 percent of natural forests in the country may have been destroyed and large areas of land have been contaminated by land mines and hazardous chemicals.

Unless these contaminated sites (also referred as 'environmental hotspots' in this document) are identified and remediated and/ or managed appropriately as part of the broader reconstruction program of Iraq, it is likely that the negative impacts (both economic and environmental) will be felt for generations to come. In addition, creating better environmental conditions and investments in human and physical capital is crucial for the economic diversification, job creation and healthy citizens for a stable and sustainable development of post-conflict Iraq.

The main objective of this report is to present a broad framework and suggested prioritization for the remediation and/or management of environmental hotspots in Iraq. The recommendations have been informed by a detailed inventory and assessment of hotspots carried out by the Ministry of Environment (MoE), Government of Iraq (GoI) with capacity building support provided through the Advisory Services and Analytical (ASA) work of the World Bank. The work involved analysis of the scale and significance of contamination in the conflict affected governorates of Al Anbar, Babil, Baghdad, Diyala, Kirkuk, Nineveh and Salah Al-Din and identifying essential elements of a program for the remediation/ management of environmental hotpots in the country.

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1 World Bank, 2018.

2. Inventory and assessment of environmental hotspots

The inventory and assessment work carried out by the MoE with technical support from the World Bank's ASA involved:

- **Screening and developing an inventory of hotspots** through spatial analysis of satellite imagery using the Continuous Change Detection Classification (CCDC) algorithm.
- **Field visits and initial assessments of suspected hotspot sites** including laboratory analysis of soil and water samples to understand the nature and magnitude of contamination, and its impacts on local communities.
- **Risk-based classification and prioritization of sites** for detailed assessments and remediation
- **Detailed mapping of identified hotspots** along with Web Geographical Information System (WebGIS) database for future updating.

The inventory and assessment activities established that Iraq's pollution hotspots indicate widespread hydrocarbon and chemical contamination. Of the total 76 "suspected hotspots" identified, field assessment could be carried out for 69 sites in 47 locations (including 20 damaged industrial units). This assessment suggests that about 1,333.03 hectares (ha) of land is likely to have been contaminated, affecting an estimated 55,050 people directly and more than 1.70 million people indirectly. Most of the pollution hotspots are in the three governorates of Kirkuk (24 sites), Nineveh (17 sites), and Salah Al-Din (13 sites).

Environmental analysis of the soil and water (surface and groundwater) samples at these sites indicated that the level of contamination exceeds 100 times the Dutch Intervention Values (DIVs) at 32 sites; 50 times the DIV at seven sites; and 10 times the DIV at the remaining 30 sites. The Kirkuk governorate is estimated to have the largest impacted population, with about 1.1 million people affected by pollution.

Site assessments further indicated that about 1,569 ha of agriculture land; 3,018.38 ha of vegetation; and 8,482 structures are impacted by contamination. Nine major industries are completely damaged and are currently not in operation. This indicates the level of environmental and health challenges posed by the hotspots in Iraq, as well as the potential gains due to their management or remediation.

To better understand these challenges, the burden of diseases, economic cost of destroyed industries, opportunity cost of affected agricultural land, and loss of livelihoods due to destroyed industries and agriculture was estimated. These estimates indicate that the overall cost of Health, Economic, Agriculture and Livelihood (HEAL) impacts at the identified suspected hotspots in Iraq is around US$1.44 billion per year.

Further, an assessment of risks due to these suspected pollution hotspots identified that the risks are very high at five sites; high at 18 sites; moderate at 24 sites; moderate/low at 16 sites; and low at five sites. Stakeholder consultations carried out as part of the assessment also confirmed the significant impacts faced by local communities around these hotspots and emphasized the urgent need for remediation and management of contamination.

3. Policy and institutional framework for the management of hotspots

Building on the inventory and assessment of hotspots, an analysis of regulatory, institutional, and capacity-building requirements for the management of environmental hotspots in Iraq was carried out. This involved reviewing both international practices in contaminate site management (from the United States of America (USA), the United Kingdom (UK), Canada, the Netherlands, and South Africa) and Iraq's current regulatory and institutional framework. This analysis indicated that Iraq has a comprehensive set of environmental regulations that includes certain aspects relevant to contaminated sites management, such as regulations for hazardous waste, storage and handling of chemicals, and inclusion of "Polluter Pays" principle. However, some important requirements for the identification, assessment, remediation, and institutional mandate for managing contaminated sites need to be included in the current regulatory framework.

Accordingly, the analysis identified the specific need to: strengthen policy and regulatory framework in line with the international good practices; establish an institutional mechanism that ensures coordination between various stakeholder ministries; and build the technical and institutional capacity of MoE. The report identified a set of options for each of the above enhancements. However, these options need to be further evaluated based on more detailed analysis of each element, more specifically in the context of an overall program on contaminated sites management in Iraq and its specific interventions.

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4. Technology options for remediation

In order to develop a roadmap for the remediation of pollution hotspots in Iraq, a review of technology options that may be relevant to the nature, type, and local context was carried out. The review focused on four critical elements of remediation: remediation approaches (risk based versus standards based); available technologies; factors that influence the selection of technologies; and the criteria to be followed in selecting remediation technologies. While no specific technology is recommended, the ASA presents salient features of available technologies along with the advantages, disadvantages, and indicative costs of each option per unit of contaminant to be removed. These elements should be closely evaluated based on a detailed assessment of each hotspot and stakeholder consultations in order to choose suitable technology for the targeted land use of the respective site.

5. Roadmap for contaminated sites management in Iraq

Based on the analysis of pollution hotspots, their potential to cause health and environmental impacts, and a review of the legal, institutional, and technological aspects related to the assessed contaminated sites, the report recommends establishing a National Program for Contaminated Sites Management (NPCSM). In the initial phase, the NPCSM is recommended for five years at a broad estimated cost of US$422 million.

A proposed roadmap detailing specific actions for policy, regulatory, institutional, and demonstration remediation projects is also presented. The actions recommended in the roadmap include developing a contaminated site management policy; promulgating legislation on contaminated sites; establishing standards for remediation; establishing an institutional mechanism supported by capacity-building measures; identifying financing mechanisms for implementation; and ensuring the participation of all government and community stakeholders in the proposed NPCSM.

A project to implement the actions recommended for the development of NPCSM and demonstration remediation projects has also been recommended. Implementation of this project and roadmap actions will help ensure better management of contaminated sites in Iraq.

1 Introduction

1.1 Background

Successive conflicts in Iraq were characterized by tactics to damage the country's oil and industrial assets. This led not only to huge economic loss, but to the pollution of air, land, and water on an unprecedented scale. The Damage and Needs Assessment[2] published by the World Bank in 2018 estimates environmental resources damages resulting from various conflicts at Iraqi Dinar (IQD) 85 billion (US$73 million), with sectoral losses at IQD3.5 trillion (US$3 billion). The Damages and Needs Assessment also estimated that as much as 47 percent of the country's natural forests may have been destroyed, while 2.4 million hectares of high-use land has been rendered unusable due to landmines, and at least 10,569 ha have been lost due to pollution by hydrocarbons and other chemicals. The true extent of conflict-related land contamination, however, is yet to be confirmed.

Without any intervention, the contamination of land is expected to have long-lasting impacts for the safety, health, and livelihoods of communities, with disproportionately high impacts on the most vulnerable members of society, who continue to access these contaminated sites for agriculture, animal grazing, and other domestic activities. These groups, as estimated by the Damage and Needs Assessment, include about three million internally displaced persons, women, female-headed households, and the youth.

Future generations will likely suffer the economic and environmental impacts of these contaminated sites (also referred as "pollution hotspots" in this document) unless they are identified and remediated or managed appropriately as part of Iraq's broader reconstruction program. Creating better environmental conditions and investments in human and physical capital are crucial for the economic diversification, job creation, and healthy citizens that will form the foundation of stable and sustainable development in post-conflict Iraq.

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2 World Bank, 2018.

1.2 Objectives

This report presents a broad framework for the remediation and management of pollution hotspots in Iraq and identifies priorities for further action. Its recommendations are informed by an inventory and assessment of hotspots carried out by the Ministry of Environment (MoE), Government of Iraq, with capacity-building support provided through the Advisory Services and Analytical (ASA) work of the World Bank.

The work analyzed the scale and significance of contamination in conflict-affected governorates and identified essential elements for a remediation and management program in targeted pollution hotspots. In addition to improving the environmental conditions and reducing associated health risks for communities, implementing such a framework would also enable the restoration of livelihoods and economic development in affected governorates.

Another important objective of the World Bank's ASA was building the capacity of the MoE and other government agencies under which this report is prepared. This was achieved by providing technical support and delivering virtual, classroom, hands-on, and on-site training programs that followed a "learning by doing" approach. The training focused on identifying, mapping, assessing, and prioritizing hotspots for remediation. A customized training program on estimating the Cost of Environmental Degradation (CoED) was also provided.

1.3 Data, information sources, and methodology

The main regions of Iraq impacted by conflicts were the governorates of Al Anbar, Babil, Baghdad, Diyala, Kirkuk, Nineveh, and Salah Al-Din. Since the focus of this ASA report (and that of the Iraq Reform, Recovery, and Reconstruction Fund [I3RF]) is on conflict pollution, it focuses only on these seven governorates.

While most of the conflict-related contaminated sites are expected to be in these governorates, the broad framework proposed in this report and the enhanced capacity of the MoE to assess and manage such sites will help analyze pollution hotspots in other regions of Iraq. In addition to conflict pollution, radioactive contamination is anticipated in some southern areas of the country. This aspect, however, was not analyzed by this ASA, as it is usually assessed by the International Atomic Energy Agency. Similarly, the landmine and explosive remnant contamination in the country is also not analyzed, since these assessments are coordinated at the local and international levels by the United Nations Mine Action Service.[4]

DATA AND INFORMATION SOURCES

This report relied on existing data and information available from the MoE and further updating carried out by the ministry's Chemicals Monitoring and Contaminated Sites Assessment Department. The work carried out by the MoE, with support from this ASA, involved:

- **Updating the inventory** and mapping of suspected contaminated sites
- **Field visits and initial assessments of suspected sites** to understand the nature and magnitude of contamination and its impacts on local communities.
- **Risk-based classification and prioritization** of sites for detailed assessments and remediation.

3 IAEA 2018.
4 UNMAS 2021.

METHODOLOGY

Agencies and international experts that specialize in the above aspects provided virtual, classroom, and on-site field training to officials from the MoE, the Ministry of Oil (MoO), their regional and local teams, and Environment Protection Directorates (EPDs). In addition to building technical capabilities, the training ensured that appropriate data was collected and managed in a consistent manner to aid future analysis.

Capacity-building involved the following training programs:

1. **A five-day comprehensive virtual training program** for 30 environmental engineers and scientists from the MoE, MoO, and EPDs, was provided by the World Bank's technical experts on contaminated site management, totaling 150 person-days. This training focused on the identification, assessment, remediation, management, and post-remediation monitoring of contaminated sites (June 8–15, 2021).

2. **On-the-job virtual training** on identifying and taking inventory of suspected contaminated sites by analyzing satellite imagery was provided for eight members of the MoE's Geographical Information System (GIS) team between June and December 2021 (64 person days). This training was provided by experts hired by the European Space Agency (ESA) through its Earth Observation (EO) Satellites Clinic program.

3. **A two-day classroom training program** on the design of environmental sampling strategies and initial assessment of contaminated sites was provided for 30 environmental engineers and scientists from the MoE, the MoO, and the EPDs (60 person days) by an expert international consulting firm on contaminated site assessment (April 3–4, 2022).

4. **On-site and on-the-job training** (following a "learning by doing" approach) was provided for 30 environmental engineers and scientists from the MoE, the MoO and the EPDs (900 person days) by an expert international consulting firm on environmental sampling, assessment, and baseline profiling of contaminated sites (April–July 2022).

5. **A two-day laboratory and hands-on training program** was provided for eight environmental scientists of the MoE (16 person days) on analyzing water and soil samples for chemical contamination. This training was provided at the advanced laboratory of an expert international consulting firm (August 28–29, 2022).

6. **On-the-job (virtual) and a five-day hands-on training program** on detailed mapping of contaminated sites, developing an online GIS (that is, a WebGIS), and managing and updating data related to contaminated sites was provided for eight members of the MoE's GIS team (40 person days) (October 17–21, 2022) at a specialized laboratory in France.

7. **A five-day comprehensive face-to-face training program** on assessing CoED (November 7-11), was provided for 20 government officials in Beirut, Lebanon (100 person days) (November 7–11, 2022).

OUTPUTS

The following outputs were produced through the above capacity building programs.

- **A comprehensive inventory** with detailed maps of suspected pollution hotspots was prepared using innovative spatial analysis techniques based on the Continuous Change Detection Classification (CCDC) algorithm and grid-based characterization of sites.[5]
- **An environmental, social, and chemical baseline profile** of all the suspected contaminated sites was developed.[6]
- **A risk-based classification of sites** and prioritization for further assessments and remediation was completed.[7]
- **An interactive WebGIS database** for continuous monitoring and updating of information on contaminated sites was developed.[8]

5 MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022, MoE and Hatfield Consultants LLP 2022.
6 MoE and RSK Environment LLC 2022.
7 MoE and RSK Environment LLC 2022 and 2023.
8 MoE and Hatfield Consultants LLP 2022.

Building on the above outputs, the World Bank team conducted a review of Iraq's legal and institutional framework for managing contaminated sites, with an aim of identifying areas for enhancement. A review of technologies for the remediation of chemical and hydrocarbon contaminated sites was also carried out to identify the technologies that would be most suitable in the context of Iraq.

This report draws on the above analyses, reviews, and consultations and presents a framework for the management or remediation of pollution hotspots in Iraq.


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1.4 Data limitations and constraints

Analyzing and assessing sites affected by chemical contamination requires detailed sampling and extensive field investigations. Water and soil samples collected from the sites also require careful analysis for a wide range of contaminants such as Total Petroleum Hydrocarbons (TPH), Volatile Organic Compounds (VOCs), Semi Volatile Organic Compounds (SVOCs), and Heavy Metals. These analyses require expertise and use of advanced equipment such as Gas Chromatography-Mass Spectrometry, Inductively Coupled Plasma-Mass Spectrometry, and Energy Dispersive X-Ray Fluorescence. Access to this level of expertise and infrastructure required for extensive field investigations is limited in Iraq.

The COVID-19 pandemic and the security situation in the country also severely hampered the MoE team's field work. These challenges were addressed by providing extensive training (virtual, classroom/face-to-face and on-the-job trainings as elaborated in section 1.3 above) to government officials on all relevant aspects such as (1) conducting site assessments and sampling; (2) use of satellite imagery, GIS, and other digital tools for collection and analysis of field-level data; (3) collection and collation of information through earlier studies; as well as (4) use of data from MoE and consultations with various stakeholder agencies.

While these efforts did help in obtaining the most relevant data and information required for the development of a framework for the management of environmental hotspots in Iraq, further refinement and more detailed field assessments are needed before designing and implementing remediation plans for individual sites. The findings and observations in this report should therefore be considered from this perspective and policies and programs shall be developed accordingly.

1.5 Structure of the report

The results of the analysis along with the broad framework for addressing the issues related to environmental hotspots in Iraq is presented in five chapters.

While **Chapter 1** (the current chapter) provides an overall background of the work, objectives, and approach followed in carrying out the analysis, **Chapter 2** presents an inventory and analysis of the profile, type, magnitude, and an initial assessment of impacts of contamination in the hotspots across seven targeted governorates of Iraq. **Chapter 3** provides an analysis of the current regulatory and institutional regime to address the issue of land contamination and enhancements or improvements needed for implementing a sustainable contaminated sites management program. Based on the profile of hotspots, **Chapter 4** evaluates the technological options for the remediation of hotspots, their relevance in the context of Iraq, and associated cost implications. Building on the analysis carried out in the earlier chapters, **Chapter 5** presents the recommended roadmap for developing a program for the management or remediation of hotspots in Iraq.


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2 Inventory and Assessment of Pollution Hotspots

This ASA builds on earlier work conducted by the MoE and the United Nations Environment Programme (UNEP) to understand and assess the environmental pollution caused by a series of conflicts in Iraq. This included the following studies and projects.

Strengthening environmental governance in Iraq through environmental assessment and capacity building project (2004–05): This project was funded by the United Nations Trust for Iraq. It focused on identifying potentially contaminated sites and building the MoE's capacity to conduct site assessment.[9,10] The project identified five priority sites for remediation of more than 100 sites identified across the industrial, mining, and oil refinery sectors. A follow-up project to contain and clean hazardous material at two sites was proposed.

Capacity Needs Assessment of the institutional and regulatory framework for environmental management in oil and gas sector (June 2018): With the support from the Norwegian government's Oil for Development program, UNEP assessed the needs of the oil and gas sector for environmental management after conflicts in Iraq subsided in 2018.[11] This study identified regulatory and institutional gaps and recommended establishing an inventory of environmental issues (including contaminated hotspots) related to the oil and gas sector.

Mapping of oil pollution in Iraq (2018–19): UNEP, with financing from its Disaster Management Branch, conducted field visits and prepared GIS maps of the sites affected by oil pollution in Nineveh, Kirkuk, Salah Al-Din, and Diyala. The study produced a rapid inventory of 75 sites contaminated with hydrocarbons and diagnosed 23 sites as high risk. It also recommended developing plans to address the issues of oil or hazardous waste pollution and building the MoE's capacity to assess sites and design remediation plans.

2.1 Screening and inventory of hotspots

International practice to identify and manage contaminated sites follows a sequential process. In the first step, "**suspected sites**" are identified based on current or past site use or historical incidents. After an initial site assessment and preliminary risk assessment of suspected sites, "**potentially contaminated sites**" are identified. This process is referred to as "Phase 1 Assessment". In the next step, detailed assessment (referred to as "Phase 2 Assessment") of potentially contaminated sites involving comprehensive environmental investigations is conducted to establish the levels of contamination and risks to neighboring communities. "**Contaminated sites**" are identified based on this detailed assessment. Necessary steps for the preparation of management or remediation plans (referred to as Phase 3) based on the information obtained above and their implementation (Phase 4) is then initiated. The effectiveness and results of the management or remediation are subsequently monitored in Phase 5.

9 UNEP 2005.
10 UNEP 2007.
11 UNEP 2018a.
12 MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.

Referring to the above process, the sites identified by the MoE so far can be termed as "suspected sites" through Phase 1 assessment. These sites, however, are limited to four governorates where the majority of the sites were reported. Building on this work, during the period June to December 2021, the MoE developed a comprehensive inventory of hotspots across all seven conflict-affected governorates of Iraq: Al Anbar, Babil, Baghdad, Diyala, Kirkuk, Nineveh, and Salah Al-Din.[12]

However, security situation in Iraq and COVID 19 pandemic during the years 2021 and 2022, posed challenges to MoE team in conducting field visits and preparing the inventory of hotspots. Considering this, technical support from ESA's EO clinic was leveraged (through Hatfield Consultants LLP), who provided handholding support to MoE team (technical and GIS teams) in the development of inventory of hotspots through spatial tools.

The approach as presented in the figure below involved a multistage process to identify and screen the sites with the help of multiple digital data sets involving the following steps:

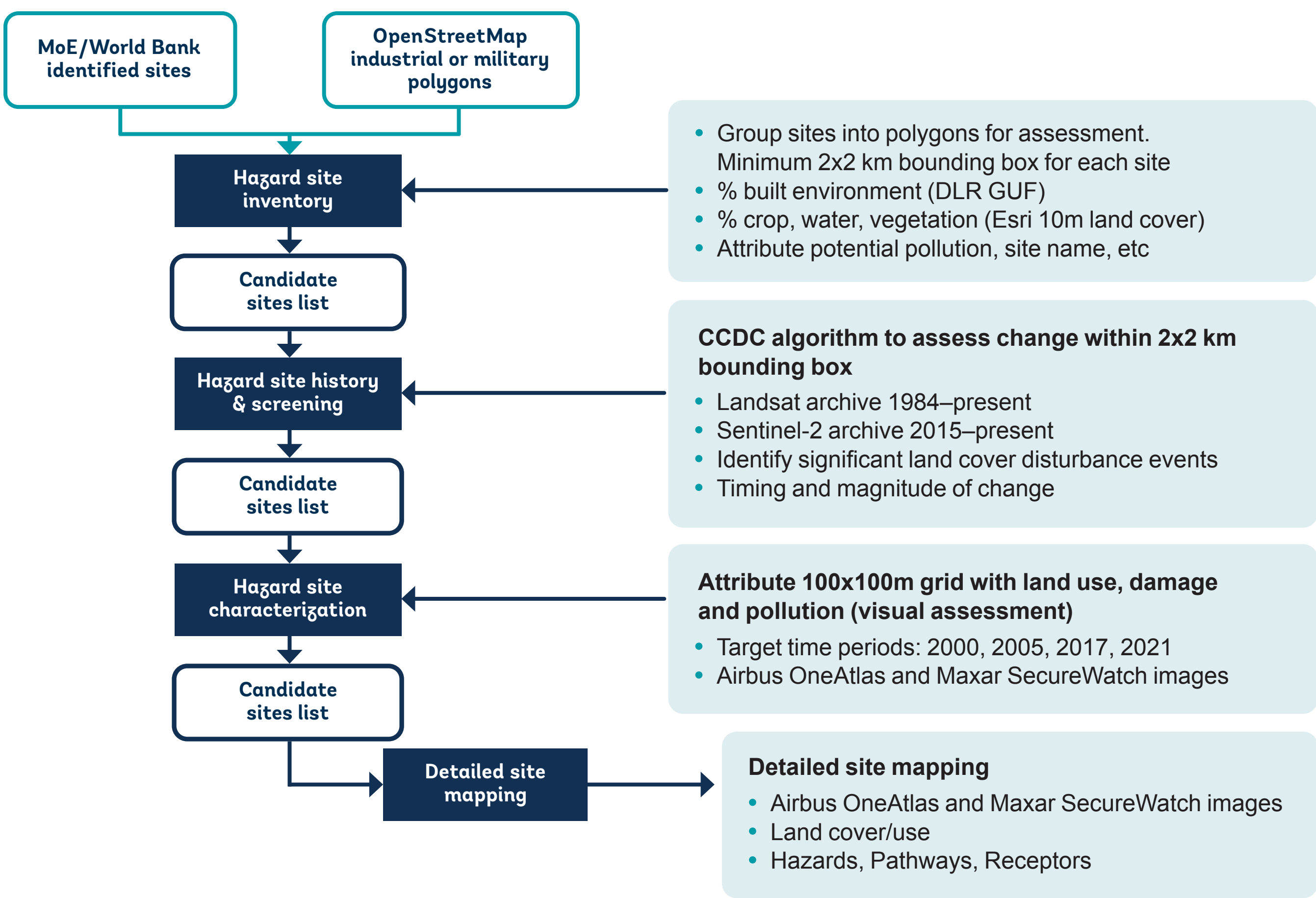
1. **An inventory of suspected pollution hotspot sites was prepared** based on an analysis of information from the MoE; spatial data from OpenStreetMap (OSM) (industrial and/or military polygons from OSM for possible contamination); and German Aerospace Center, Global Urban Footprint, and Environmental Systems Research Institute data sets. This analysis sought to identify potential pollution to develop a hazard site inventory.

2. **Candidate sites and land-cover disturbance events were screened** using the CCDC algorithm on the Landsat archive (1984 to present) and Sentinel-2 archive (2015 to present) to identify significant land cover disturbance events.

3. **An inventory of suspected hotspot sites was then prepared** based on the grid-based assessment of sites for targeted time periods using Airbus OneAtlas and Maxar SecureWatch. These sites were verified by on-the-ground knowledge of the MoE team.

In addition to providing a robust inventory on suspected hotspot sites (Appendix A), this exercise demonstrated the effectiveness of spatial data analysis for screening, identifying, and mapping contaminated sites in situations where access is restricted, and time is limited. A more detailed description of spatial analysis followed for preparing the inventory of "suspected hotspot sites" is presented in Appendix B.

Figure 1: *Multistage process to identify, screen, and map contaminated sites*



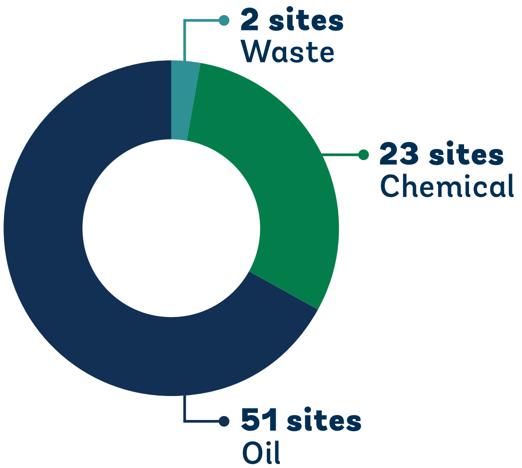
Based on the knowledge gained through virtual training in 2021, the MoE's GIS team screened 216 candidate sites and identified 76 suspected hotspots in Iraq (Table 1). Of these sites, 51 (67.1 percent) are oil-contaminated, 23 (30.26 percent) are chemical-contaminated, and two (2.63 percent) are waste-contaminated sites. In terms of geographical distribution, 36.84 percent (28 sites) of the sites are in Kirkuk governorate, 22.37 percent (17 sites) in Nineveh, and 19.73 percent (15 sites) in Salah Al-Din. The detailed list of suspected contaminated sites within each governorate is presented in Appendix A.

Table 1: *Summary of candidate and suspected hotspot sites*

Governorate	Candidate Hotspot Sites				Suspected Hotspot Sites			
	Chemical	Oil	Waste	Total	Chemical	Oil	Waste	Total
Al Anbar	16	1	0	17	5	1	0	6
Babil	6	2	0	8	1	0	0	1
Baghdad	17	2	2	21	8	0	0	8
Diyala	5	2	0	7	1	0	0	1
Kirkuk	14	30	21	65	1	26	1	28
Nineveh	17	63	0	80	4	12	1	17
Salah Al-Din	8	8	2	18	3	12	0	15
Total	**83**	**108**	**25**	**216**	**23**	**51**	**2**	**76**

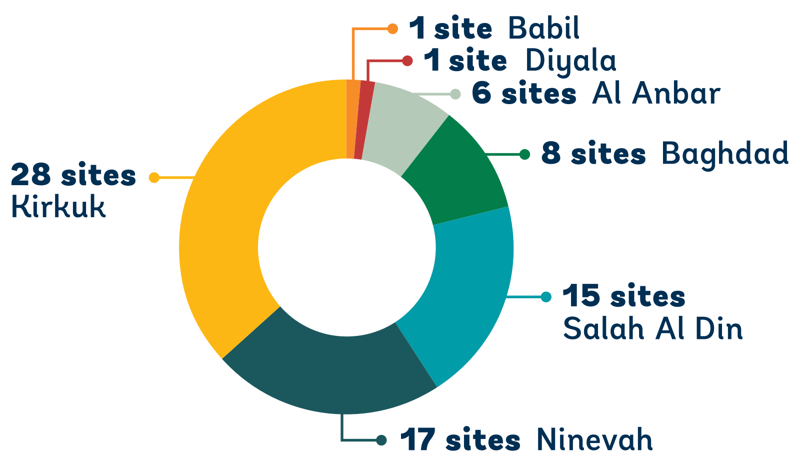
Source: *Based on inventory by MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

Figure 2: *Distribution of hotspots by pollution category*



Source: *Analysis of inventory by MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

Figure 3: *Distribution of hotspots by governorate*



Source: *Analysis of inventory by MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

The inventory of contaminated sites includes only the seven conflict-affected governorates of Iraq. Significant industrial activity and waste management challenges could mean that there are pollution hotspots in the other 12 governorates of Iraq as well. This limitation was addressed by the training provided to the MoE's GIS team in October 2022, which focused on identifying, screening, and mapping suspected contaminated sites using spatial tools. An updatable WebGIS on identified hotspots has also been developed (Figure 4). Through this training and WebGIS, MoE can identify hotspots in other governorates of Iraq.

Figure 4: Geographical overview of hotspots in Iraq

Source: *MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

2.2 Initial assessment of hotspots

Governorate-specific site-assessment teams were formed to carry out the initial assessments of suspected pollution hotspots between April and August 2022.[13] These teams comprised members of the relevant ministries, notably the MoE; local agencies with knowledge of the sites; and other stakeholders.

The World Bank team provided the MoE and other stakeholders with technical and capacity building support in carrying out the following steps of initial assessment:

- A two-day training program was held for the MoE, MoO, and governorate-level EPD teams focusing on how to review available data and information; identify and finalize site-level additional information to be collected; and design sampling strategies and site-specific sampling plans. This training also covered health and safety measures to be taken up in carrying out site assessments, among other topics.
- A detailed site-inspection checklist (Appendix C) was developed. This checklist included basic information such as the site's name and Global Positioning System (GPS) coordinates, the source and history of contamination, and visible and reported impacts, as well as an option for photographic evidence.
- Administrative and security permissions were obtained from relevant site-owning authorities and agencies to conduct site visits.
- Site visits were conducted to collect basic data and obtain limited environmental samples to confirm the nature and type of contamination at the sites.
- Environmental samples were analyzed in a laboratory to establish the level of contamination.
- An overall environmental profile of each site was prepared.

13 MoE and RSK Environment LLC 2022.

2.2.1 PROFILE OF POLLUTION HOTSPOTS

Following the above process, site assessments were conducted at 69 suspected sites in 47 locations. Seven sites could not be assessed due to lack of security or access permissions from relevant site authorities.

The assessment found that about 1,333.03 ha of land might have been contaminated (980.55 ha directly and 352.48 ha indirectly), impacting about 1.75 million people, or about 8.55 percent of the total governorate population (Table 2).

In addition to environment and health impacts, the contamination is also expected to have affected the livelihoods of these people owing to reduction or loss in productivity of agriculture lands and job opportunities due to destroyed industrial facilities and other economic assets. This aspect is discussed in more detail in Section 2.2.4.

Table 2: *Profile of suspected pollution hotspots in Iraq*

Governorate	Affected locations	Total hotspots*	Suspected Contaminated Area, (ha)		Affected Population (approximate)		Governorate population**
			Direct	Indirect	Direct	Indirect	
Al Anbar	5	5	501.66	25.12	4,260	89,000	1,771,656
Babil	1	1	6.20	12.56	1,080	10,000	2,065,042
Baghdad	6	6	27.64	56.52	10,930	78,500	8,126,755
Diyala	1	1	0.30	3.14	1,200	10,000	1,637,226
Kirkuk	13	24	33.45	94.20	2,660	1,100,900	1,597,876
Nineveh	8	17	275.20	82.44	25,570	181,500	3,729,998
Salah Al-Din	13	15	136.10	78.50	9.350	231,677	1,595,235
Total	**47**	**69**	**980.55**	**352.48**	**55,050**	**1,701,577**	**20,523,788**
Grand Total			**1303.03**		**1,756,627 (8.55% of governorates population)**		

* Seven sites could not be assessed due to access issues: three in Kirkuk, two in Baghdad, and one each in Al Anbar and Nineveh.
** Central Statistics Organization (Government of Iraq) 2018.[14]

Source: *Based on inventory by MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

Across the seven governorates, Kirkuk had the largest number of hotspots (24 out of the total 69 hotspots), affecting over 1.1 million people (Figure 5). Al Anbar had the largest area of contaminated land, totaling about 501.66 hectares over five hotspots in five locations (Figure 6). The Nineveh governorate led in the number of people directly affected by the contamination (55,050 people), followed by Baghdad (19,930 people).

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14 Central Statistics Organization. (Government of Iraq). 2018. “Populations Projections 2015–18”.

Figure 5: Number of people possibly directly and indirectly affected by pollution, by assessed governorate

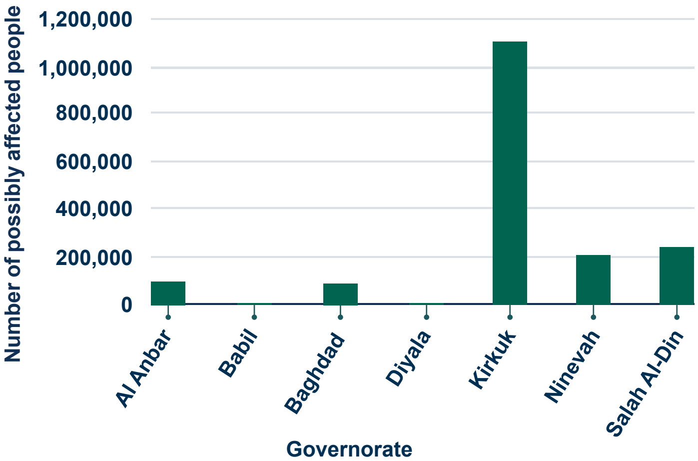
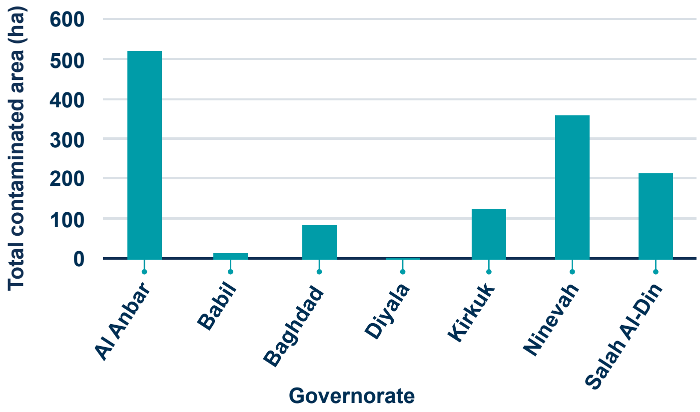


Figure 6: Suspected contaminated area, by assessed governorate



2.2.2 ENVIRONMENTAL PROFILE OF SUSPECTED HOTSPOTS

To prepare the environmental profile of hotspot sites, the basic characteristics of each site with regard to the nature of industrial and/or production activities, area of the site, environmental features, land use, and socio-economic profile, were analyzed. This analysis, as summarized in Table 3, indicates that 43 of the total 69 sites assessed (62.31 percent) are oil refinery and gas isolation facilities and 10 sites (14.49 percent) are fertilizer/chemical industrial sites. These suspected hotspots are distributed in 47 locations, 27 of which are oil/Hydrocarbon, and 20 industrial hotspots.

A site-specific sampling strategy was developed to understand the type of pollutants and the level of contamination by collecting three or four soil, surface water, and groundwater samples from each site. These samples were analyzed for the following potential contaminants: Volatile Organic Compounds (VOCs), Semi Volatile Organic Compounds (SVOCs), Heavy Metals, Total Petroleum Hydrocarbons (TPHs), and other basic environmental parameters.[15]

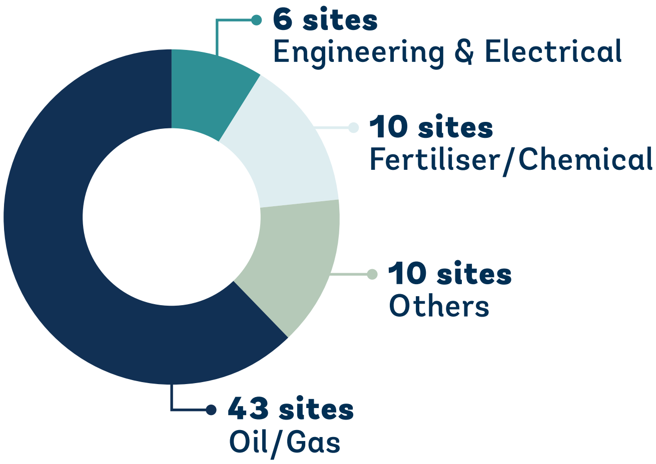
Table 3: *Environmental profile of suspected hotspots in Iraq*

Governorate	Hotspot nature/type				Major pollutants			
	Oil/gas	Fertiliser/ chemical	Engineering & electrical	Others	Hydro-carbons	Heavy Metals	Chemicals & Asbestos	Metals
Al Anbar	1	3	0	1	1	0	2	2
Babil	0	1	0	0	0	1	0	0
Baghdad	1	3	2	0	1	4	0	1
Diyala	0	0	1	0	1	0	0	0
Kirkuk	22	1	0	1	19	1	0	4
Nineveh	12	1	1	3	11	3	3	0
Salah Al-Din	7	1	2	5	13	2	0	0
Total	**43**	**10**	**6**	**10**	**46**	**11**	**5**	**7**

Source: *Based on site assessment by MoE and RSK Environment LLC 2022.*

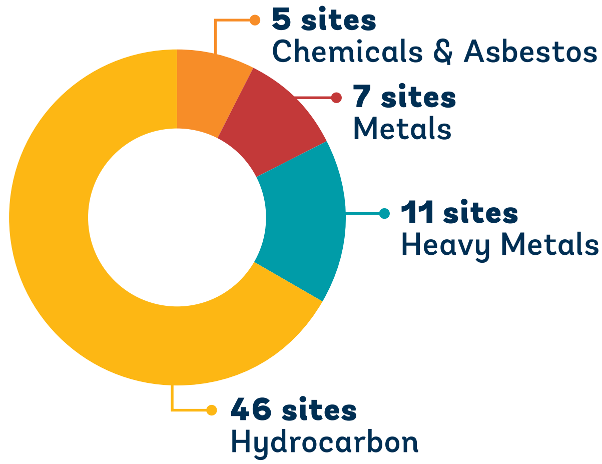
15 Standard parameters to understand pollution at the sites identified.

Figure 7: *Suspected pollution hotspots by nature of activity*



Source: *Based on site assessment by MoE and RSK Environment LLC 2022.*

Figure 8: *Suspected pollution hotspots by major pollutant*



Source: *Based on site assessment by MoE and RSK Environment LLC 2022.*

The results of the laboratory analysis of water samples were compared with the MoE's guidance values and found to be within standards.

Soil contamination levels were determined by comparing soil sample results with the Dutch Intervention Values (DIVs).[16] The soil analyses found that, out of 69 sites, 46 were polluted by Hydrocarbons and TPHs, 11 were contaminated by Heavy Metals, five sites were contaminated by chemicals and Asbestos, and seven sites were contaminated by Metals. All contaminated sites exceeded the DIVs of their pollutants tenfold, with 32 of the sites exceeding 100 times the DIVs for some pollutants (Table 4).

Table 4: *Number of sites exceeding Dutch Intervention Values for soil contamination*

Governorate	Hydrocarbons and Total Petroleum Hydrocarbons			Heavy Metals		Chemical & Asbestos		Metals
	10xDIV	50xDIV	100xDIV	10xDIV	100xDIV	10xDIV	50xDIV	10xDIV
Al Anbar	0	0	1	0	0	2	0	2
Babil	0	0	0	1	0	0	0	0
Baghdad	1	0	0	3	1	0	0	1
Diyala	0	0	1	0	0	0	0	0
Kirkuk	4	0	15	1	0	0	0	4
Nineveh	4	3	4	4	0	0	3	0
Salah Al-Din	3	1	9	1	1	0	0	0
Total	12	4	30	9	2	2	3	7
Grand Total	46			11		5		7

Source: *Based on MoE and Hatfield Consultants LLP 2022.*

16 Dutch Ministry of Housing, Spatial Planning, and the Environment 2000.

Hydrocarbon and TPH contamination exceeded 100 times the DIV in 30 (65 percent) of the total 46 Hydrocarbon and TPH contaminated sites. The level of Heavy Metal contamination exceeded 10 times the DIV in nine (82 percent) of the total 11 sites and the chemical contamination exceeded 50 times the DIV in three of the five sites. Metal contamination in all seven contaminated sites exceeded 10 times the DIV. The contamination of sites with hazardous substances poses significant and direct environmental and health risks to more than 55,050 people who either work at these sites or live close by. In addition, the contamination poses significant risks to more than 1.75 million people within the sites' influence area.

2.2.3 LAND-USE PATTERN AT HOTSPOT SITES

High levels of contamination could cause agricultural and economic losses. Land-use patterns around the hotspots were analyzed as part of the initial site assessment exercise. This revealed that cropland constitutes about 1,569 ha (27.68 percent) and vegetation about 3,018.38 ha (53 percent) of the total area. Roughly 94 percent (1,476.55 ha) of the cropland and about 82.02 percent (2,475.72 ha) of land with vegetation is in Kirkuk, Nineveh, and Salah Al-Din. The remediation of hotspots in these governorates could therefore also contribute to the enhancement of agricultural productivity and growth of vegetation in surrounding areas.

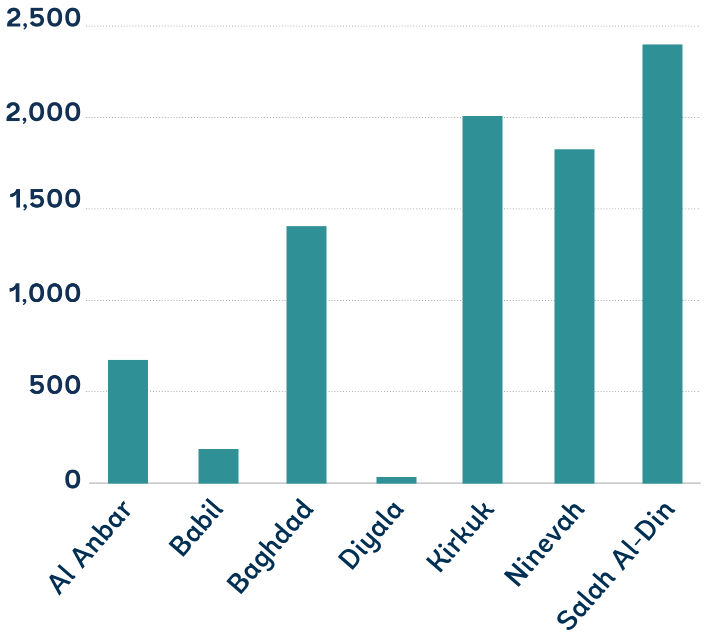
Table 5: *Land-use profile of pollution hotspots in Iraq*

Governorate	Number of structures around hotspots	Land-use pattern around hotspots (ha)					
		Cropland	Built up	Vegetation	Shrubs	Water	Total
Al Anbar	672	5.73	110.83	295.28	1.38	0.27	413.49
Babil	193	8.15	23.92	14.08	0.01	0.00	46.17
Baghdad	1,394	77.77	178.79	226.39	2.54	0.00	485.49
Diyala	38	0.81	4.70	6.91	0.00	0.00	12.42
Kirkuk	1,990	567.81	114.45	682.83	74.25	0.00	1,439.34
Nineveh	1,813	681.13	151.88	465.02	1.02	0.00	1,299.05
Salah Al-Din	2,382	227.60	274.27	1,327.87	130.41	11.28	1,971.42
Total	**8,482**	**1,569.00**	**858.84**	**3,018.38**	**209.61**	**11.55**	**5,667.39**

Source: *Based on mapping of hotspots by MoE and Hatfield Consultants LLP 2022.*

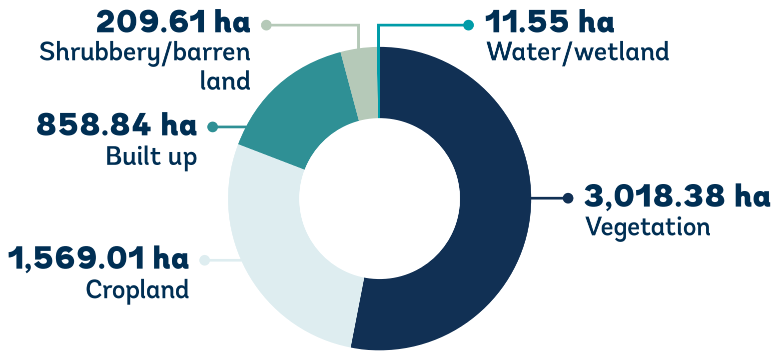
Across all hotspots, 8,482 structures were found to be damaged or destroyed. Of the 20 industrial hotspots identified, nine were destroyed and abandoned. Remediation of these hotspots could help rehabilitate and operationalize industrial units and contribute to the local economy and jobs.

Figure 9: *Number of structures*



Source: *Hotspots mapping by MoE and Hatfield Consultants LLP 2022.*

Figure 10: *Land-use patterns*



Source: *Hotspots mapping by MoE and Hatfield Consultants LLP 2022.*

2.2.4 THE HEALTH, ECONOMIC, AGRICULTURE, AND LIVELIHOOD IMPACTS OF POLLUTION HOTSPOTS

Three main valuation techniques are generally used to assess the health, economic, agriculture, and livelihoods (HEAL) impacts of pollution:

- Change in production
- Change in health
- Change in behavior.

Building on the analysis of land-use pattern, a preliminary assessment was done to determine the magnitude and significance of the HEAL impacts. This involved estimating the following.

- **The burden of disease on directly and indirectly affected populations** by considering changes in health ("dose-response function").
- **The changes in economic productivity from loss of economic activity** due to destroyed industries and agricultural land that was abandoned due to site and cropland contamination ("opportunity cost").
- **The loss of livelihoods (jobs)** due to decreased sectorial productivity and its effects on local economies.

The assessment was limited in its accuracy due to lack of site-specific information and the analysis (for example, of the effects of contamination on ecosystem services including water bodies, vegetation, and so on) needed to calculate the real cost of environmental degradation.

HEALTH IMPACTS: THE BURDEN OF DISEASE

The hotspot sites in the seven governorates will cause an estimated three instances of mortality and 14 instances of morbidity every year. These estimates are based on the Institute for Health Metrics and Evaluation's dose-response functions for Iraq[17] and the direct and indirect effects of chemical- and oil-contaminated hotspots on populations in all seven governorates was assessed. Waste was not considered as no specific dose-response functions were available for this aspect. Clusters of diseases such as cardio-pulmonary, cancer, metabolic, immune-endocrine, skin, psychological, and birth disorders were identified[18] as relative risks to derive specific dose response function.

To estimate the monetary value of these risks, a mortality value factor (value of a statistical life) of US$416,971 and a morbidity value factor of US$5,048 per disability adjusted life year lost was used. Based on these assumptions and the estimated number of people directly and indirectly affected (Figure 5), the burden of disease is estimated to be approximately US$1.33 million per year (at 2021 prices), with oil hotspot sites costing US$1.28 million and chemical contaminated sites costing US$50 000 (Table 6). These estimates are conservative because they are calculated without any site-specific and/or governorate-specific information on health and disease. Furthermore, as most of the hotspot sites have been active since 2003 or 2004, the cumulative burden of diseases over the past 20 years is likely to be much higher. A comprehensive health impact assessment on the prevalence of hotspot-related diseases is hence needed to provide more exact information on the burden of disease.

ECONOMIC IMPACTS: LOSS OF INDUSTRIAL PRODUCTION

About 20 of the 69 hotspots assessed are industrial hotspots located in 20 industrial units, most of which were completely destroyed or are operating at low capacity. These hotspots included large fertilizer, chemical and engineering industries that made important contribution to Iraq's economy. (Other hotspots sites such as oil refineries and gas isolation stations that were damaged but are currently operating were not considered in this analysis.)

The loss of production from the destruction of these 20 industry sites is expected to have affected the local and national economy. However, no information on the production capacity or annual turnover of these industries is available. Available information including the average annual turnover of pharmaceutical industries (US$11.60 million per year), the average annual production capacity of vegetable oil industries (1,200 tons per year), and the actual capacity of the General Phosphate Company (150,000 tons/year) in Al Anbar was used to calculate the cost of lost industrial production from four industrial hotspot sites.

At 2021 prices, the cost of lost industrial production from these four industries is estimated as follows:

- General Phosphate Company in Al Anbar: US$1.15 billion per year
- Two pharmaceutical industry hotspot sites: US$23.15 million per year
- One vegetable oil industry hotspot site: US$2.25 million per year.

The total cost of lost industrial production for the four hotspot sites (for which information on production capacity or turnover was available) is estimated to be US$1.17 billion. The cost could be much higher if a similar assessment is carried out for 16 other destroyed industrial hotspots.

AGRICULTURE IMPACTS: LOSS OF AGRICULTURE YIELD

Wheat was considered as a proxy for assessing the loss of crop yield on affected land for the following reasons:

- It is the predominant crop in the northern, central, and southern governorates
- It requires one season for harvesting
- About 25 percent of the land is rainfed and 75 percent is irrigated in Iraq.

A study by the World Food Programme in 2021 estimated Iraq's wheat yield to range between 3.3 and 20 tons per hectare per year.[19] The same study found that the price of wheat ranged between US$346.90 and US$462.50 per ton. Based on these assumptions, the total cost of lost agriculture production for the 1,569 hectares of agriculture land affected by contamination is estimated to be US$8.16 million per year, which is likely a conservative estimate as this estimate does not consider the supply chain disruption since 2022 or the cumulative loss of agriculture production since the hotspots were first polluted.

17 https://www.healthdata.org.

18 At chemical contamination sites, sulfuric acid was considered for lower-bound risk (relative risk for mortality of 0.0025 and relative risk for morbidity of 0.031 per 100,000 population) and carcinogens such as polycyclic aromatic hydrocarbons and lead were considered for upper-bound risks (relative risk for mortality of 0.42 and relative risk for morbidity of 1.31 per 100,000 population). For oil, polycyclic aromatic hydrocarbons were considered as a lower-bound risk (relative risk for mortality of 0.03 and relative risk for morbidity of 0.0073 per 100,000 population) and Lead as an upper-bound risk (relative risk for mortality of 8.63 and relative risk for morbidity of 49.19 per 100,000 population).

19 WFP 2021.

LIVELIHOODS: LOSS OF AGRICULTURE AND INDUSTRIAL JOBS

Information on employee numbers at each industrial hotspot site shows that about 31,201 jobs were lost due to the abandonment of these industries. And, based on values from the 2021 Iraq Labor Force Survey, an estimated 1,250 jobs may have been lost due to the pollution of agricultural land in the seven governorates.[20] The net effect of lost jobs on local gross domestic product (GDP) is estimated at US$191.10 million per year for industrial jobs and US$7.66 million per year for agricultural jobs at 2021 prices.

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SUMMARY OF HEAL IMPACTS

Pollution hotspots in the seven conflict-affected governorates have had a cumulative HEAL impacts of about US$1.45 billion per year. With a large fertilizer industrial hotspot (General Phosphate Company) and associated loss of industrial production, Al Anbar governorate, at US$1.17 billion per year is affected the most, followed by Baghdad, Salah Al-Din, and Kirkuk. If the high economic cost (US$1.15 billion) of General Phosphate Company is excluded (which is an outlier), the cost of HEAL impacts can be estimated at US$295.98 million per year.

***Table 6:** Health, economic, agriculture, and livelihood impacts of pollution hotspots (US$ millions)*

Governorate	Impact cost (US$ million)							
	Health			Economic	Agriculture	Livelihood		Grand total
	Chemical	Oil	Total	Total	Total	Industry	Agriculture	
Al Anbar	0.01	0.04	**0.05**	1,150.50	0.03	19.97	0.03	1,170.57
Babil	0.00	0.00	**0.00**	CNA*	0.04	0.49	0.04	0.57
Baghdad	0.02	0.02	**0.04**	CNA*	0.40	79.19	0.38	80.02
Diyala	0.00	0.00	**0.00**	CNA*	0.00	1.22	0.00	1.24
Kirkuk	0.00	0.24	**0.24**	CNA*	2.95	0.19	2.77	68.49
Nineveh	0.01	0.74	**0.75**	23.15	3.54	25.72	3.32	56.49
Salah Al-Din	0.01	0.24	**0.25**	2.25	1.18	64.31	1.11	69.10
Total	**0.05**	**1.28**	**1.33**	**1,175.90**	**8.16**	**191.10**	**7.66**	**1,446.48**
* Could not be assessed								

***Source:** Estimations by the ASA team.*

These estimates are indicative and intended to provide a broad understanding of the significance of HEAL impacts due to pollution hotspots. Section 5 of this report outlines a need for a more comprehensive and detailed site-specific assessment as part of the recommended roadmap for appropriate mitigation and management actions.

20 ILO 2022.

2.3 Hotspots mapping and information management system

Reviewing the data collected during initial site assessment, mapping hotspots based on this information, and developing information systems are all critical steps for designing and developing management programs for contaminated sites. To assist the MoE on these aspects, the World Bank provided technical and capacity-building support focusing on the following activities:[21]

- Assessing the nature, type, and form of environments
- Collecting social and digital information during site assessment
- Reviewing data virtually for quality assurance and adapting data requirements based on site assessments
- Designing strategies for data organization, storage, and management
- Developing maps for each hotspot
- Developing a WebGIS to collate the information and maps produced by MoE on hotspots in a system that can be managed and updated.

In addition, the ASA supported the MoE in identifying software and hardware requirements for the maintenance, management and updating of data, and provided customized training on basic principles, tools, and techniques of mapping and updating hotspots for eight MoE GIS team.

2.3.1 DATA FOR MAPPING AND INFORMATION MANAGEMENT

Field data

A standardized field data checklist (Appendix C) was developed to ensure consistency in data capture and to minimize note taking errors during field assessment work. The field data checklist included basic details, such as location, nature, and type of pollution, as well as other complex information, like GPS coordinates of the sites, locations of soil and water sampling, sensitive environmental features, and affected structures. Digital coordinates of photos, sketch maps, and other features were also collected by the assessment teams.

Digital data

High-resolution maps and satellite images are essential for site assessment and sampling work. These resources provide not only accurate digital coordinates, but also geospatial datasets such as roads, streams, and other critical features related to the sites. The MoE team used Universal Traverse Mercator (UTM)—the standardized digital data format—and a standard GPS device for digital data collection. Online resources such as Google Maps, Google Earth Pro, and OSM were also used.

The World Bank ASA team helped to optimize the MoE's data storage methodology by supporting in the design of a file folder structure and naming convention, standard operating procedures for storage and management of field and other ancillary data, and so on, so that the data can be updated as more is collected and more information becomes available.

Secondary data

Detailed maps of hotspots and the best available site-specific information helps with developing a Conceptual Site Model and carrying out Human Health Risk Assessments, which are important steps towards developing appropriate management and mitigation measures for hotspots.

To support this process, datasets such as Microsoft Building Footprints on Bing Maps (for assessing affected populations); the Copernicus Digital Elevation Model (DEM) and OSM (for understanding site drainage and transport of contaminants); and the ESA's WorldCover 10m 2020 (to identify farming adjacent to sites) were identified (Table 7). These data sets were accessed through Maxar and Skywatch, incorporated into Very High Resolution (VHR) images, and used to develop base maps and Conceptual Site Models of the sites.

21 MoE and Hatfield Consultants LLP 2022.

Table 7: *Data sets for mapping hotspot sites*

Data set	Source and description
Population density	**Microsoft Building Footprints** • Detects buildings using deep neutral networks and RessNet34 with RefineNet algorithm applied to Bing Maps. • Provides an estimate of the size of population potentially found within a defined distance from the pollution sources, thereby providing an indirect means of assessing potential receptors.
Site drainage and water supply	**Copernicus Digital Elevation Model** • A model that presents the surface of the earth which, together with ArcMap tool, can be used to estimate water-flow accumulation and identify the presence of drainage channels. **Stream network from OpenStreetMap** • Complements above drainage analysis by providing data on major streams and river channels.
Agriculture and vegetation	**ESA WorldCover 10m 2020** • Global land cover product based on Sentinel-1 and -2 data. • Used to quickly assess critical land use such as cropland, built-up areas, and their potential exposure due to the pollution hotspot.

Source: *Compiled by the ASA team.*

2.3.2 MAPPING OF HOTSPOTS

Using the data sets summarized in Table 7, the MoE and technical support consultant developed detailed base maps for each contaminated site/hotspot comprising common map template design; a VHR image; an image map generation (in A3 PDF format); an overlay of existing vector data on maps (for example, OSM such as roads, building footprints); and integration of historical imagery from a period before the damage or conflict impacts (based on availability of images).

In addition, the following outputs were produced.

- An overview map at the country and governorate level showing all hotspots (Figure 4)
- A "Sites Map Book" presenting all hotspots with land cover/land use, developed through analyzing ESA WorldCover 10m 2020 data and integrating building footprints and site drainage derived from Copernicus DEM (for example, Figure 11)
- A "Sites Map Book" presenting all hotspots developed through satellite imagery analysis with building footprint and drainage layers (for example, Figure 12).

In addition to the base maps, the following key statistics (elaborated in Section 2.2.3 and summarized in Table 5) relating to each site were also generated from the maps through GIS analysis:

- **Buildings per site** as an indicator of human settlement/activity at the site and potential receptors (derived from the building footprint data). Receptors are those entities—people, an ecological system, property, or a water body—that could be adversely affected by contamination.
- **Area of cropland per site** as an indicator of human farming activity and potential exposure pathways (derived from ESA WorldCover 10m 2020 data).
- **Built up area per site** as an indicator of human settlement/activity at the site and potential receptors (derived from ESA WorldCover 10m 2020 data).
- **Areas of vegetations, shrubs, and water bodies at each site** as an indicator of other land use features (derived from ESA WorldCover 10m 2020 data).

These statistics provide important information on risks associated with contamination at hotspots and were used in estimating HEAL impacts and carrying out risk assessment of hotspots sites. However, these statistics are only indicative, as they are generated through visual interpretation of satellite imagery (using ESA WorldCover 10m 2020 data). Such automated land-use classifications in arid/semi-arid environments such as Iraq are always challenging.

2.3.3 WEBGIS: A WEB-BASED, GIS-ENABLED INFORMATION SYSTEM

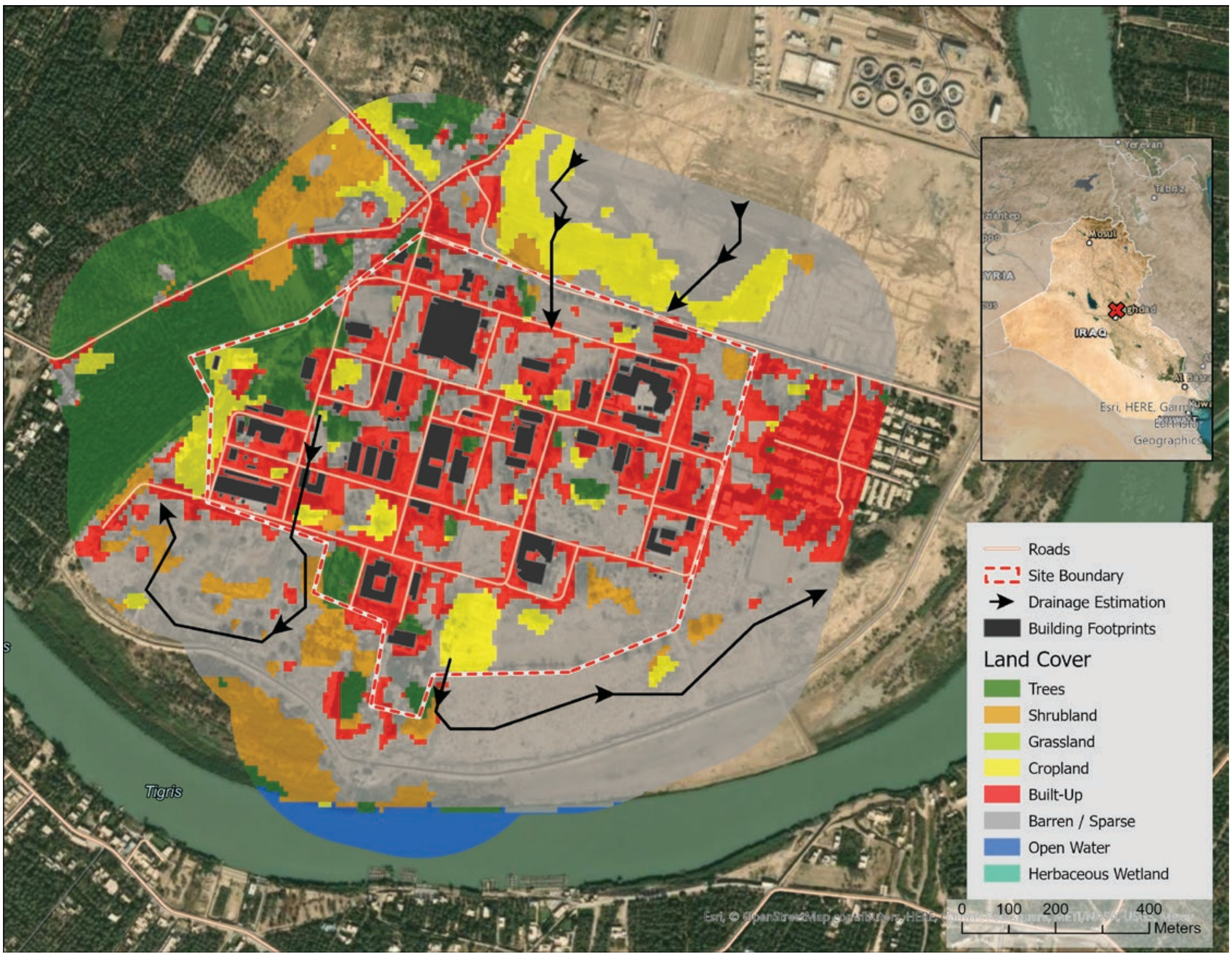
Information management systems are key for any contaminated sites management program. They help in designing appropriate remediation actions and facilitate continuous data monitoring and updating when additional information becomes available. Considering this, a WebGIS was developed for pollution hotspots in Iraq that uses the information collected during site assessment exercise and further analyses.

WebGIS includes basic information of hotspots such as site identification number, site name, name of the governorate it is located, boundary, location, and coordinates of sampling locations (both soil and water), sample ID, and risk rating of the site presented as a triangle symbol. The application includes a feature to update relevant data.

To improve the user experience, the WebGIS included the following navigational features:

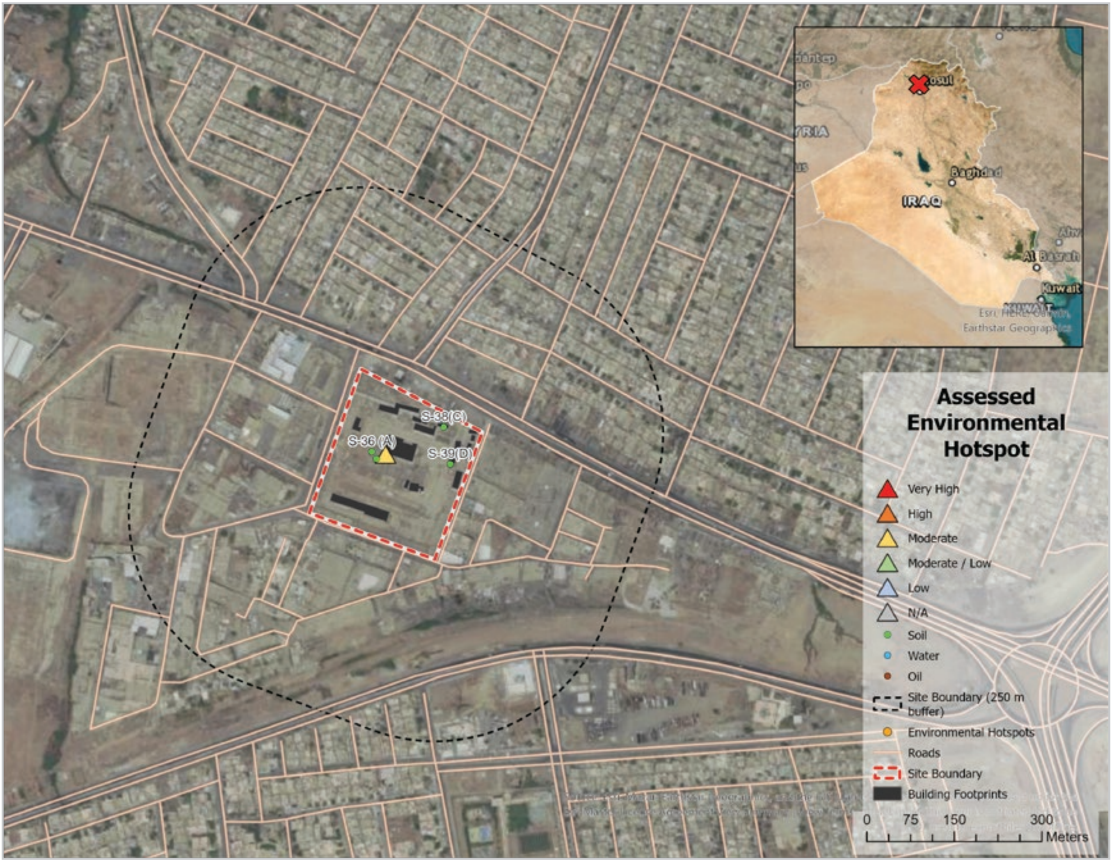
- An option to zoom into a site for a clearer view
- An option to zoom into a governorate to provide an overview of hotspots in the governorate
- The ability to turn desired information layers on or off. These layers include, for example, basic information, water sampling locations, and soil sampling locations
- A pop-up box that displays attributes logged into the system (for example, facility status and the maximum exceedance value of water and soil samples analyzed) (Figure 13).

***Figure 11:** Typical detailed map of hotspot with land cover—Ibn Sina Company*



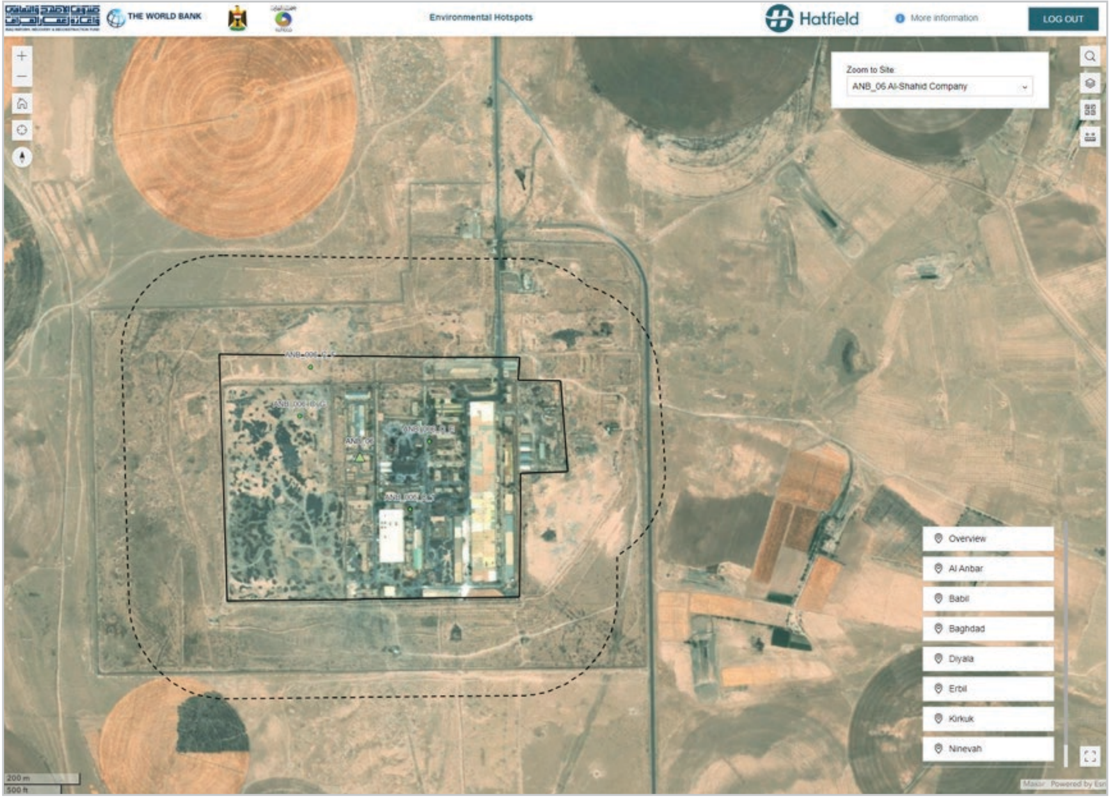
***Source:** MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

Figure 12: *Typical detailed map of hotspot without land cover—the chemical contaminated site in Nineveh governorate (NIN 015)*



Source: *MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

Figure 13: *Typical WebGIS view of hotspots at site level—Al Shahid Company, Al Anbar*



Source: *MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

2.4 Assessment of risks and prioritization of hotspots for remediation

2.4.1 RISK ASSESSMENT METHODS

Risk assessments determine the health and environmental risks posed by pollution hotspots to help prioritize sites for further detailed site investigations and develop management or remediation plans. Considering the level of data available and MoE's capacity limitations, this method needs to be simple yet robust, and based on the contaminants and their concentrations at each site.

A quick review of international risk assessment practices was carried out to choose an appropriate risk assessment method for Iraq (Box 1). The five methods reviewed systematically classify contaminated sites according to their current or potential adverse impacts on human health and the environment. The methods are not designed to provide a quantitative risk assessment, but to screen and prioritize sites for further actions that could involve detailed investigation, characterization, risk assessment, or remediation.

The methods assessed all broadly follow the Source-Pathway-Receptor concept in assessing the risks.[22] However, the United States Department of Defense and the United Kingdom Land Contamination Risk Management systems classify the sites in terms of high, medium, and low categories, whereas the United States Environmental Protection Agency (US EPA) and the Canadian system assign scores to sites for prioritization. Alternatively, the Netherlands uses country-specific DIV standards to calculate expected concentrations and exposure.

After carefully considering all the above international approaches and the data/information available for the hotspots in Iraq, the MoE chose the United Kingdom Land Contamination Risk Management method due to its flexibility in categorizing sites rather than scoring and ranking them. This method is qualitative and does not require any calculations or comparisons with standards, which is important since Iraq does not have standards for soil contamination or pollution.

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22 "Source-Pathway-Receptor" is a concept that is followed in assessing pollution risks in which (1) the **source** of pollution is identified, (2) a **pathway** for the movement of pollution exists, and (3) the environment/ecological element/ life that may be affected (**receptor**) by the pollution is established. A risk is considered present only if there is a link between all three elements.

BOX 1: OVERVIEW OF RISK ASSESSMENT APPROACHES

United Kingdom Land Contamination Risk Management System

- A qualitative model that uses an outline Conceptual Site Model for the risk assessment.
- Defines risk as a combination of the likelihood of an event and the consequence of its occurrence.
- Categorizes likelihood as highly likely, likely, low likelihood, or unlikely.
- Categorizes consequence of an event as severe, medium, mild, or minor.
- Categorizes risks as very high, high, moderate, low, or very low.

United States Department of Defense relative risk site evaluation

- Uses site information to evaluate exposure endpoints of groundwater, surface water, sediments, and surface soils.
- Rates relative risks as high, medium, or low by evaluating three risk factors: containment hazard, migration pathway, and receptor factor.
- The highest relative risk determines the overall relative risk.

United States Environmental Protection Agency Hazard Ranking System

- Assesses relative importance of sites for inclusion into National Priorities list.
- Evaluates four pathways of pollution: ground water migration, surface water migration, soil exposure and subsurface intrusion, and air migration.
- Calculates scores for risk-related factors based on site conditions.
- Groups risk-related factors into three categories: likelihood of pollutants released into the environment, characteristics of pollution, and people/sensitive environments affected by pollutants.
- Normalizes category values to 100. Sites with an overall score of 28.5 and above are included in the National Priorities list.

Canada National Classification System for Contaminated Sites

- Used to establish a rational and consistent basis for a comparative assessment of sites.
- Uses an additive numerical method to assign scores to sites.
- Considers site characteristics such as contaminant characteristics, migration potential and exposure, and site hazards. These are scored between zero and 100 based on severity.
- Site characteristic scores are categorized into five classes:
  - **Class 1**: > 70 (highest priority)
  - **Class 2**: 50–69.9
  - **Class 3**: 37–49.9
  - **Class N**: <37 (lowest priority)
  - **Class INS**: Insufficient information.

The Netherlands’ remediation urgency method

- A framework used to define remediation urgency for sites affected by serious soil contamination.
- If site contamination exceeds the Dutch Intervention Values, the expected exposure is assessed against human-toxicological intervention values and ecological risks.
- Contaminant concentrations in soils are used to calculate expected concentrations in contact media (and thus exposure).
- Sites are prioritized accordingly for remediation.

2.4.2 RISK ASSESSMENT

The risk assessment was conducted in accordance with the technical approach presented in the United Kingdom Land Contamination Risk Management method for Tier 1 preliminary risk assessment.

The assessment involved desk-based analysis of risks based on the data available from the initial site assessment carried out by MoE team to meet the objectives of a preliminary (Phase 1 Assessment) investigation of contaminated sites. As noted earlier, the objective of this assessment was to provide an understanding of the risks associated with the hotspots and prioritize sites for the detailed assessment (Phase 2 Assessment) and the preparation of remediation plans.

Key terms used in the risk assessment included:

- **Vicinity:** The area within a 250-meter (m) radius of the site.[23]
- **Receptor:** Physical, environmental, ecological, or human beings that could be adversely affected by contamination.
- **Pathway:** A route or means by which a receptor is (or could be) exposed to or affected by a contaminant.
- **Contaminant source:** A hazard that poses a risk to receptor where a pathway is present.

The relationships between sources, pathways, and receptors collectively combine to create a Conceptual Site Model. A risk can only be considered present where a contaminant source, pathway and receptor are all in place, referred to as a "pollutant linkage".

In line with the above definitions and the British Standard 10175:2011+A2:2017 on Investigation of Potentially Contaminated Sites Code of Practice, contaminant sources (hazards), receptors that may be impacted, and plausible linking pathways were identified for each of the suspected hotspots. Where all three elements were present, a contaminant linkage was assumed, and a qualitative risk estimation was made. The risk classification was based on a combination of hazard consequence and probability using the risk matrix from Rudland et al (2001).[24]

2.4.3 RISK RATINGS AND PRIORITIZATION

The risk assessment identified five hotspots as "very high risk" and 18 hotspots as "high risk". Furthermore, 24 sites were rated as "moderate" risk, 16 sites as "moderate/low" risk, and five sites as "low" risk (Table 8). A more detailed risk assessment of each site is presented in Appendix F.

Four of the five "very high risk" sites are currently in operation (Alkask Refinery [NIN 10], Al-Furat Company [BAB01], Mulla Abdulla Station [KIR 26], and Baiji Refinery [SAL 9 C]), while only one site (Al Fatha [SAL 15 H]) is abandoned. Similarly, all "high risk" sites except Baghdad Lead Extraction Facility (BAG 08) are operational. The workers at these operational sites are likely to be/have been exposed to harmful contaminants. An urgent interim response may hence be needed for all operational sites to mitigate exposure risk until full remediation and management actions are initiated.

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23 Certain sources and/or sensitive features farther than 250 meters have also been considered. The purpose is to identify and assess the potential risks and liabilities associated with ground contamination both on and in the vicinity of the sites.

24 Rudland DJ, Lancefield RM, and Mayell PN. 2001. Contaminated Land Risk Assessment: A Guide to Good Practice: C552. London: CIRIA.

Table 8: *Summary risk ratings and prioritization of hotspots*

Risk rating	Remarks
Very high (5 sites) Al-Furat Company (BAB 01), Mulla Abdulla Station (KIR 26), Alkask Refinery (NIN 10), Baiji Refinery (SAL 9 C), Al Fatha (SAL 15 H).	There is a high probability that severe harm could occur or that severe harm is currently happening. If realized, this risk could result in substantial liability. Urgent investigation and remediation are needed.
High (18 sites) Baghdad Lead Extraction Facility (BAG 08), Bai Hassan North Degassing Station (KIR 7, 8, 9, 10, 12, 13), Sarolo Station (KIR 02), Baba Gurgur Station (KIR 14), Bai Hassan South Oilfield (KIR 15, 17, 23), Qutan Gas Isolation Station- Babakkar Oilfield (KIR 28), Gas & Oil Separation Plant in Jabal Bur (KIR 30), Al-Qayyarah (NIN 3, 4), General Company for Communication Equipment and Power (SAL 014 C), Al Sahl Valley (SAL 16 H).	Harm is likely to occur and realization of the risk is likely to present a substantial liability. Urgent investigation is required. Remedial works may be necessary in the short term and are likely over the long term.
Moderate (24 sites) Haditha Oil Refinery (ANB 4), Ibn Sina Company (BAG 1), Diyala Electrical Industries Company (DIY 01), Sarolo Station (KIR 01, 04, 05), Sarolo Station (KIR 03), Dawood Station for Oil Refining (KIR 06), Serbach Station (KIR 16), Haljira Gas Isolation Station (KIR 18, 20), Al-Qayyarah (NIN 1), Al-Qayyarah (NIN 5, 17), Ein Zalah Station (NIN 8, 9), Chemical Contaminated Sites (NIN 15), Ajil Oil Field (SAL 001 H, 011 H, 012), Alass Oil Field (SAL 2 H), Northern Fertilizers Company (SAL 003 H), AL Mansour Factories for Vegetable Oils (SAL 004 H), Al Seenia Oil Refinery (SAL 007 H).	Harm could occur, but it would likely be relatively moderate. Investigations are normally required to clarify the risk and determine the liability. Some remedial works may be required in the longer term.
Moderate/low (16 sites) Pesticides Factory Al-Falluja City (ANB 05), Al Shahid Comp. (ANB 06), Bader Company (BAG 02), That Alsawary Comp. (BAG 03), Ibn Al Waleed (BAG 04), Al Harith Factory (BAG 06), Baba Gurgur Stn (KIR 19), Hawija Pesticides (KIR 25), Khabaz Gas Station (KIR 31), Al-Qayyarah (NIN 18), Chemical Contaminated Sites (NIN 11), Nineveh Pharmaceutical Industrial Company (NIN 14), Al Kindy General Company (NIN 16), Baiji Power Plant (SAL 5 H), Salah Al-Din (SAL 006 H), Salah Al-Din (SAL 010 IC).	Harm could occur at these sites, but it would likely be moderate to mild. Investigations may be conducted to clarify the risks and determine the liability.
Low (5 sites) State Company for Phosphate in Al-Qaaim (ANB 01), Alamer Factory (ANB 03), Showraw Station & Kat Factory (KIR 24), Alhukamaa Pharmaceutical Company (NIN_12), K2 Station (SAL 013).	Harm could occur but it would, at worst, likely be mild.

Source: *Based on site assessment by MoE and RSK Environment LLC 2022.*

2.5 Stakeholder engagement and consultations

Stakeholder input is crucial for determining the nature and significance of HEAL impacts that pollution hotspots have on local communities and to identify objectives for the management or remediation of contaminated sites. The MoE therefore ensured continuous stakeholder engagement after the initial screening of hotspots. This involved interacting with local people to identify suspected hotspots and conducting on-site assessments and verification regarding the extent of pollution and its impacts on people and the surrounding affected areas.[25]

After compiling an inventory of suspected hotspots and completing the initial site and risk assessments, the MoE organized formal stakeholder consultations both at the governorate level and at the national level in Baghdad. The objective of these consultations was to seek input from stakeholders on the appropriateness of hotspot sites, the area of impact identified, and the people affected, and to share the results of the site and risk assessments.

To ensure adequate and active participation, stakeholders were comprehensively mapped by identifying all relevant public, private, civil society, community-based organizations, and other grassroot organizations operating in the seven conflict-affected governorates. A governorate-level summary of information on suspected hotspots, identified levels of contamination, anticipated impacts around sites, and key discussion points for consultations was prepared.

Government stakeholder consultations in Kirkuk.

Separate consultations were organized for government entities and for Civil Society Organizations (CSOs) to address the interests of each stakeholder group. The location of these consultations considered the total number of hotspots in each governorate, their geographical linkages, and security and access issues. The chosen locations were Kirkuk (covering the governorates of Kirkuk, Nineveh, and Salah Al-Din) and Baghdad (covering the governorates of Baghdad, Babil, Diyala, and Al Anbar).

2.5.1 SUMMARY OF CONSULTATIONS

In total, four consultations were held on March 12 and 19, 2023: one each in Kirkuk and Baghdad, one for government stakeholders, and one for CSOs. A total of 64 people (42 government officials and 22 CSO representatives) participated in these consultations. The consultations were designed to facilitate active participation and deliberation from all stakeholders.

Overall, the participants agreed with the MoE's inventory and assessment work. The discussions further strengthened the case for the remediation of hotspots and highlighted the concerns of health, environment, agricultural productivity, water contamination, and impacts on animals around certain hotspots sites. The participants also made specific suggestions relating to the risk ratings assigned to the sites and suggested additional hotspots to be included in the inventory.

CSO consultations in Kirkuk.

The CSOs indicated that, while local communities were conceptually aware of the risks from contaminated sites, they were often not fully aware of specific health and safety issues. They also lacked an official platform to express their concerns and find resolutions. It was therefore suggested that the MoE establish a stakeholder platform for pollution hotspots for continuous dialogue between government agencies and CSOs. CSOs volunteered to assist in communication and awareness programs on behalf of the government.

25 MoE and RSK Environment LLC 2023.

Table 9: *Summary of issues discussed during stakeholder consultations*

Government stakeholders	CSO stakeholders
Impacts and issues faced	
• Direct impacts on agriculture and animal husbandry activities due to contamination hotspots in Baghdad governorate. • Health impacts (including cancer cases) reported in Baghdad governorate. • Expansion plans of some of the industries with hotspots need to consider the existing environmental and expansion-related issues.	• Impacts experienced on plants, birds, and animals due to hotspots in the Baghdad governorate. • Health impacts on children, women, and the elderly in hotspot areas in Baghdad governorate. • Health problems like congenital malformations in fetuses and other chronic diseases are also experienced. • Education and awareness programs on the health and environmental impacts of contamination at hotspots are needed. • Stakeholder platforms need to be established for better coordination and engagement on hotspots.
Risk rating of hotspot sites	
• Risk rating for Al Sahl Valley in Salah Al Din (SAL1) be changed from “high” to “very high”. • Risk rating for Bai Hasan North Degassing Station in Kirkuk (KIR 7–10 and 12/13) to be changed from “high” to “very high”. • Risk rating for Al Qayyarah in Nineveh (NIN 3, 4) to be changed from “high” to “very high”. • Risk rating for Ibn Sina Factory in Baghdad (BAG 1) be changed from “moderate” to “high”.	Risk rating for Ibn Sina Factory in Baghdad (BAG 1) to be changed from “moderate” to “high”.
Additional hotspots	
• Al Dawani landfill and Hadith hospital in Al Anbar. • Al Nasir, Al Somod and missile factory in Tarmiya and Abo Garib sites in Baghdad. • Khazna Bar, Yai ji, Southern Bai Hasan, Al Dibis and Kat Oil Company in Kirkuk.	• Al Rafid irrigation canal, Abo Garib, Baghdad. • Al Harish, Al Somod factory, Tarmiya, Baghdad. • Hotspots, Hadith Rawa, All Fallouja, Al Anbar. • Ajeel and Alaas oil fields and Asphalt factory, Al Alam in Salah Al Din. • Medicine Factory, Nineveh. • Mekanian Area, Erbil Road, Kirkuk.

Source: *Based on stakeholder consultations by MoE and RSK Environment LLC 2023.*

2.6 Conclusion

An overall review of pollution hotspots in Iraq indicated widespread hydrocarbon and chemical contamination in the country. Of the 76 “suspected hotspots” identified, the MoE conducted field assessment of 69 sites in 47 locations. The assessments suggested that about 1,333.03 ha of land is likely to have been contaminated, directly affecting an estimated 55,050 people and indirectly affecting more than 1.7 million people.

Most of the pollution hotspots were found to be in the three governorates of Kirkuk, Nineveh, and Salah Al-Din. Environmental analyses of the soil and water at these sites indicated that contamination levels exceeded 100 times the DIV in 32 sites, 50 times the DIV in seven sites, and 10 times the DIV in the remaining 30 sites. In terms of the affected population, Kirkuk has an estimated 1.1 million affected people, which is the highest count of all seven governorates. Nine major industries were destroyed and are currently not in operation. This indicates the level of environmental and health challenges posed by these hotspots and the potential gains due to their management or remediation.

The site assessment further indicated that over 1,569 ha of agriculture land, 3,018.38 ha of vegetation, and 8,482 structures are impacted by damage and contamination at pollution hotspots. To better understand the HEAL impacts of pollution hotspots, the burden of diseases, the economic cost of destroyed industries, the opportunity cost of affected agriculture land, and the loss of livelihoods due to destroyed industrial and agricultural land were analyzed. The total cost of HEAL impacts at the suspected hotspots was estimated at about US$1.44 billion per year.

Furthermore, a risk assessment identified five sites as “very high risk”, 18 sites as “high risk”, 24 sites as “moderate risk”, 16 sites as “moderate/low risk”, and five sites as “low risk”. Stakeholder consultations carried out as part of the assessment confirmed the ramifications of these risks for local communities around pollution hotspots and emphasized the urgent need for remediation and management programs.

The remainder of this report explores technological options for hotspot remediation and discusses a proposed roadmap for the development of a pollution hotspot management program for Iraq.

26 https://www.epa.gov/superfund/superfund-history

3 Policy and Institutional Framework for the Management of Hotspots

3.1 Introduction

Sound management of contaminated sites/hotspots primarily relies on three pillars: policy and institutional framework; planning and development of management and remediation plans; and program design and financing.

There is a wealth of experience in United States, Europe, Canada, Australia, China, and many other countries on contaminated sites management. This section briefly reviews some of these international examples as well as the current policy and institutional framework in Iraq on contaminated sites management. Subsequent sections of this report discuss the remaining two pillars in the context of managing environmental hotspots in Iraq.

3.2 Review of international practices

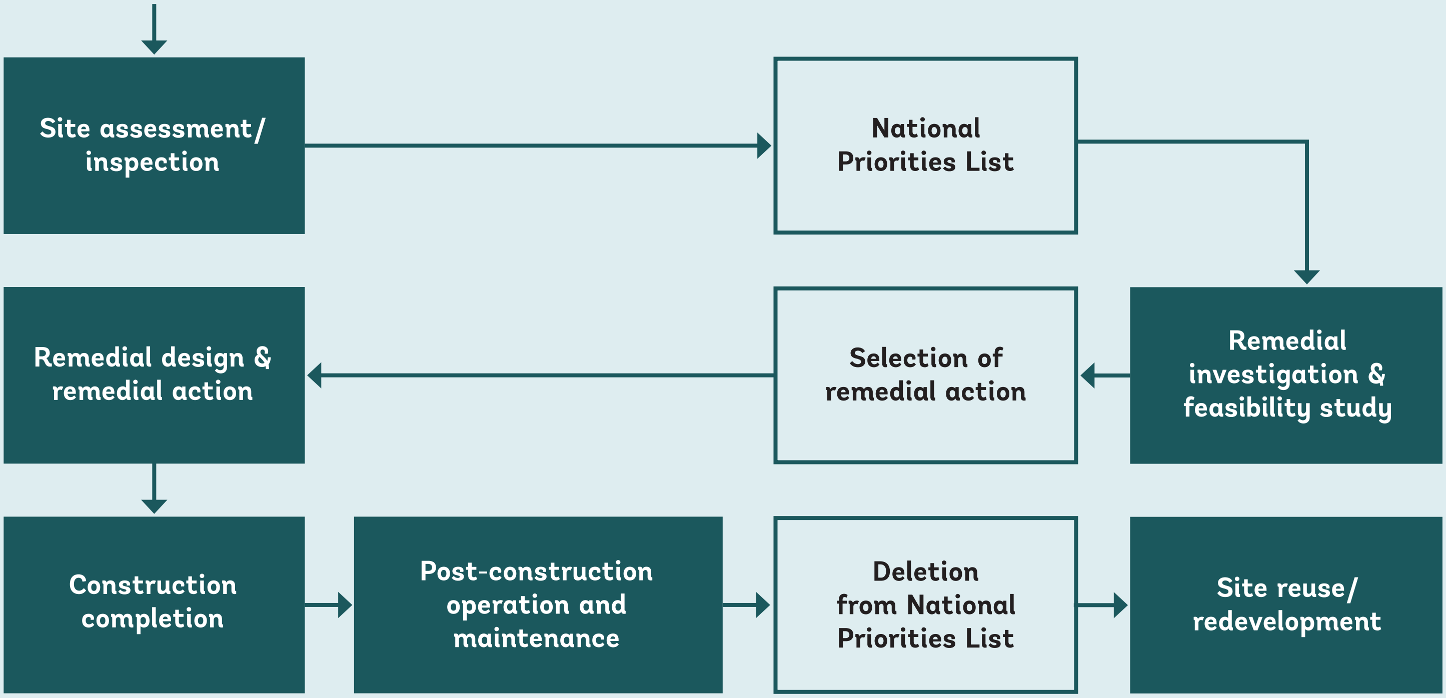
3.2.1 THE UNITED STATES SUPERFUND PROGRAM

Legal framework

Contaminated sites management in the United States (US) is governed by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, generally referred to as the Superfund Program, and its amendment, the Superfund Amendments and Reauthorization Act of 1986. Both acts authorize the US EPA to respond to actual or threatened releases of hazardous substances.

The law includes clear provisions to respond to the situations of contaminated sites (both orphan and non-orphan sites), to fix liabilities for cleanup actions, and to access private lands for investigations and cleanup. Both acts are also complemented by other federal laws of the USA, including the Resource Conservation and Recovery Act, Clean Water Act, and Toxic Substances Control Act.[26]

***Figure 14:** Process of contaminated site management in Superfund program*



***Source:** Compiled by the ASA team.*

Process

The Superfund program (Figure 14) involves carrying out series of actions comprising an initial assessment of reported sites to evaluate the need for action, followed by inclusion of sites in the National Priorities List (NPL). Detailed investigations and feasibility studies are then done to determine the nature and extent of contamination at the site and the costs of various remediation options, which are submitted for approval by the National Remedy Review Board. Upon approval, a remediation action is designed and implemented (referred to as "construction"), after which the long-term response actions and operation and maintenance of the site is carried out. When the remediation objectives are achieved, the site is removed from the National Priorities List and site reuse/redevelopment activities (if any) may commence.

Soil screening guidance

The EPA's Soil Screening Guidance presents a framework for developing risk-based soil screening levels to help with the evaluation of contaminated sites and to facilitate decisions on cleanup actions through the Superfund program. These soil screening levels are not cleanup standards, but are guiding factors for identifying and defining areas, contaminants, and conditions at a particular site that do or do not require action. At sites where contaminant concentrations exceed soil screening levels, further action or investigations may be required, but cleanup is not necessarily warranted.

26 https://www.epa.gov/superfund/superfund-history.

Institutional framework

The US EPA is the lead agency for the implementation of the Superfund program, which it manages through the Office of Superfund Remediation and Technology Innovation. This office is supported by six other offices within EPA, two regional offices, three federal agencies, and six state agencies.

Financing mechanisms

The central theme for financing the Superfund program is the "Polluter Pays" Principle. Following this principle, the program assigns liability for cleanup-related costs to the landowners, disposal operators, transporters, or generators of hazardous waste associated with contaminated sites. This principle is supported by strong legal and administrative power and aids in the program's success to recover up to three times the damages from the "polluters" for cleanup actions. Otherwise, the federal government provides the US EPA with funding to clean sites where no responsible parties are found.

3.2.2 CONTAMINATED SITES ACTION PLAN OF CANADA

Legal framework

Canada's Federal Contaminated Sites Action Plan (FCSAP) is based on the principles of prevention, remediation-reclamation, the "polluter pays", and fairness. It includes provisions that make landowners liable for the rehabilitation and remediation of contaminated sites, authorize access to sites to perform necessary investigations, and require landowners to perform site characterization studies before changing the land use of any site. It is governed by several policies and legislation, including the Canadian Environment Protection Act, the Fisheries Act, and the Canadian Environmental Assessment Act. These acts are supported by the Soil Protection and Contaminated Sites Rehabilitation Policy. In 2007, Canada also adopted the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. These guidelines prescribe specific standards for the presence of various chemical substances in soil for agriculture, residential, commercial, and industrial uses.

Process

The FCSAP's approach to contaminated sites management follows risk-based criteria involving a 10-step process (Figure 15). These steps involve identifying potentially contaminated sites based on past or current activities (step one); reviewing historical information related to the site (step two); and initial testing to understand the characteristics of contamination and conditions at the sites (step three). Depending on the outcome of these tests, the sites are classified as per the National Classification System for Contaminated Sites (step four). Site classification involves scoring sites based on analyses of the contaminations' characteristics, exposure pathways, and receptors.

Depending on the scores, the sites are classified as:

- Class 1: Action required.
- Class 2: Action likely required.
- Class 3: Action may be required.
- Class N: Action not likely required.
- Class I: Insufficient information.

Step five consists of detailed testing to delineate the boundaries of contaminants, define site conditions in detail, and provide the information necessary for risk assessment and to develop remediation plans, after which sites may be reclassified (step six). Detailed remediation and risk management strategies are then prepared (step seven), followed by their implementation (step eight). Confirmatory sampling and final reporting are carried out (step nine) subsequently and long-term monitoring is conducted as required (step 10).

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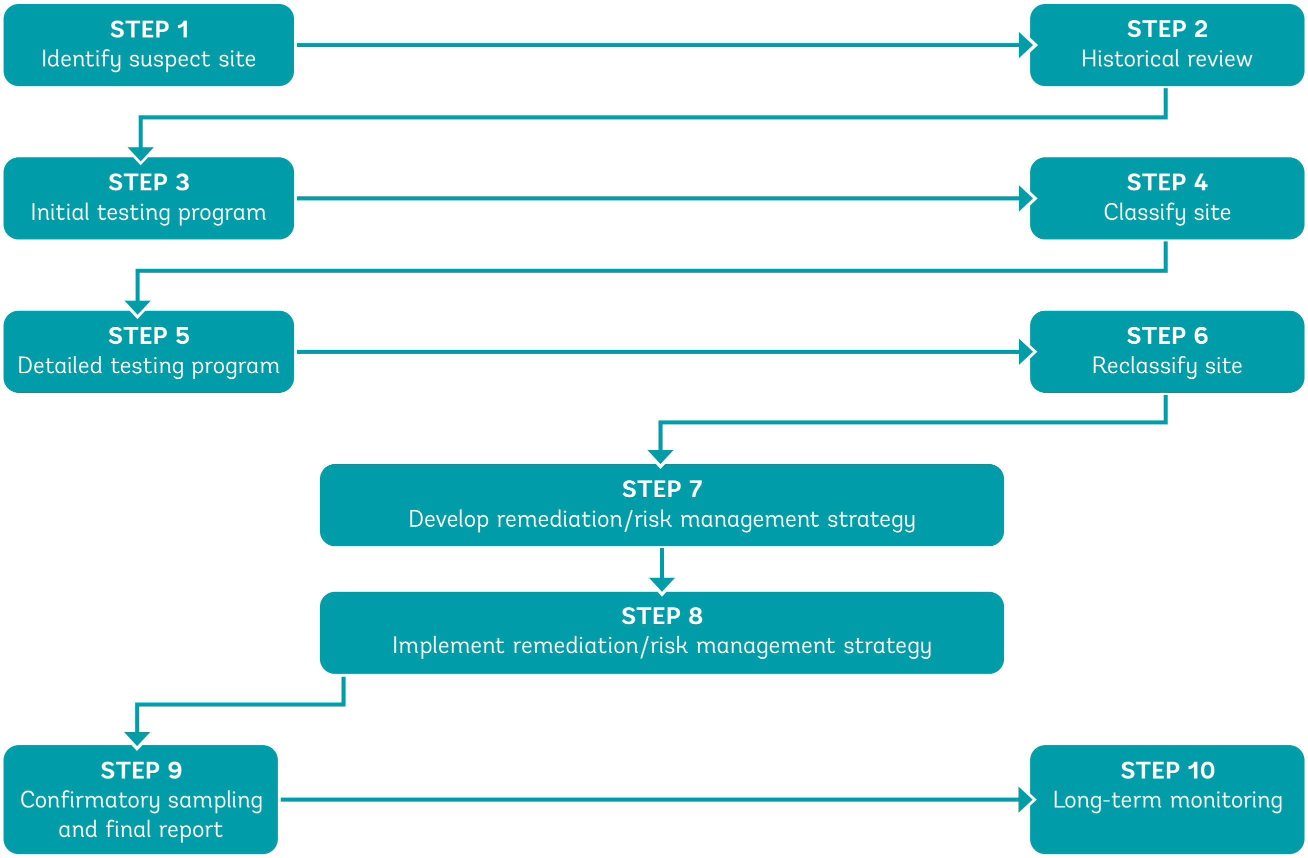
Figure 15: *The Federal Contaminated Sites Action Plan's 10-step process in Canada*



NOTE: The steps shown above illustrate the complete process involved in dealing with contaminated sites. There will be instances where some of the steps may not be required.

Source: *Compiled by the ASA team.*

Institutional framework

The FCSAP is implemented by Environment and Climate Change Canada, the state department responsible for coordinating environmental policies and programs, with participation from relevant federal departments, agencies, and Crown Corporations (state-owned entities that are also referred as Custodians in this context). Initially, only sites contaminated prior to April 1, 1998, were eligible for funding under the program. Phase IV of the program (2020–2024) introduced eligibility for certain sites after 1998. As of July 2022, 23,954 sites have been listed under the program, and 17,602 have been closed. About 20,700 jobs (person-years of employment) were reportedly created or maintained through FCSAP.

Financing mechanisms

FCSAP was established in 2005 as a 15-year program with US$4.54 billion funding from the Government of Canada. The program was renewed for another 15 years (2020–34) in 2019, with US$1.16 billion allocated for the period 2020–24.[27]

27 https://www.canada.ca/en/environment-climate-change/services/federal-contaminated-sites.html.

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3.2.3 CONTAMINATED LAND MANAGEMENT IN THE UNITED KINGDOM

Legal framework

Contaminated land management in the United Kingdom (UK) is governed by Part 2A of the Environment Protection Act of 1990 and statutory guidance issued by the Department for Environment, Food, and Rural Areas. The guidance explains how local authorities should implement the legal regime for contaminated land management, especially with regard to identifying contaminated land, setting the goals for remediation, liability arrangements, and recovering costs. However, the statutory requirements of Part 2A of Environment Protection Act and guidance are only applicable when no appropriate solutions are available under the planning regimes for land development or regimes for water, wastewater, environmental permitting, and Environment Damage Regulations.[28]

The Part 2A regime emphasizes risk management and introduces risk-based definitions of contaminated land. Only those sites that are causing (or are likely to cause) unacceptable risks are considered for an appropriate response or remediation.

The other important features of this statutory regime are:

- Local authorities are responsible for managing contaminated land.
- Risk-based identification of sites and management or remediation using the source-pathway-receptor concept and soil guidance values are employed.
- The "suitable to use" principle for remediation is adopted.
- The requirement to include land remediation as an obligatory consideration under remits such as land development or redevelopment, environmental permitting, and so on.
- Financial and legislative incentives for remediation and redevelopment are provided.
- Liability is placed on the original polluter, current landowner, or occupier.

The Part 2A regime requires proactive land management to address risks. By contrast, the planning regime is reactive in its risk management, only requiring assurance that the development or redevelopment of a site is safe.

Process

The process of contaminated site management as set out by the statutory guidance described above primarily involves the following sequential steps, with the outcomes of each step deciding whether the next is required or not:

1. **Regular inspection by local authorities** to identify potentially contaminated land. These inspections must use a strategic approach relevant to the local circumstances.

2. **Detailed inspection of identified sites** aims to collect sufficient information and conduct qualitative risk assessment to identify whether the site is contaminated.

3. **Detailed risk assessment using a Conceptual Site Model** of sites is carried out. Based on the risk assessment, a determination of contaminated land may be indicated.

4. **Determination of contaminated land** is conducted as per the four possible grounds defined by the Part 2A regime.[29]

5. **Initiation of remediation** by the enforcing authority, including the issuing of a remediation notice to the owner.

6. **Liability assignment and cost recovery** once the remediation techniques and costs are identified.

28 CL:AIRE 2010.

29 These grounds are: significant harm is being caused to human or relevant non-human receptor; there is a significant possibility of significant harm being caused to a human or relevant non-human receptor; significant pollution of controlled waters is being caused; or there is a significant possibility of significant pollution of controlled waters being caused.

Institutional framework

Multiple agencies are responsible for managing contaminated land in the UK. While the Department for Environment, Food, and Rural Affairs and the Ministry of Housing, Communities, and Local Government are responsible for leading policy and statutory guidance, the Environment Agency is responsible for managing contamination at special sites, permitting remediation processes, and handling enforcement. As per the Part 2A regime, local authorities are responsible for contaminated site designation and planning controls, while HM Revenue & Customs Department is responsible for taxes on landfilled material.

Financing mechanisms

Under the Part 2A regime, all costs relating to identifying and managing contaminated land are the responsibility of local authorities and no funding is provided by the central government. The cost of remediation is assigned to the landowner or responsible party wherever liability for contamination is established. However, central funding is provided to special sites that are managed by the Environment Agency. In the case of sites under the planning regime, costs of remediation and management are assigned to the respective landowner or responsible persons or agencies. The central government does provide some tax relief on the cost of remediating brownfield sites.

3.2.4 CONTAMINATED SITES MANAGEMENT IN THE NETHERLANDS

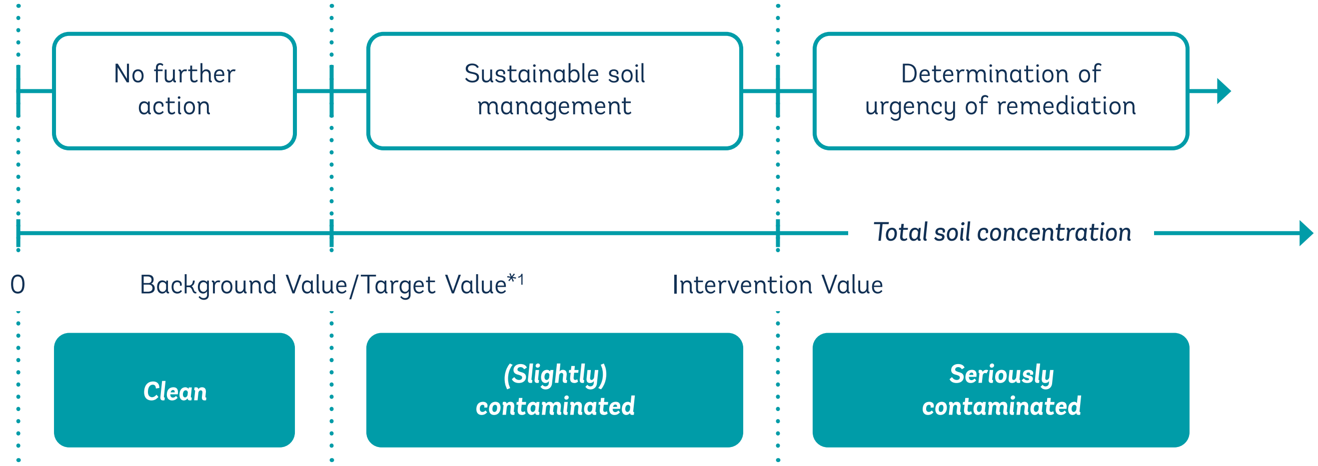
Legal framework

The Netherlands, one of the first countries to focus on contaminated land management, approved its Interim Soil Remediation Act and Soil Quality Standards in 1983, followed by the Soil Protection Act in 1987. The Soil Protection Act establishes accountability of parties and their liability for soil contamination. In 1994, the Soil and Groundwater Quality Standards and approaches for identifying the need for soil remediation were issued. After subsequent evaluations, the Soil Quality Decree of 2008 was issued, which balances protecting human health and the environment and allowing for the reuse of contaminated soil for limited purposes. These acts and standards provide the basis for contaminated site management in the country. In addition, the National Environmental Policy of 2001 and Environment Management Act of 2004 provide an overarching legal framework for Contaminated Sites Management in the Netherlands. In 2006, the Spatial Planning Act was amended to introduce liability of site remediation for land developers as per the land use plan of the area.

Process

Contaminated land management in the Netherlands is primarily driven by the Soil Quality Standards, which introduced the concept of A-, B-, and C-values. Concentrations below the A-value means that there is no soil contamination, and no remediation is needed. B-value soil may be seriously polluted and requires further investigation. C-value soil requires remediation. In subsequent revisions of the Soil Quality Standards, the concept of a “target value” and an “intervention value” was introduced. While soil meeting the target value is not contaminated, soil that meets the “intervention value” requires remediation (Figure 16). The issuance of the Soil Quality Decree in 2008, subsequent updates to the framework for the assessment of historically contaminated sites, and revisions of soil quality standards have introduced standards for the use of soil for specific functions.

***Figure 16:** Contaminated sites management framework in the Netherlands*



***Source:** Swartjes et al. 2012.*

Institutional framework

As in the UK, the responsibility for remediating contaminated sites in the Netherlands rests with local provinces and authorities, whereas the central government and ministries of environment and housing are responsible for developing policy and regulatory framework. The Ministry of Economic Affairs and Climate Policy plays an overarching role in policy formulation and financial aspects.

Financing mechanisms

Contaminated site management in the Netherlands is financed by a combination of payment from polluters, interested parties, government funds, and annual budget allocations. The “Polluter Pays” Principle is primarily applied for the remediation of sites. Interested parties (land developers) and other stakeholders may also finance the cost of remediation. If the responsible party or polluter is insolvent, the sites are remediated with government funding in the form of an advance, which must be recovered in due course. The costs of cleanup for orphan sites are borne by the government.

3.2.5 LAND REMEDIATION MANAGEMENT IN SOUTH AFRICA

Legal framework

South Africa recently enhanced its management of contaminated land and implemented several regulatory and institutional actions. While the Environment Conservation Act (Act 73 of 1989) included some provisions for the regulation of contaminated land, it required specific provisions related to soil contamination and standards to effectively address this critical issue. The subsequent National Environment Management Act (Act 107 of 1998) and the Waste Act (Act 59 of 2008) addressed pollution and waste management in the country. However, Part 8 of the Waste Act on contaminated land only came into effect in 2014, after the “National Norms and Standards for the Remediation of Contaminated Land and Soil Quality” were promulgated. These standards provide a unified national approach to managing contaminated sites (including determining the land’s contamination status) and provide the legal basis for soil screening values, which is needed to protect human and ecological health while considering existing or proposed land uses. These regulations also specify a participatory and consultative approach with key stakeholders—including various government entities and communities—for the management of contaminated sites and stipulate penal provisions for non-compliance (such as significant fines or prison terms). Part 8 of the Waste Act of 2008 is applicable even in cases where the contamination occurred before the act commenced, or in cases where contamination arose (or is likely to arise) at a different time from the attributing event or activity.

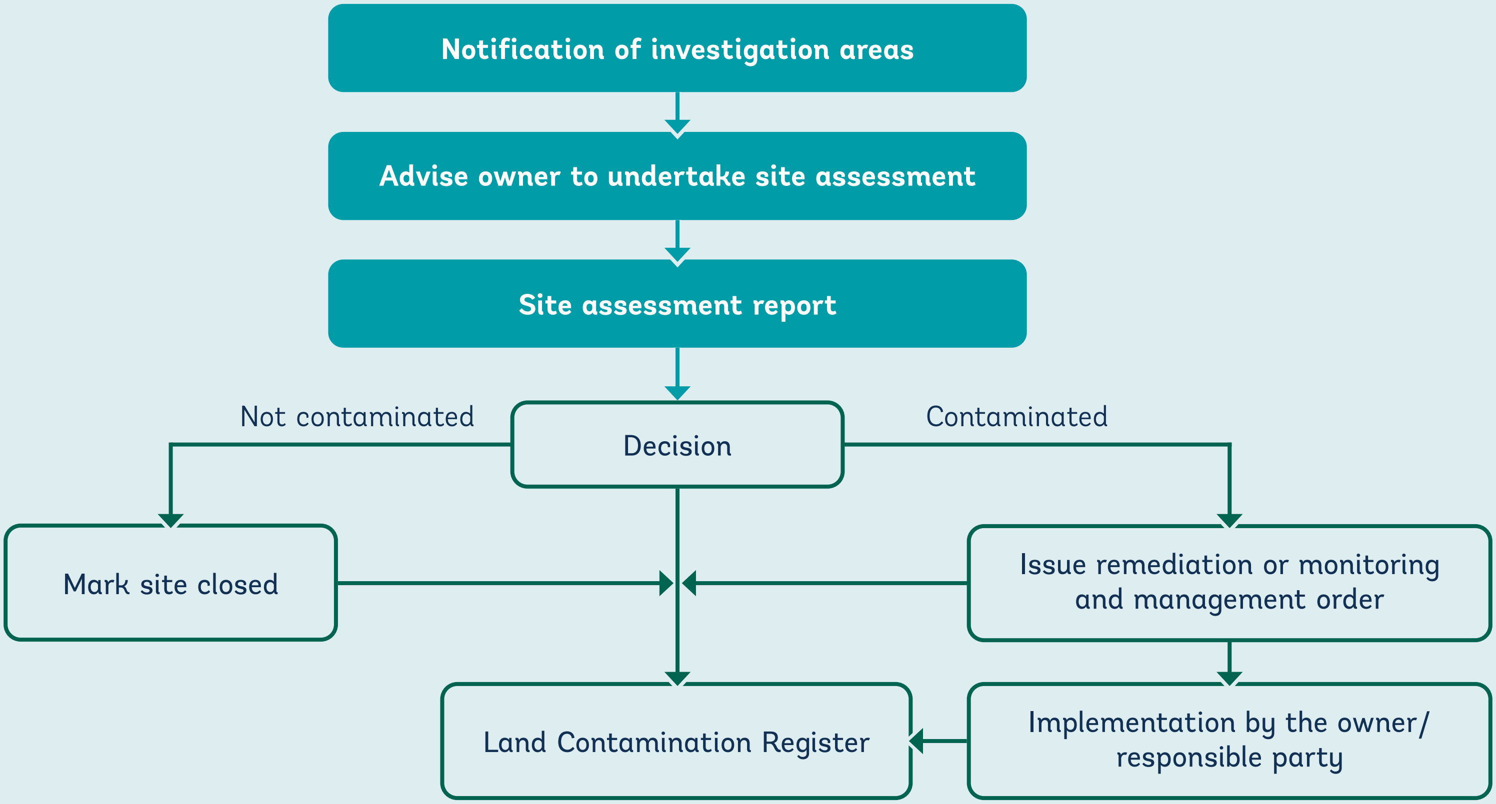
Process

As a first step, an “investigation area” is notified by the Minister of Forestry, Fisheries and the Environment or a relevant Member of Executive Council (MEC) of the province where high-risk activities have taken or are taking place. It is also obligatory for the landowner or person whose activity is suspected to have caused significant land contamination to notify the minister of any significant land contamination. After this notification, two rounds of consultations shall be carried out with Cabinet members and MECs, followed by notification in the Government Gazette.

In the next step, after consulting with other relevant ministers, the minister or relevant MEC notifies the owner of the land to obtain an independent expert assessment of the site that provides details of contamination, its impacts, exposure pathways, exceedance of applicable standards, and measures to remediate or manage risks.

Based on the recommendations of the independent assessment report, the minister then issues a remediation or monitoring and management order, as appropriate. This order also establishes liability for implementing remediation or monitoring actions, which may be allocated to the landowner or any other responsible party. The Department of Forestry, Fisheries and the Environment maintains a Contaminated Land Register with comprehensive information on investigation areas; the status of remediation; and land use restrictions, if any.

Figure 17: *Contaminated sites management process in South Africa*



Source: *Compiled by the ASA team.*

Institutional framework

The Directorate of Land Remediation is a branch of the Chemicals and Waste Management division of the national Department of Forestry, Fisheries, and the Environment. This directorate is responsible for overseeing the implementation of the Waste Act of 2008 at the national and provincial level, including the investigating possibly contaminated sites, overseeing the management of contaminated sites, and maintaining a national Contaminated Land Register.[30]

The Environmental Management Inspectorate is responsible for enforcement. Other relevant ministries and Members of the Executive Council where the site is located are also important stakeholders in the cycle of land remediation management, from site notification and assessment to remediation and monitoring.

Financing mechanisms

The "Polluter Pays" principles is fully embedded in the National Environment Management Act of 1998 and the Waste Act of 2008. As a consequence, the recipient of a remediation order (the landowner or any other responsible party) is responsible for the cost of remediation or management of a contaminated site. At the time of writing, the South African Waste Information System reported that a total of 503 contaminated sites had been notified since Part 8 of the Waste Act came into force in 2014. Of this, 288 sites were given remediation orders and 215 were issued monitoring and management orders. In response, a total of 116 sites had completed actions – remediation in 49 sites and monitoring and management of 67 sites.[31]

30 Government Notice 331. 2014. Waste Act of 2008: National Norms and Standards for the Remediation of Contaminated Land and Soil Quality.
31 https://sawic.environment.gov.za/documents.

3.3 Policy and regulatory framework in Iraq

This section identifies gaps in current policy and regulatory framework and suggests related improvements for managing of contaminated sites in Iraq based on international practices and the nature and type of contaminated sites in the country.

3.3.1 CURRENT LEGAL FRAMEWORK

Although Iraq has no specific law relating to contaminated sites management, the constitution and some environmental legislations do include aspects relevant to hazardous waste and pollution management (Table 10). These aspects include the "right to live" guaranteed through Article 33 of the Constitution, which states that "every individual has the right to live in safe environmental conditions" and commits that the "state shall undertake protection and preservation of the environment and biodiversity". Building on these provisions, the National Environmental Protection Strategy (2013–17) includes specific actions for hazardous chemicals management, oil pollution, and solid waste. Though the period of this national strategy has lapsed, the actions it highlights are still relevant for Iraq.

In terms of individual laws, Article 17, Section IV of the Protection and Improvement of the Environment Law 27 of 2009 refers to the protection of land and requires the prevention of any activity that directly or indirectly results in the degradation or pollution of soil. Reference to the establishment of an environmental protection fund can also be found in Article 26, Chapter VI of the law. Further, Section VII explicitly refers to pollution resulting from exploration and extraction of oil and gas, while Chapter VIII introduces the concept of the "Polluter Pays" principle.

Despite their relevance to contaminated sites management, these provisions require further strengthening, especially to address historical or legacy pollution resulting from conflicts or other sources. Moreover, a better understanding of the current status of the environment protection fund and its operational modalities is required.

Table 10: *Summary of existing legislation relevant to contaminated site management in Iraq*

Legislation	Key Features
The Constitution	Guarantees "right to live" and commits to protect and preserve the environment and biodiversity (Article 33). Requires formulation of environmental policy in cooperation with regions and governorates (Article 114).
National Environment Protection Strategy (2013–17)	Analyzes Iraq's environment status and identifies strategies for nine critical areas of environment. Includes specific strategies for hazardous chemicals, oil pollution, and solid waste.
Protection and Improvement of the Environment Law 27 of 2009	Overarching law to protect the environment and natural resources. Includes provisions related to solid waste and hazardous chemicals. Section IV relates to the protection of land and Article 17 aims to prevent activities resulting in soil degradation or pollution.
System No. 25 of 1967 on Water Quality Conservation, Law of Rivers and Public Water Areas	Prescribes standards for water quality and wastewater discharges. Requires permits for discharge of wastewater into public waters areas.
Preservation of Water Resources Regulation No. 2 of 2001	Prescribes regulations for water use, conservation, and so on. Requires discharge license from environment authority.
Safe Storage and Handling of Chemicals Law 89 of 1981 and Instructions No. 4 of 1989	Details requirements for safe handling and storage of chemicals. Relevant for management of hazardous chemicals in hotspots.
Safety Instructions for Use of Asbestos No. 1 of 2002 and Decision to Ban Use of Asbestos No. 41 of 2016	Requires protecting the environment, workers, and surrounding air from the use of asbestos. Cabinet resolution 41 of 2016 seeks to ban the use of asbestos.
Regulation No.3 of 2015	Prescribes regulations for the management of hazardous waste Requires approvals for waste treatment and the rehabilitation of contaminated sites.
Worker Employer Labor Law 151 of 1970 and Regulation 3 of 1985	Prescribes requirements for occupational health and safety that would be relevant for contaminated sites management.

Source: *Analysis by ASA team.*

The Water Quality Conservation, Law of Rivers and Public Water Areas (System No. 25 of 1967) and the Preservation of Water Resources Regulation 2, 2001, deal with water quality, the discharge of wastewater, open dumping of wastes into water bodies, utilization and conservation of water resources, and permits for the discharge of wastewater. Both these laws apply to assessment of water pollution due to contaminated sites, when establishing remediation objectives, and when designing remediation plans.

Iraq also has laws that relate to the storing and handling of chemicals (Safe Storage and Handling of Chemicals Law 89 of 1981 and Instructions No. 4 of 1989), the use of asbestos (Safety Instructions for Use of Asbestos No. 1 of 2002 and Decision to Ban Use of Asbestos No. 41 of 2016), and the management of hazardous waste (Worker Employer Labor Regulation No. 3 of 2015). These laws will help in assessing contamination at pollution hotspots and choosing remediation technologies for individual sites.

Other important laws in the country are:

- Regulation No. 471 of 2012 on the Preservation of Air Quality
- Protection of Ambient Air Quality Regulation No. 3 of 2012
- Environmental Assessment Law 37 of 2008 and 27 of 2009
- Environmental Impact Assessment Categorization Instruction No. 3 of 2011
- Worker-Employer Labor Law 151 of 1970.

Various provisions of these laws are relevant for assessing the impacts of contaminated sites and designing appropriate management or remediation strategies.

In addition, Iraq is signatory to several international conventions and agreements on the environment and sustainability.

Agreements relevant to hazardous substances and contaminated sites include:

- The Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal, 1992 (ratified by Iraq on May 2, 2011)
- The Stockholm Convention on Persistent Organic Pollutants, 2004 (ratified by Iraq on March 8, 2016)
- The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, 2004 (ratified by Iraq on April 18, 2017)
- The Montreal Protocol on Substances that Deplete the Ozone Layer and the Vienna Convention for the Protection of the Ozone Layer, 1989 (ratified by Iraq on June 25, 2008, except Kigali amendment, 2016).

All these policies, strategies, acts, regulations, and commitment to international conventions, confirm the availability of basic enabling framework for the management of contaminated sites in Iraq.

3.3.2 GAP ANALYSIS

This section presents an analysis of gaps based on the above review of international examples and the regulatory framework in Iraq, together with the various steps for contaminated sites management relating to legal and regulatory requirements.

Iraq has a comprehensive set of environmental regulations and includes certain aspects relevant to contaminated sites management (such as regulations for hazardous waste, storage and handling of chemicals, inclusion of “Polluter Pays” principle, and so on (Table 11). However, some important requirements for identifying, assessing, and remediating pollution, as well as the institutional mandate for the management of contaminated sites, are missing from the current regulatory framework.

Table 11: *Environmental laws of Iraq relative to contaminated site management process*

Contaminated sites management steps	Requirements or gaps in laws of Iraq
IDENTIFICATION Identification of probably contaminated sites Preliminary investigation Notification of contaminated sites Identification of priority sites	• National and local authorities are responsible for protection of the environment, but "contaminated sites" need to be defined. • Legal provisions for identifying suspected sites, notification, establishing a national inventory of suspected sites, and developing site management programs. • Per the Protection and Improvement of the Environment Law 27 of 2009, local councils have the authority to perform field inspections and to issue fines should provisions of the law be breached. Officials of these councils have already been trained through the current ASA and can perform initial assessment of sites. • Dutch Intervention Values (DIVs) for soil are currently applied for assessing hotspots, but these values or relevant local standards need to be legally notified. • Environmental Law 27 of 2009 provides for the establishment of an Environmental Protection Council represented by various ministries. While the mandate of the council is broad, this institutional arrangement can be used as an empowered body for the contaminated site management program in the country. • Regulation No. 3 of 2015 includes issuing environmental approvals for projects to rehabilitate contaminated sites. • Legal provisions to carry out site assessments and risk analyses, prioritize sites, and conduct remediation. • Legal provisions to determine the liability, although "Polluter Pays" principle is recognized by the Environment Law 27 of 2009.
ASSESSMENT AND PLANNING Detailed investigations Remediation design Approval and financing	• Legal provisions and guidelines for carrying out detailed assessment of contaminated sites. • Standards for soil quality to be established. Provisions exist for the management and disposal of hazardous wastes, wastewater discharge, management of hazardous chemicals, and air quality. • Projects that are likely to have effects on human health and environmental integrity (such as contaminated sites remediation) will require Environmental Impact Assessments. • Although the legislation requires polluters in the oil and gas sector to pay for remediation of contamination resulting from their activities, clear guidance on the responsibilities for funding remediation of contamination resulting from conflict is needed. There is reference to the "Polluter Pays" principle, an Environmental Protection Fund, and an approach to calculating the amount of compensation. These provisions can be used to develop an appropriate financing mechanism for remediation of contaminated sites.
IMPLEMENTATION Implementation of remediation Approval of remediation completion	• Legal provisions related to implementation of remediation activities, including monitoring and reporting progress. • Provisions for defining and approving remediation completion. • Labor law includes a requirement to adhere to an approved site safety plan, which must include a task-based hazard and risk assessment, and description of risk management measures.
POST-REMEDIATION Post-remediation plan and action Long-term monitoring Cost recover Priority list deletion Site reuse	Provisions related to the post- remediation phase.

Source: *Analysis by ASA team.*

3.3.3 REQUIRED POLICY AND REGULATORY ENHANCEMENTS

Given the magnitude of risks and geographical spread of the sites, as well as the pollution challenges around them, Iraq requires a comprehensive national program that is supported by an appropriate policy and regulatory framework. The environmental legislation of Iraq includes elements that can be related to the management of contaminated sites, but key gaps should be addressed for the implementation of a broader program on pollution hotspots. Experience from other countries and regions provides valuable insights on how these gaps can be addressed.[32]

Policies for contaminated site management

Iraq currently has no national policy that outlines its approach to managing contaminated sites. Countries have followed different approaches in developing their programs, primarily driven by the local context. However, decisions regarding the management of contaminated sites should be based on the level of risks they pose to humans and the environment. Moreover, remediation efforts are not free of consequence, and poorly planned remediation projects can also be associated with significant negative impacts. A policy for pollution hotspots in Iraq would be a constructive first step towards developing programs that address these challenges.

Definition of contaminated site

Defining what constitutes a contaminated site is an important gap in Iraq's regulatory framework. The MoE currently refers to contaminated sites as "environmental hotspots". An acceptable name and definition consistent with the country's constitutional and policy framework and international good practice must be developed to form the basis for identifying and managing contaminated sites.

Enabling legislation and regulations

There are two broad options to strengthen the legislative framework related to the management of contaminated sites. The first option involves enhancing or strengthening existing legislation through amendments or additions. The second option is to develop dedicated legislation on contaminated sites management.

Identifying the most suitable option will require comprehensive analyses of the legislation from both a technical and legal perspective, as well as consultations with various stakeholders in the country. **These analyses and consultations should address both low- and high-level enabling legislation and answer the following:**

- Which legislative elements relating to contaminated site management already exist, are missing, or should be strengthened?
- What are the pros and cons of strengthening existing regulations versus a dedicated legislation?

If the option of enhancement or strengthening current legislation is chosen, the Protection and Improvement of the Environment Law (No. 27 of 2009) and laws relating to the protection of water resources could be amended. Ultimately, the chosen option should align with national policy and the definition of contaminated sites suggested above.

Soil quality standards and screening levels

Iraq has no standards or screening levels for pollutant concentrations in soil. The MoE currently draws on the DIVs for soil, but standards that considers country context should ideally be developed. The absence of national determinants of contaminated soil limits efforts to identify and manage contaminated sites. Internationally, soil quality screening levels are defined based on risks to human health and environmental integrity. The proposed standards should be included in relevant legislation (for example, Environment Law No.27 of 2009 or dedicated legislation on contaminated sites, as the case may be). However, given that the development of these standards is a prolonged process that requires consensus among stakeholders, the current practice of following DIVs could be formalized through appropriate regulatory action as an interim measure.

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32 World Bank 2010.

Framework for the management of contaminated sites

A technically sound and logical framework for the identification, assessment, and remediation or management of contaminated sites is another important element that is absent in Iraq's current regulatory regime. **The framework should—with the help of other statutory provisions such as an overarching policy, sound definition of contaminated sites, and soil screening levels—clearly define the process to:**

1. Assess suspected sites.
2. Identify contaminated sites.
3. Prepare an inventory and prioritize sites.
4. Carry out detailed investigations and risk assessments.
5. Decide the need for remediating a particular site and its design.
6. Monitor the site after remediation.
7. Close the site.

Adoption of risk-based cleanup targets

Full remediation, such as removing every contaminant from the site, is often excessively costly. The optimal target level for cleanups depends on the risks the contaminant poses to the environment and the surrounding population, which hinges on the site's proximity to population centers and the intended use of the land. Cleanup targets should consider these risks, as well as the proposed or future land use of the site, threats to water resources, and other ecological and environmental attributes.

3.4 Institutional framework

3.4.1 CURRENT FRAMEWORK

Designing, developing, and successfully implementing a hotspots management program involves effective coordination, and active participation by, various public, private, and community stakeholders. Pollution hotspots in Iraq are diverse and owned or managed by different entities, including the MoO and the Ministry of Petroleum (oil wells and gas extraction sites); the Ministry of Agriculture (pesticides and fertilizer industry sites); the Ministry of Electricity (power plants and electrical industry sites); the Ministry of Defense (defense facilities), the Ministry of Industries (various industrial facilities), and private owners of industrial sites.

Although not covered in this ASA report, pollution hotspots are likely present across all Iraq governorates. Implementing a hotspots management program will rely on the participation of all governorates, their respective municipalities, and other local agencies.

At the broader level, the Ministry of Finance and the Ministry of Planning will play a pivotal role in finalizing the overall framework and the financial aspects of a hotspots management program. The Ministry of Science and Technology and the Ministry of Health will also play a role in the technological and health-impacts perspective of such a program.

Yet, aside from the MoE and the MoO, none of the ministries understand the issues related to the management of contaminated sites. Extensive awareness programs and consultations would be needed to achieve consensus when conceptualizing, designing, developing, and implementing a hotspots management program.

Table 12: *Role of stakeholder ministries in hotspots management*

Ministry/Department/Agency	Role/ Function
Ministry of Finance	National ministry responsible for financial planning and budgeting. Will play a critical role in conceptualizing, designing, and funding the hotspots management program.
Ministry of Planning	National ministry that leads in policy development and the design of various projects in Iraq. Will be important for developing and monitoring the hotspots program, as well as developing the policy and regulatory framework around it.
Ministry of Environment	National ministry responsible for overall environmental management in Iraq. Will be the lead agency in coordinating with stakeholder ministries and in conceptualizing, designing, implementing, and monitoring the hotspots management program.
Ministry of Science and Technology	National ministry that leads on aspects relating to technology and research. Will play a crucial role in establishing soil standards or screening levels and identifying remediation technologies.
Ministry of Agriculture	National ministry responsible for formulating and implementing policy, as well as developing the country's agriculture sector. Will play an important role in remediating sites contaminated with pesticides and fertilizer.
Ministry of Electricity	National ministry responsible for electricity generation, transmission, and distribution in Iraq. Will play an important role in remediating sites owned or monitored by the ministry.
Ministry of Oil	National ministry responsible for oil extraction, export/import, and related activities. Will play an important role in decommissioning and disposing of hydrocarbon-contaminated sites.
Ministry of Industry	National ministry responsible for industries. Will play an important role in the decontamination and remediation of sites and facilities owned or monitored by the ministry.
Ministry of Construction, Housing, Municipalities, and Public Works	National ministry that provides policy and administrative oversight for municipalities. Will play an important role in the post-remediation land use of sites and coordination with municipalities.
Governorates in the project area	Regional bodies of the Government of Iraq that provide administrative oversight of urban and rural bodies within their jurisdictions. Will play an important role in coordinating with various agencies and implementing the hotspots program.
Municipalities and local agencies	Local entities who benefit from project activities and will reap anticipated benefits from pollution management, will play an important role during implementation.

Source: *Discussions with MoE and other Government of Iraq entities.*

3.4.2 INSTITUTIONAL MECHANISMS FOR HOTSPOT MANAGEMENT

Contaminated site management requires a multi-stakeholder approach. International experience shows that one institution cannot lead such a comprehensive and complex program. Yet, due to its institutional mandate and technical knowledge in the sector, the MoE will be a key player in leading such a program. The Government of Iraq may explore the following institutional arrangements.

Option 1: Program Management Unit at the MoE with an inter-ministerial steering committee

Advantages

- Will require no major parliamentary or constitutional approval process.
- Can start quickly once overall program is approved by the government.
- Will leverage the technical capacity developed at the MoE through the current ASA.
- Will build implementation capacity and knowledge of hotspots management within the MoE and other Government of Iraq institutions, so providing long-term sustainability.

Disadvantages

- The MoE has no prior experience of implementing large pollution management projects, more so with participation from various other ministries.
- Other ministries may be apprehensive of working with the MoE because it is a regulatory agency.
- It would require hiring a number of external experts to support the MoE.
- Implementation could be challenging for the MoE with limited local and regional presence.

Option 2: Program Coordination Unit at the MoE with other ministries as implementing agencies

Advantages

- Ensures use of the MoE's technical capacity and sectoral responsibilities of other ministries and agencies.
- Has potential for good stakeholder coordination.
- Offers stronger local presence and better implementation with support from other ministries.
- Will also provide all other advantages of Option 1.

Disadvantages

- Clear roles, responsibilities, and fund-flow arrangements between agencies should be agreed upfront to avoid implementation disputes.
- The number of national ministries, local governorates, and agencies could present challenges in overall program ownership and delivery.
- Institutional structure and staffing distribution would need to be agreed between ministries to ensure that adequate capacity is available within all agencies.
- A person or ministry to head the project, who can lead all these institutions and resolve obstacles as they arise, would need to be designated.

Option 3: A dedicated institution/agency with an inter-ministerial coordination committee

Advantages

- Offers a clear mandate and responsibility to one agency.
- Will offer the flexibility of developing a technical institution with strong expertise to handle the complex contaminated sites program.
- Project implementation could be efficient and timely.
- Would ensure long-term institutional capacity for the management of hotspots in Iraq.

Disadvantages

- Requires constitutional and parliamentary approvals, which could take time.
- Setting up a new institution in terms of hiring people or redeploying people will take time.
- The powers and responsibilities of the new institution should be clearly defined to avoid overlap with other agencies.
- Coordination with other ministries could be challenging for a new institution.

"Ultimately, the choice of option should be based on detailed deliberations and consultations with the agencies and a more robust assessment of institutions."

3.5 Technical, institutional, and infrastructure requirements

Regardless of the choice of institutional mechanism, contaminated sites management will require a high level of technical and institutional capacity. This could vary for a new institution when compared to an existing institution, but the basic requirement will remain the same.

This section focuses on the necessary technical and institutional capacities and infrastructure requirements to consider when choosing a suitable institutional model and designing the capacity-building components of a contaminated sites program.

3.5.1 TECHNICAL CAPACITY

Technical capacity in a wide range of topics is required for the personnel involved in contaminated sites management. Depending on the nature and type of pollution at sites, subject-specific experts will likely be required. These experts could be contracted on a case-to-case basis. Technical capacities can be clustered under 10 broad functions to which specific skills can be related (Table 13).

Table 13: *Technical capacity requirements for contaminated sites management*

Function	Capacity or skills required
Concepts and principles of contaminated site management	Professional with engineering or science background, and basic training and field experience on the subject.
Identification, screening, and initial assessment of sites	Professional with environmental engineering or science background and specific training (academic and field) on screening techniques, the development of data checklists, data collection, site assessments, use and handling of GPS instruments, analysis, and the interpretation of secondary and field data.
Detailed site assessment and investigations	Senior professional with advanced training and field experience in the design of environmental sampling programs, engineering investigations (topographic surveys), soil sampling, development of Conceptual Site Models, and data interpretation and analysis.
Laboratory analysis and interpretation	Senior chemists with experience in analyzing soil and water samples using advanced equipment such as Gas Chromatography-Mass Spectrometry, Inductively Coupled Plasma-Mass Spectrometry, and Energy Dispersive X-ray Fluorescence.
Health risk assessment	Senior professional with experience in carrying out Human Health Risk Assessments.
Design and development of contaminated site management or remediation plans	Remediation experts with experience preparing remediation plans relevant to the nature and type of contamination at the site.
Communication, stakeholder engagement, and consultations	Stakeholder consultation experts and other team members with a basic understanding of stakeholder engagement and consultation.
Project structuring, procurement, supervision, and contract management	Experts on project structuring, procurement, and contract management, with support from technical and remediation experts.
Post-remediation monitoring	Remediation and environmental monitoring experts.
GIS and information management	GIS experts with experience in using spatial tools, analyzing satellite imagery, and managing information.

Source: *Analysis by ASA team.*

The Government of Iraq has experience in some of the above functions together with the technical capacities of various entities.

The MoE has a dedicated Contaminated Sites Assessment Department that performs site inspections and assessments. Through UNEP's technical assistance and the current ASA, about 30 officials (from the Contaminated Site Assessment Department of the MoE, the MoO, and governorate officials) were trained on **concepts and principles of contaminated site management** and the **identification, screening, and initial assessment of sites**. Using the skills developed through these training programs, the joint MoE and MoO teams carried out the inventory and initial assessment of suspected hotspots in Iraq.

Eight laboratory officials from the MoE were also provided with hands-on training to carry out **laboratory analysis and interpretation** of water and soil samples using advanced equipment. **Training on GIS and information management** was also provided for eight members of the MoE. This training covered the mapping of hotspot sites and updating site information using GIS tools.

Overall, as highlighted in section 1,3, seven training programs for a total of 57 days were provided to 66 officials (cumulatively 134 participants and 7,638 person days of training) from the MoE, the MoO, and other Government of Iraq officials on all critical aspects of contaminated sites management. Although these training programs enhanced the capacity of the MoE team, additional capacity-building initiatives will be necessary to enable the ministry to independently manage a contaminated sites program.

3.5.2 INSTITUTIONAL CAPACITY

Three aspects must be considered when assessing an institution's capacity to perform mandated activities: the presence of adequate and qualified personnel, the presence of appropriate systems and procedures, and the presence of appropriate infrastructure.

Adequate and qualified personnel

The MoE's Contaminated Sites Assessment Department currently has a total of 52 staff members, of which 22 work at the central/national level and 30 are distributed across all governorates in the country. Although this workforce may be adequate for routine monitoring and inspection of hotspots, contaminated sites management requires carrying out additional activities. These include identifying and assessing contaminated sites, preparing and implementing remediation plans, and monitoring sites after remediation.

The need for additional staffing should be assessed based on detailed personnel planning and should, among other skills, include:

- Personnel with expertise on contaminated sites.
- GIS and database management specialists for maintenance and updating of the hotspots database.
- Civil and construction engineers.
- Procurement specialists.
- Contract management experts.

Appropriate systems and procedures

To enable the MoE's Contaminated Sites Assessment Department to perform its functions efficiently, specific procedures and protocols for inspecting and assessing contaminated sites need to be developed. Customized technical guidance will also need to be developed for each function of contaminated sites management. Such guidance will be based on the country's regulatory and policy framework and should provide practical guidance to staff from the ministry, industries, and practitioners to execute contaminated site assessment, remediation, and management activities.

Key documents should include:

- Procedures for identifying and conducting initial assessment of contaminated sites.
- Guidance for designing sampling programs and performing field sampling.
- Guidance for developing Conceptual Site Models.
- Procedures for conducting human health and ecological risk assessment.
- Protocols for developing cleanup objectives based on risk assessment.
- Guidance on conducting feasibility studies and preparing remediation plans.
- Supervision and monitoring protocols for implementing remediation plans.
- Guidance for the post-remediation monitoring and management of contaminated sites.

3.5.3 INFRASTRUCTURE REQUIREMENTS

The required infrastructure can be divided into three categories: field sampling equipment, laboratory infrastructure, and office infrastructure including information technology and allied tools.

For contaminated sites, **field sampling equipment** include handheld GPS instruments, sampling tools for collecting samples for environmental parameters, personal protective equipment for conducting site assessments, and field sampling and site assessment toolkits. While the MoE has some GPS instruments, these need to be upgraded. An adequate number of instruments should be made available for all field assessment staff of the ministry.

The MoE's central laboratory in Baghdad is the main laboratory at the national level. Based on UNEP's assessment, the **laboratory has basic infrastructure** and some key elements of organizational structure.[33] However, the equipment required for analyzing advanced environmental parameters and the trained staff to use such equipment is not available. Furthermore, although the laboratory has a quality assurance department, it does not have quality assurance certification (ISO 9000, 14001, or 17025 accreditation). Similar deficiencies are noted in the MoE's regional laboratories.

Basic **office infrastructure** and facilities for managing substantial data related to hotspots, such as computers, printers, scanners, plotters, hardware, and software, also require upgrades. High-end computers and other hardware infrastructure will be required to run specialized software (such as ArcGIS Pro) for mapping, for data interpretation through spatial tools such as GIS, and very high-resolution images.

3.6 Conclusion

An analysis of regulatory, institutional, and capacity-building requirements for the management of pollution hotspots in Iraq indicate the need to; strengthen policy and regulatory framework in line with the international good practices; establish an institutional mechanism that ensures coordination between various stakeholder ministries; and build the technical and institutional capacity of MoE. While a broad set of options for each of the above enhancements have been identified, these options need to be further evaluated based on more detailed analysis of each element, more specifically in the context of an overall program on contaminated site management in Iraq and its specific interventions.

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33 UNEP 2018b.

4 Technology Options for Remediation

4.1 Introduction

Remediation technologies should be relevant to the nature, type, and local of context of Iraq. The selection of a specific technology for remediation will be dependent on whether a "risk-based" or "standards based" approach is taken. Factors influencing the technology's performance and its indicative cost are other important considerations.

This section discusses these points and presents a menu of technology options, which can be further assessed during the preparation of remediation plans for individual sites.

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4.2 Remediation approaches

Internationally, the following two approaches are followed for the remediation of contaminated sites:

- **"Risk-based" or "fit for use" approach:** Aims to remove or treat the contaminants to a level that reduces the risks to human health and existing/proposed land use of a site.
- **"Standards based" or "multifunctional soil remediation" approach:** Aims to remediate the contaminated land to a pristine condition or to a prescribed concentration level.

4.2.1 RISK-BASED APPROACH

This approach follows an acceptability criterion tied to human health risks and future land use of the site to be remediated. Present and projected land use can also be considered when identifying remediation objectives, in usage is expected to change soon. A basic principle is that reuse or redevelopment of a site should fix or improve soil and groundwater quality.

The risk-based approach can be followed for every type of source-pathway-receptor contamination. In cases of immobile soil contamination, as with many heavy metals, it requires assessing the quality of the topsoil layer alone because the quality of this part of the soil is responsible for most human and environmental risks. This approach saves effort in carrying out assessment of contaminated sites deeper than the top layer of the soil, thus providing an opportunity to balance the scientific assessment of sites with the pragmatism of dealing with site or region-specific preconditions at the contaminated sites. The threshold values for a specific site use offer basic safety warranties.

Contamination without receptors presents no risk, and a risk-based approach would not call for intervention. However, alternative remediation options could be considered if it is decided to nonetheless remediate such a contaminated site in order to, for example, improve the quality of an aquifer to meet drinking water standards.

A risk-based approach also incorporates sustainability aspects by providing the opportunity to choose technologies that combine economic and sustainable benefits without sacrificing public health or safety. In doing so, it facilitates a balance between human health and environmental protection versus the opportunity to reuse contaminated soil and to optimize the economic aspects of site redevelopment.

In the context of Iraq, where a broader national program for remediation of multiple contaminated sites is needed, adoption of a "risk based" approach offers opportunities for choosing remediation technologies that optimize the need for remediation while considering the economic and health benefits of local communities.

4.2.2 STANDARDS-BASED OR MULTIFUNCTIONAL SOIL REMEDIATION APPROACH

The standards-based approach aims to remediate all contaminated land to a pristine condition, which would entail restoring soil quality from an intervention value back to a standard target or natural background level, regardless of the site's current characteristics or future land use. This approach is also known as a multifunctional soil remediation approach because remediated sites would ideally be fit for all uses.

Given that the target levels are well defined and non-negotiable, this approach provides a simple decision-making system that is easy to apply. If remediating the soil of a site is not feasible with this approach, a fallback option would be containing the pollutant. However, containment should be comparable to the complete removal of the pollutant and be designed in a way that results in the lowest possible emissions.

The concept of multifunctionality was most relevant during 1990s when the direct link between soil contamination and serious health risks could be established on a one-to-one basis. This was the ultimate aim of contaminated land remediation at that time. However, subsequent studies indicated that, even after prohibitive investments in remediation, restoring soil to a pristine state would take a long time. Multifunctionality is therefore not likely to be technically feasible or economically viable in the short term. An example of the costs and inefficiency of a multifunctional remediation approach would be removing every last drop of mineral oil from mineral oil-contaminated soil—a technical challenge that would be disproportionate to the costs and energy required to achieve it, because the extraction of every last drop would likely demand much more energy than represented by the drop itself.

The idea that soil contamination could stagnate the (re) development of urban or prime sites gained traction during the first half of the 1990s. This stagnation was largely due to the stringent contamination policies in place, which leaned towards a standards-based or multifunctional approach. Given the higher cost of remediation when following this approach, developers were dissuaded from working on (potentially) contaminated sites. Even in the densely populated areas of north-western Europe, greenfield developments were the most economical option.

Despite these drawbacks, a multifunctional approach has not been phased out completely and it is still useful in specific circumstances. For example, the cost of a multifunctional approach is relatively low in a small contaminated area. This approach may also be the most appropriate option for a liable party when the policy is to avoid any future liability issues.

4.2.3 POSSIBLE APPROACH FOR HOTSPOTS MANAGEMENT IN IRAQ

Compared to a risk-based approach, a standards-based approach is relatively simple and easy to understand, even for non-professionals. While some countries (notably Finland, the Netherlands, and Switzerland) have retained the goal of multifunctionality, most countries follow a risk-based approach. This characteristic may attract support, especially from residents, when proposing remediation solutions. However, a standards-based approach is also less flexible: Once the standards have been set, which are policy-level decisions, remediation efforts are far less likely to consider the local context of individual sites. Lastly, given their intensity and inflexibility, standards-based approaches will be financially and energetically costly.

By contrast, risk-based approaches develop remediation options specific to individual sites and local conditions. In accordance with the site assessment phase, this approach also usually includes a risk assessment to determine the need to remediate. Risk-based approaches are more flexible in their individual, site-specific targets, which can be derived from—or combined with—other target values, such as drinking water standards. A risk-based approach, however, requires more data on the local situation. In most cases, the return on investment in acquiring this information increases with time because of the reduced costs of remediation. Considering the complexity of hotspots scenarios in Iraq, both in terms of size and nature of the contamination, the importance of remediation cost cannot be ignored. The sites are distributed over a wide geographical area, meaning that remediation options need to be tailored to meet local conditions and the requirements of stakeholders.

Ultimately, the risk-based approach appears to be an appropriate approach for Iraq. However, the Government of Iraq and MoE should make a final choice on the acceptable approach with detailed consultations with various stakeholders while preparing the broader program on hotspots remediation.

4.3 Remediation options and technologies

Once the broader approach for remediation has been decided, technology is the most important aspect that will determine the outcome of any intervention. Globally, several remediation technologies have been developed and applied successfully to treat and remediate contaminated sites. **Potential options for remediation of contaminated sites, focusing on those that are most likely to be relevant in the context of Iraq, should consider the following:**

- Most of the hotspots identified in Iraq are contaminated by hydrocarbons and heavy metals.
- The sources of contamination at most the sites are leaks at oil refineries and pipelines, or chemical spills at industrial sites.
- Based on the initial assessment and environmental sampling, soil is the most impacted medium, while groundwater seems to have not been contaminated
- Very few small-scale remediation projects have been implemented in the country, and there is limited local experience on the performance of remediation technologies.

Table 14 provides a list of potential remediation technologies for pollution hotspots in Iraq. These technologies include both *in situ* treatments (at the site of the contamination) and ex situ treatment (contaminated material is removed from the original location and then treated) techniques, each with their own applicability (media, contaminant types, and so on). In certain instances, a combination of two or more of the technologies described in the table may be required to achieve remediation targets.

The technologies discussed are indicative and not exhaustive. The actual choice of technology should be based on the overall remediation objectives, detailed site investigations, and health risk assessment of contamination at the site.


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Table 14: *Potential remediation technologies relevant to the profile of hotspots in Iraq*

Contaminants	Description	Advantages	Disadvantages
1. Excavation and offsite disposal			
Heavy Metals	Removes contaminated soil and disposes it at an authorized site	Technically less complicated. Widely available and accepted.	Creates large volumes of contaminated solid waste. Not feasible in some geological situations. Excavation below water table would be expensive.
2. Phytoremediation			
Heavy Metals and Petroleum Hydrocarbons	Uses plants to absorb contaminants from the surface and to store them in tissue.	Less expensive with limited maintenance. Only periodic maintenance is needed (harvesting and processing of plants or plant detritus) once plants are established.	Requires long preparation time and long-term access to treat soils. Difficult to treat deep groundwater. Requires hyper-accumulating plants that may not exist for metals that are not essential nutrients.
3. Soil washing			
Heavy Metals and Petroleum Hydrocarbons	Dissolves contaminants in a wash solution or concentrates them into a smaller volume.	Can be used for a wide range of contaminants.	Complex waste mixtures make formulating a wide range of fluids difficult. High humic content in soil may require pretreatment. Aqueous streams need demobilization.
4. Electrokinetic separation			
Heavy Metals	Deploys electrodes in sub-surface to create an electric field that drives contaminants to electrodes.	Effective in clay-rich aquifers. Potential for less solid waste.	Increase of pH near cathode could cause precipitation of metal salts. Efficiency decreases outside of specific aquifer and contamination conditions.
5. Solar vapor extraction			
Petroleum Hydrocarbons	Extracts vapors from the soil above the water table by applying a vacuum to pull the vapors out.	Low cost. Can be applied in-situ. Very effective in removing volatile contaminants such as Petroleum Hydrocarbons. Established process.	Vapor requires treatment. Effectiveness typically diminishes over time as readily extracted contaminant mass is removed.
6. Landfarming			
Petroleum Hydrocarbons	Places excavated contaminated soils over a treatment area or in a biotreatment cell, typically lined to prevent leaching.	Low cost. Facilities are simple to construct and easy to operate. Uses standard equipment.	Requires large land mass. Regulatory limitations on wastes that can be treated. May not be effective for highly impacted soils. Dust and vapor emissions may pose air-quality concerns.
7. Natural Source Zone Depletion			
Petroleum Hydrocarbons	Uses naturally occurring processes of dissolution, volatilization, and biodegradation to reduce containment mass.	Low cost: Little to no engineering effort is required.	Sophisticated monitoring is required. Site-specific conditions will drive the magnitude and rates of degradation.

Source: *Compiled by the ASA team.*

4.3.1 EXCAVATION AND OFFSITE DISPOSAL

According to the US Federal Remediation Technologies Roundtable (FRTR), the excavation and off-site disposal process involves selecting the "appropriate methods for dewatering, handling, transport, pre-treatment, and disposal", while "excavation and off-site disposal is a proven and readily implementable technology".[34]

Excavation and Offsite Disposal can be used as a remediation technology for handling a variety of contaminants, including Petroleum Hydrocarbon and Heavy Metals. According to the FRTR, the major steps of this technology are excavation, dewatering, soil handling, and pre-treatment and disposal. These steps are described in detail below:

Excavation: Excavation is the mechanical removal of waste or contaminated soil from the subsurface with a variant of an excavator or backhoe. Other earthmoving equipment (e.g., clamshell buckets, bulldozers) may also be used based on the size and configuration of the excavation. Air knife techniques followed by a hi-tech vacuum are also used for precise removal of soil from around sensitive structures, utilities, or plant roots.

Dewatering: Dewatering refers to control of groundwater in the area of excavation, removal of water (stormwater or infiltrated groundwater) from within an excavation area or draining of excavated material to meet transport and disposal restrictions. All water generated from dewatering requires on-site management, and typically requires treatment prior to discharge. In some cases, the removed water is classified as a hazardous waste and must be managed as such. Portable water treatment systems to manage stormwater at standard grading sites can be used in some cases, but often additional treatment must be performed, and discharge requirements must be met based on the site contaminants and receiving facility (typically storm drains or a publicly owned treatment works).

Soil handling: Involves relatively simple (e.g., direct loading of trucks by the excavator) to a very complex (e.g., segregation of hazardous and non-hazardous waste streams, segregation of debris and other waste, lead recovery, on-site stabilization or other ex situ treatments, dewatering, and stockpiling) process depending on the site situation. Planning soil handling and transport during the design phase is critical to a successful excavation project. For example, sufficient land area must be identified near the excavation site to provide for soil handling, and temporary haul roads must be laid around the site of excavation, a stable surface shall be provided for on-road dump trucks that bring them near the load-out area. For some projects a combination of truck and rail transport is warranted. For sites with mixed hazardous and non-hazardous waste with different transport restrictions, careful management of truck traffic and manifesting is necessary. For large projects during peak construction season, securing adequate transport resources (e.g., a sufficient number of trucks each day) should be planned well in advance.

Pre-Treatment and Disposal. The type of contaminant and its concentration will impact off-site disposal requirements. Soil characterization as dictated by land disposal restrictions is required. Most hazardous wastes must be treated to meet either Resource Conservation and Recovery Act or non-[Resource Conservation and Recovery Act] treatment standards prior to land disposal. Pre-treatment, generally consisting of stabilization by mixing with fly ash or similar amendments to reduce contaminant leaching potential, is often conducted at the receiving facility but is sometimes performed on site Pretreatment or placement of hazardous waste outside the area of contamination (on site or off site) may require development of a Corrective Action Management Unit, so as to not violate requirements. Radioactive wastes would have to meet disposal facility waste form requirements based on waste classification.[35]

34 https://www.frtr.gov/matrix/Excavation-and-Off-Site-Disposal.
35 https://www.frtr.gov/matrix/Excavation-and-Off-Site-Disposal.

Advantages

- The technology is well-established and readily deployable.
- Applicable to the complete range of contaminant groups and has no particular target group.

Disadvantages

- A large amount of solid waste is generated.
- It is not feasible in some geology, such as heaving sand.
- The cost increases significantly for excavation below the water table.
- The accessibility (that is, depth) of contaminated soil is limited by the excavation equipment.
- The presence of any infrastructure needs to be removed or protected.

The need for dewatering for groundwater control, maintaining a dry excavation, and draining of the removed media, as well as treatment of recovered water, adds additional costs and effort to the project. Health and safety requirements for on-site workers and off-site population also need to be ensured.

Costs

The FRTR describes the costs of Excavation and Offsite Disposal as the following: "Upfront costs for excavation and disposal can be high compared to *in situ* treatment technologies. However, excavation can result in substantially shorter restoration timeframes, resulting in lower lifetime costs when operation, maintenance, and monitoring costs for *in situ* systems are considered. An overall life cycle assessment of costs can be challenging."[36]

4.3.2 PHYTOREMEDIATION

The phytoremediation approach involves cultivating specific species of plant on the contaminated medium (either water or soil) and the contaminants are then either taken up into the plant tissues or absorbed to the surface of the roots. Once the concentration of contaminants in the medium is below target levels, the plants (and associated contaminants) are removed and either disposed of safely or incinerated. Phytoremediation is particularly effective for removing heavy metals from soil. While phytoremediation may include the use of microorganisms in conjunction with plants, it is distinguished from bioremediation in that bioremediation does not use macroscopic plants or trees.

Plants can be used for phytoremediation in several ways. These are described as follows by the FRTR:

Enhanced Rhizosphere Biodegradation takes place in the soil surrounding plant roots. Natural substances released by plant roots supply nutrients to microorganisms, which enhances their ability to biodegrade organic contaminants. Plant roots also loosen the soil and then die, leaving paths for transport of water and aeration. This process tends to pull water to the surface zone and dry the lower saturated zones.

Hydraulic Control. Depending on the type of trees, climate, and season, trees can act as organic pumps when their roots reach down towards the water table and establish a dense root mass that takes up large quantities of water.

Phyto-degradation is the metabolism of contaminants within plant tissues. Plants produce enzymes, such as dehalogenase and oxygenase, that help catalyze degradation. Investigations are proceeding to determine if both aromatic and chlorinated aliphatic compounds are amenable to phyto-degradation.

Phyto-volatilization occurs as plants take up water containing organic contaminants and release the contaminants into the air through their leaves. Plants can also break down organic contaminants and release breakdown products into air through leaves.[37]

36 https://www.frtr.gov/matrix/Excavation-and-Off-Site-Disposal.
37 https://www.frtr.gov/matrix2/section4/4-33.html.

Advantages

- The cost is low, because it uses plants to remediate contaminants.
- Phytoremediation only requires periodic maintenance once the plants are installed.
- The technology is versatile and can be used to clean up heavy metals and organic contaminants from soil, groundwater, surface water, and leachate.
- The plants produce enzymes that help catalyze the degradation of contaminants.

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Disadvantages

- Phytoremediation requires long-term access to treat soils.
- The FRTR specifies the following limitations of this technology:
  - It is limited to shallow soils, streams, and ground water.
  - High concentrations of hazardous materials can be toxic to plants.
  - It involves the same mass transfer limitations as other biotreatments.
  - Climatic or seasonal conditions may interfere or inhibit plant growth, slow remediation efforts, or increase the length of the treatment period.
  - It can transfer contamination across media, e.g., from soil to air.
  - It is not effective for strongly sorbed (e.g., Polychlorinated Biphenyls) and weakly sorbed contaminants.
  - Phytoremediation will likely require a large surface area of land for remediation.[38]

Costs

The key drivers of the cost of deploying phytoremediation technology are the area of contamination and the tree size (maturity). Based on the cost analysis developed in 2006 using the Remedial Action Cost Engineering and Requirements software published by the FRTR, it is estimated that the cost of remediating a small site would be around US$5.40 per cubic meter for an easy site to US$6.00 per cubic meter for a difficult site. Phytoremediation of a large site would cost about US$1.60 per cubic meter for an easy site and up to US$2.30 per cubic meter for a difficult site.

4.3.3 SOIL WASHING

Soil Washing is described by the FRTR as follows:

> Soil washing is a water-based process for scrubbing soils ex situ to remove contaminants. **The process removes contaminants from soils in one of the following two ways:**
>
> - By dissolving or suspending them in the wash solution (which can be sustained by chemical manipulation of pH for a period of time); or
> - By concentrating them into a smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing (similar to those techniques used in sand and gravel operations).
>
> Soil washing systems incorporating most of the removal techniques offer the greatest promise for application to soils contaminated with a wide variety of heavy metal, radionuclides, and organic contaminants.
>
> The concept of reducing soil contamination through the use of particle size separation is based on the finding that most organic and inorganic contaminants tend to bind, either chemically or physically, to clay, silt, and organic soil particles. The silt and clay, in turn, are attached to sand and gravel particles by physical processes, primarily compaction and adhesion. Washing processes that separate the fine (small) clay and silt particles from the coarser sand and gravel soil particles effectively separate and concentrate the contaminants into a smaller volume of soil that can be further treated or disposed of. Gravity separation is effective for removing high or low specific gravity particles such as heavy metal-containing compounds (lead, radium oxide, etc.). Attrition scrubbing removes adherent contaminant films from coarser particles. However, attrition washing can increase the fines in soils processed. The clean, larger fraction can be returned to the site for continued use. The contaminated water generated from soil washing are treated with the technology(s) suitable for the contaminants.[39]

38 https://www.frtr.gov/matrix/Excavation-and-Off-Site-Disposal.
39 https://www.frtr.gov/matrix2/section4/4-19.html.

Advantages

- Its ability to target various contaminant groups (such as VOCs, fuels, and Heavy Metals).
- According to the FRTR, the technology offers the ability to recover metals and can clean a wide range of organic and inorganic contaminants from coarse-grained soils.[40]

Disadvantages

- According to the FRTR, factors that may limit the applicability and effectiveness of the process include:
  - Complex waste mixtures (e.g., metals with organics) make formulating washing fluid difficult.
  - High humic content in soil may require pretreatment.
  - The aqueous stream will require treatment at demobilization.
  - Additional treatment steps may be required to address hazardous levels of washing solvent remaining in the treated residuals.[41]

Costs

Soil quantity and treatment speed are the key drivers in adopting this technology. Based on the cost analysis developed in 2006 using the Remedial Action Cost Engineering and Requirements software published by the FRTR, it is estimated that, through soil washing technology, the cost of remediating a small site would be around US$187 per cubic meter and a large site would be about US$70 per cubic meter.

4.3.4 ELECTROKINETIC SEPARATION

The Electrokinetic Separation process removes metals and organic contaminants from low permeability soil, mud, sludge, and marine dredging. It uses electrochemical and electrokinetic processes to desorb, and then remove, metals, and polar organics. This *in situ* soil processing technology is primarily a separation and removal technique for extracting contaminants from soils.

The FRTR provides the following description of Electrokinetic Separation:

> The principle of Electrokinetic Remediation (ER) relies upon application of a low-intensity direct current through the soil between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move towards the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move towards the cathode. Anions such as chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move towards the anode. The current creates an acid front at the anode and a base front at the cathode. This generation of acidic condition *in situ* may help to mobilize sorbed metal contaminants for transport to the collection system at the cathode.
>
> The two primary mechanisms transport contaminants through the soil towards one or the other electrodes: electromigration and electroosmosis. In electromigration, charged particles are transported through the substrate. In contrast, electroosmosis is the movement of a liquid containing ions relative to a stationary charged surface. Of the two, electromigration is the main mechanism for the ER process. The direction and rate of movement of an ionic species will depend on its charge, both in magnitude and polarity, as well as the magnitude of the electroosmosis-induced flow velocity. Non-ionic species, both inorganic and organic, will also be transported along with the electroosmosis induced water flow.[42]

Advantages

- Being an *in situ* technology avoids the efforts and costs related to the excavation and transportation of contaminated soil.
- The ability to treat a wide range of contaminant concentration levels in soil.
- Efficacy in treating soil with low permeability, which is difficult to treat with many other *in situ* technologies.

40 https://www.frtr.gov/matrix2/section4/4-19.html.
41 https://www.frtr.gov/matrix2/section4/4-19.html.
42 https://www.frtr.gov/matrix2/section4/4-4.html.

Disadvantages

- According to the FRTR:
  - Effectiveness is sharply reduced for wastes with a moisture content of less than 10 percent. Maximum effectiveness occurs if the moisture content is between 14 and 18 percent.
  - The presence of buried metallic or insulating material can induce variability in the electrical conductivity of the soil, therefore, the natural geologic spatial variability should be delineated. Additionally, deposits that exhibit very high electrical conductivity, such as ore deposits, cause the technique to be inefficient.
  - Inert electrodes, such as carbon, graphite, or platinum, must be used so that no residue will be introduced into the treated soil mass. Metallic electrodes may dissolve as a result of electrolysis and introduce corrosive products into the soil mass.
  - Electrokinetics is most effective in clays because of the negative surface charge of clay particles. However, the surface charge of the clay is altered by both charges in the pH of the pore fluid and the adsorption of contaminants. Extreme pH at the electrodes and reduction-oxidation changes induced by the process electrode reactions may inhibit ER's effectiveness, although acidic conditions (i.e., low pH) may help to remove metals.
  - Oxidation/reduction reactions can form undesirable products (e.g., chlorine gas).[43]

Costs

As per the analysis done by the FRTR:

> Costs will vary with the amount of soil to be treated, the conductivity of the soil, the type of contaminant, the spacing of electrodes, and the type of process design employed. Ongoing pilot-scale studies using "real-world" soils indicate that the energy expenditures in extraction of metals from soils may be 500 kilowatt hours/m^3 or more at electrode spacing of 1.0 m to 1.5 m. Direct costs estimates of about US$15/$m^3$ for a suggested energy expenditure of US$0.03 per kilowatt hours, together with the cost of enhancement, could result in direct costs of US$50/$m^3$ or more. A recent study estimated full scale costs at US$117/$m^3$. If no other efficient in situ technology is available to remediate fine-grained and heterogeneous subsurface deposits contaminated with metals, this technique would remain potentially competitive.[44]

4.3.5 SOIL VAPOR EXTRACTION

Soil vapor extraction is a remediation technology that extracts vapors from the soil above the water table by applying a vacuum to pull the vapors out. The technology involves drilling one or more extraction wells into the contaminated soil to a depth above the water table, which must be deeper than three feet below the ground surface. Attached to the wells is equipment (such as a blower or vacuum pump) that creates a vacuum. The vacuum pulls air and vapor through the soil and up the well to the ground surface for treatment.

The basis of Soil Vapor Extraction can also be understood as follows:

> The technology is based on mass transfer of contaminant from the solid (sorbed) and liquid (aqueous or non-aqueous) phases into the gas phase, followed by collection and extraction of the contaminated soil gas. Extracted contaminant mass in the gas phase (and any condensed liquid phase) is then treated in above ground systems. The technology is most effective for contaminants with higher Henry's Law constants, including a range of chlorinated solvents and petroleum hydrocarbons. It is not effective for remediating heavy metal impacted sites. The technology is a well-demonstrated, mature remediation technology that has been identified by the US EPA as a presumptive remedy.[45]

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43 https://www.frtr.gov/matrix2/section4/4-4.html.
44 https://www.frtr.gov/matrix2/section4/4-4.html.

Advantages

- As an *in situ* technology, it avoids the effort and costs related to the excavation and transportation of contaminated soil.
- Very effective in removing volatile contaminants, such as Petroleum Hydrocarbons
- Relatively simple and well established.

Disadvantages

- Requires a secondary process (for example, granular activated carbon) to treat the volatile contaminants extracted from the subsurface in the vapor phase.
- Effectiveness diminishes over time as readily extracted contaminant mass is removed.
- At decreased contaminant levels, mass transfer limitations begin to control the recovery of remaining contaminant mass.

Costs

The key drivers of soil vapor extraction cost are quantity of soil to be treated and the speed of treatment. The cost can be radically different if no airflow treatment is required at a site. Based on the cost analysis developed in 2006 using the Remedial Action Cost Engineering and Requirements software published by the FRTR, it is estimated that the cost of remediating a small site would be around US$1,275 per cubic meter for an easy site to US$1,485 per cubic meter for a difficult site. A large site would cost about US$405 per cubic meter for an easy site and US$975 per cubic meter for a difficult site.[46]

4.3.6 LANDFARMING

The process and aftermath of Landfarming can be laid out as follows:

Landfarming is a well proven ex-situ bioremediation technology that has been successfully used since the 1980s for treating petroleum impacted soils/sediments, drill cuttings, low brine drilling fluids, oily sludges, tank bottoms and pit sludges. The material to be treated is incorporated into surface soil. Naturally occurring microbes in the soil and waste material transform the organic contaminants to carbon dioxide, water and biomass. Maintaining optimum soil conditions for rapid biodegradation of organic contaminants can help meet clean-up goals within a reasonable timeframe.

During landfarming, the waste materials are typically placed as a layer on the ground surface with variable thickness. The waste is then tilled and amended with nutrients to enhance biodegradation by naturally occurring bacteria. Fertilizers such as urea and triple superphosphate are used to provide nitrogen and phosphate necessary for biodegradation. Reduction in hydrocarbon concentrations can be expected within a span of weeks to months, depending on the initial concentration and composition of hydrocarbons, and whether the soil conditions are optimized for biodegradation. Once clean-up goals have been achieved, the treated material can be i) re-used in construction activity such as berms, landfill cover, backfill, re-grading, or for agricultural purposes, ii) disposed at a landfill and/or iii) left in place and revegetated, depending on local regulations or site-specific considerations.[47]

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45 https://www.enviro.wiki/index.php?title=Soil_Vapor_Extraction_(SVE).
46 https://www.frtr.gov/matrix2/section4/4-7.html.
47 https://www.enviro.wiki/index.php?title=Landfarming.

Advantages

- The FRTR describes landfarming as a low-cost technology, adding that "facilities are simple to construct and easy to operate. Standard construction and farming equipment can be used to move soils to the land treatment facility, to amend the soils with fertilizer, to apply water to the soils and to till the soils (e.g., excavator, plough, rotovator, water truck)".[48]

Disadvantages

- The limitations of landfarming are as follows:
  - It requires a large land area for treatment.
  - There may be regulatory limitations on wastes that can be treated by landfarming. For example, U.S. regulations prevent landfarming soil impacted with hazardous wastes such as motor oil, hydraulic oil, and solvents.
  - It may not be effective for highly impacted soils or soils impacted with severely degraded hydrocarbons (e.g., if soils contain >8% w/w petroleum hydrocarbons after spreading).
  - Although landfarming is effective for reducing hydrocarbon concentrations, it is not effective for reducing concentrations of other oil field waste components, such as elevated concentrations of metals, salt or wastes containing naturally occurring radioactive materials...
  - Concentration reductions >95% or final concentrations <0.1% may not be successfully obtained based on the extent impacted and nature of the hydrocarbons.
  - Dust and vapor emissions may pose air quality concerns.[49]

Costs

Costs for landfarming are typically below US$100 per cubic meter of soil to be remediated.[50]

4.3.7 NATURAL SOURCE ZONE DEPLETION

Natural Source Zone Depletion (NSZD) is a term used to describe "the collective, naturally occurring processes of dissolution, volatilization, and biodegradation that result in mass losses of light non-aqueous phase liquid (LNAPL) petroleum hydrocarbon constituents from the subsurface".[51] **The passage below explains why NSZD is gaining traction as an option for remediating petroleum hydrocarbon sites:**

> [With NSZD,] much higher source attenuation rates are now being measured compared to previous rates based on incomplete conceptual models. NSZD processes occur at most petroleum release sites and quantifying NSZD rates is an important part of an overall site remediation strategy.
>
> After a release into the environment, petroleum hydrocarbon constituents in LNAPL undergo various different degradation processes including dissolution, volatilization, and biodegradation. NSZD processes occur naturally within LNAPL-impacted zones in the subsurface. These processes physically degrade the LNAPL by mass transfer of chemical components to the aqueous and gaseous phases where they are biologically broken down via anaerobic and aerobic biodegradation. Traditional methods of NSZD monitoring have focused on the groundwater transport of the solubilized LNAPL constituents and aqueous phase biodegradation that occurs through various terminal electron acceptor processes. Aerobic respiration, denitrification, sulfate reduction, iron and manganese reduction, and methanogenesis each support hydrocarbon degradation as the supply of each electron acceptor (e.g., dissolved oxygen, nitrate, sulfate), oxidation-reduction state, and the microbiological conditions allow. These processes manifest themselves as decreases in dissolved electron acceptor concentrations and production of soluble by-products such as ferrous iron, dissolved methane, and carbon dioxide. Through stoichiometric conversion of the mass of electron acceptor loss and by-product formation, the soluble or aqueous contribution to NSZD can be estimated.[52]

48 https://www.enviro.wiki/index.php?title=Landfarming.
49 https://www.enviro.wiki/index.php?title=Landfarming.
50 https://www.frtr.gov/matrix2/section4/4_13a.html.
51 https://www.enviro.wiki/index.php?title=Natural_Source_Zone_Depletion_(NSZD).
52 https://www.enviro.wiki/index.php?title=Natural_Source_Zone_Depletion_(NSZD).

Advantages

- NSZD is a low-cost technology because it uses naturally occurring processes to treat contaminants.
- Little or no engineering effort is required.

Disadvantages

- NSZD is used for petroleum hydrocarbon but does not work for heavy metals.
- Sophisticated monitoring is required to estimate the NSZD rate before it can be demonstrated as an effective remediation technology at any specific site.
- Other previously established limitations include:
  - NSZD occurs at most petroleum release sites. However, site-specific conditions will drive the magnitude of rates.
  - NSZD rates measured using the methods described above quantify total hydrocarbon mass loss and do not speciate loss or degradation rates of individual chemicals such as benzene or naphthalene from soil or LNAPL phases.
  - NSZD can fluctuate seasonally with change in ambient temperature which may induce cold/warm temperature cycles in the subsurface and also fluctuate with changes in surrounding water use.[53]

Costs

NSZD is a relatively low-cost technology. It is assumed that a detailed Conceptual Site Model is available and, therefore, the nature and extent of contamination, hydrogeology, lithology, and other site-specific conditions are relatively well understood. Similar to monitored natural attenuation, primary costs are associated with sampling and analyses.

4.4 Factors influencing technology selection and applications

Various successful technologies are available for contaminated site remediation. These technologies have different mechanisms for treating contaminants and each has its own strengths and limitations. However, there is no "silver bullet" in contaminated site remediation. No single technology can be applied to all contaminated sites due to the complex nature of contamination and site conditions. Instead, a site-specific feasibility study should be conducted to evaluate and select the most appropriate remediation technology for a particular site. **This feasibility study should consider the following key factors that may influence technology selection and applications:**

- The characteristics of contamination
- Distribution of contaminants
- Property of the impacted media.

The characteristics of contamination

When selecting remediation technologies, the first consideration is the type and properties of contaminants identified at a site. **The contaminants can be generally separated into four groups:**

- Metals and metalloids, organometallic pesticides, and herbicides
- VOCs such as Petroleum Hydrocarbons, chlorinated VOCs, Benzene, Toluene, Ethylbenzene, Xylene, and other non-halogenated VOCs
- SVOCs, such as Polychlorinated Biphenyl, Polycyclic Aromatic Hydrocarbons, organic pesticides and herbicides
- Other compounds, such as Asbestos and non-metallic inorganics. Each of these contaminants have their own property that should be considered during remedial selection.

For example, when applied properly, Soil Vapour Extraction and Thermal Desorption Technologies are highly effective for treating VOCs-impacted soil. These technologies are less effective for removing SVOCs (due to lower vapor pressure) or metals.

53 https://www.enviro.wiki/index.php?title=Natural_Source_Zone_Depletion_(NSZD).

Distribution of contaminants

The spatial and horizontal distribution of contaminants, contaminant concentrations, and identification of source zone and plume can play an important role in selecting a remediation technology that is most likely to be successfully applied. For instance, some technologies, such as thermal desorption, are more suitable for treating high contaminant source zones where much of the contaminant mass resides. By contrast, thermal desorption is less efficient at treating low-level contaminant plumes due to the high operation and maintenance costs.

Property of the impacted media

The physical properties of the soil in which contaminants are present, and through which they may be moving, should be considered during technology selection. Examples of these properties include soil type, dry bulk density, permeability, hydraulic conductivity, the organic carbon content, porosity, field descriptions from boring logs, heterogeneities within the soil column, the existence of a smear zone, and the depth to groundwater and/or bedrock. Many in situ technologies rely on injecting remedial agents (either oxidants or reductants) to the subsurface to mix with contaminants or contaminant-affected media, which would prove challenging for soil formations that have low permeability, such as clay or silt.

4.5 Criteria for remediation technology selection

The US EPA has developed nine criteria for evaluating remedial alternatives that ensure the inclusion of all key factors in selecting a suitable remediation technology and during the feasibility study stage. The criteria stem from both the statutory requirements of environmental laws and the technical and policy considerations that have demonstrated importance in selecting remediation technologies. The MoE may wish to consider adopting or developing similar criteria for determining appropriate remediation technologies.

The nine evaluation criteria can be categorized into three groups based on their significance: threshold criteria, primary balancing criteria, and modifying criteria (see detailed discussion below).

Threshold criteria

The first step in selecting a remediation technology is to identify the alternatives that satisfy the threshold criteria. To be eligible for selection, an alternative that does not justify a waiver must provide adequate protection to human health and the environment and comply with Applicable or Relevant and Appropriate Requirements (ARARs). Ineligible options should not be evaluated further. **Threshold criteria are typically as follows:**

- **Overall protection of human health and the environment:** This addresses whether a remedy will provide adequate protection and how the risks posed through each exposure pathway (assuming a reasonable maximum exposure) will be eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls.
- **Assessment of compliance:** This determines whether a remedy will fulfil the ARARs of various levels of environmental laws, or whether a waiver can be justified. Examples of ARARs include air-discharge-permit requirements and wastewater-discharge permit requirements.

Primary balancing criteria

The second step assesses the trade-offs between protective and ARAR-compliant alternatives by focusing on the five primary balancing criteria and, if known, the modifying criteria. **The five primary balancing criteria are:**

- Long-term effectiveness and permanence.
- Reduction in toxicity, mobility, or volume achieved through treatment.
- Short-term effectiveness.
- Implementability.
- Cost.

These five primary balancing criteria are used to identify the major trade-offs between remedial alternatives, which are ultimately balanced to identify the preferable alternative and select the final remedy. The sequence in which the criteria are generally considered, and pertinent considerations related to each, is as follows:

1. **Long-term effectiveness and permanence** refer to the ability of a remedy reliably protect human health and the environment over time once clean-up goals have been met. During remedy selection, this criterion is crucial for determining the extent to which performance and treatment are practicable. This factor is often determined by the types of residuals that will remain on site per alternative.

2. **Reduction of toxicity, mobility, or volume through treatment** refers to the anticipated performance of the treatment technologies that a remedy may employ. This criterion is also crucial in determining the extent to which performance and treatment of a remedy are practicable. Remedies that address the most threatening materials at a site are preferred over those that do not. Treatment should generally achieve reductions of 90 to 99 percent in the concentrations or mobility of individual contaminants of concern. There will, however, be situations where reductions outside the 90 to 99 percent range will be appropriate to achieve site-specific remediation goals.

3. **Short-term effectiveness** addresses the time required to achieve protection of human health and the environment, as well as any threats that may arise during the construction and implementation period until clean-up goals are met. Many potential adverse impacts can be avoided by incorporating mitigative steps into the remedial alternative. Poor short-term effectiveness may lead to an alternative being rejected on the basis of being unprotective if adverse impacts cannot be adequately mitigated.

4. **Implementability** refers to the technical and administrative feasibility of a remedy, including the availability of materials and services needed to implement a particular option. This criterion is important in the context of Iraq as some remediation materials or equipment may not be readily available. It is also a key factor in evaluating remedies at sites with highly heterogeneous wastes or media that could make the performance of some technologies highly uncertain. Lastly, implementability is also crucial when evaluating technologies with lower scientific backing and remedies that are dependent on a limited supply of equipment, experts, or facilities such as permitted hazardous waste disposal facilities.

5. **Cost** includes estimated capital costs, operation and maintenance costs, and the net present value of capital. Cost plays a significant role in selecting between options that appear to be comparable in criteria (such as long-term effectiveness and permanence) or when choosing between treatment technologies that provide similar performance. Cost generally will not be used to determine whether or not principal threats will be treated except under special circumstances that make treatment impracticable. Cost is generally not being used to select a remedy that is not protective.

Modifying criteria

These criteria may not be considered fully until after the former public comment period of the proposed remedial plan although the US EPA works with the State and community throughout the project.

- **State acceptance** refers to the support agency's comments where a state/local or federal/national agency is the lead agency. The US EPA's (the national agency's) acceptance of the selected remedy is also required to meet this criterion, while doing so, the state agency's views on compliance with ARARs shall also be considered.
- **Community acceptance** refers to the public's general response to the remedial alternatives that were selected in the proposed plan.

Summary

Once the relative performance of the protective and ARAR-compliant remedial alternatives under each criterion has been established, the preferred alternatives are chosen by identifying which are cost-effective and use permanent solutions that provide treatment to the maximum extent practicable. Cost-effectiveness is determined by comparing the alternatives' costs with their overall effectiveness. Overall effectiveness, for the purpose of this determination, includes long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; and short-term effectiveness. It is possible that more than one alternative can be cost-effective.

By balancing the trade-offs between the remedial alternatives with respect to the balancing criteria (and, if known, the modifying criteria), a decisionmaker can make a risk-management decision to determine which cost-effective alternatives use permanent solutions and treatment to the maximum extent practicable. As a general rule, the criteria that varies the most between alternatives will also be the most decisive factors in the balancing. Ultimately, the preferred alternative will provide the best balance of trade-offs as considered in light of the statutory mandates, preferences, and expectations.

4.6 Conclusion

Reviewing the above four critical elements of remediation technologies underscores the importance of remediation approaches, the range of available technologies, factors that influence the selection of technologies, and the established selection criteria. Evaluating these elements and consulting stakeholders will be crucial in the development of remediation programs in Iraq.

5 Roadmap for Contaminated Sites Management

5.1 Need for a national program

Analysis of environmental hotspots (contaminated sites) in seven conflict affected governorates of Iraq indicates significant hydrocarbon and chemical contamination in the country. With the support through this ASA, MoE screened 216 sites and identified 76 'suspected hotspots.' Initial assessment of 69 of these hotspots spread over 47 locations, estimated that about 1333.03 ha of land is likely to have been contaminated affecting an estimated 55,050 people directly and over 1.70 million people indirectly. Environmental analysis of the soil and water at these sites further identified that the contamination levels exceeded 100 times the DIV in 32 sites and, 50 times the DIV in 7 sites and 10 times the DIV in the remaining 30 sites. Land use analysis around these sites through satellite imagery further indicated that over 1,569 ha of agriculture land, about 3,018.38 ha of vegetation, about 8.482 structures and 20 industrial units are impacted due to the damages and contamination at these hotspots. Among these nine major industries are completely damaged and are currently not in operation. A preliminary and conservative estimate of HEAL impacts (burden of disease, lost industrial productivity, lost agriculture yield and industrial and agriculture jobs lost) indicates that about US$1.44 billion dollars is lost every year due to contamination of the hotspots.

While this ASA has focused on seven governorates, it is possible that there are additional pollution hotspots in the remaining 12 governorates. Given Iraq's industrial profile, these hotspots may be due to industrial activities rather than conflicts. However, identifying and managing all pollution hotspots, regardless of the underlying cause, is important for the country's post-conflict reconstruction because revitalizing the environment and natural resources is essential for the resilient, sustainable, and enhanced economic advancement of Iraq. Importantly, managing pollution will reduce risks to human health and enable internally displaced people to go back to their lands and return these lands back to a productive state, ultimately lowering the risk of conflict over land and other natural resources.

The Government of Iraq, and the MoE in particular, is responsible for identifying and managing contaminated sites in Iraq. The MoE's capacity is, however, limited, and effectively managing geographically dispersed contaminated sites across large and often hazardous landscapes can be challenging.

The remediation or management of contaminated sites requires a well-developed legal and institutional framework and adequate financial resources. Given these conditions, Iraq would benefit from establishing a National Program on Contaminated Sites Management (NPCSM) to help the MoE to prioritize sites based on quantitative analysis and manage them effectively, so contributing to other benefits such as agriculture productivity, livelihood opportunities, and local economic development.

This section presents a recommended roadmap for developing such a national program and details its key components.

9 UNEP 2005.
10 UNEP 2007.
11 UNEP 2018a.
12 MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.

5.2 Objectives

The overarching objectives of the recommended NPCSM should ideally be to:

- **Eliminate or minimize threat to human health and the environment** caused by the existing or potential discharge of hazardous substances from contaminated sites, so as to contribute to Iraq's post-conflict socioeconomic recovery.
- **Proactively identify and prioritize contaminated sites**, investigate all identified sites and, where contamination exists, remediate the sites by applying sustainable and risk-based land management or another suitable approach that follows international good practices and tailored to Iraq's context.
- **Use post-remediation measures and site restrictions** where contamination cannot be fully removed.
- **Enhance the Government of Iraq's capacity to implement a successful national program** by addressing current gaps in legislation; conducting an economic valuation using quantitative analysis; attracting sustainable sources of adequate financing; ensuring adequate and appropriately skilled personnel; and by ensuring appropriate infrastructure for the MoE and its team.

These objectives should ideally be achieved by applying appropriate international guiding principles.

5.3 Guiding principles

The guiding principles recommended for the recommended NPCSM are sustainable, informed by risk, and based on international good practice in contaminated site management.[54,55] They are:

Principle 1: Protection of human health and the wider environment and maximize socio-economic outcomes

The main aim of NPCSM should be to eliminate unacceptable risks to human health and to protect the wider environment, now and in the future, for the agreed land use with due consideration to the costs, benefits, effectiveness, durability, and technical feasibility of the available options. To ensure this, the decisions on affected sites should be based on quantitative analysis of information to maximize environmental, economic, and social outcomes.

Principle 2: Reliance on sound technical analysis and relevant and accurate data

Decisions on managing contaminated sites should be based on sound technical analysis with clearly explained assumptions and uncertainties related to data and professional judgement. All efforts should be made to carry out necessary studies and assessments ensuring adherence to this principle so that the decisions are based on the best available information and datasets; are justifiable; and are reproducible.

Principle 3: Risk-based decision-making should focus on HEAL impacts and outcomes

All decision on the management or remediation of contaminated sites should be consistent, clear, and based on objective rationale that consider the HEAL impacts of a particular site; the socioeconomic and environmental conditions; and both current and likely future implications. Such sustainable and risk-based remediation solutions maximize the potential benefits achieved given available public resources. Where benefits and impacts are aggregated or traded in such a way that the process is explained, and a clear rationale is provided.

Principle 4: Good governance and stakeholder engagement

Remediation decisions should be made with the active participation of stakeholders through a transparent and inclusive process.

54 World Bank 2019.
55 CL:AIRE 2010.

Principle 5: Safe working practices

Throughout the process of identifying, assessing, and managing or remediating contaminated sites, safe working practices should be followed. Risks to the teams working at contaminated sites and local communities should be avoided and minimized.

Principle 6: Transparent reporting and record-keeping

Remediation decisions, including the assumptions and supporting data used to reach them, should be documented in a clear and easily understood format in order to demonstrate that a sustainable solution has been adopted. Regular updates on the progress of implementing remediation or management measures and the achievement of outcomes shall also be shared, in a transparent manner, with all stakeholders with an opportunity to provide feedback.

5.4 Characteristics of a National Program for Contaminated Sites Management

Once fully implemented, a successful NPCSM would include:[56]

- **An efficient and effective mechanism to report** suspected contaminated sites.
- **A GIS-based national inventory of contaminated sites** that can be updated regularly.
- **Processes are in place to ensure that:**
  - Any new site in the inventory is screened, assessed. and an initial assessment is conducted within one month from the date of identification or receipt of a notification. Where there is high probability that a site poses a significant and immediate threat to human or environmental health, an initial site assessment is completed within one week from notification.
  - Detailed assessment is carried out for sites where initial assessment has identified a high likelihood of an immediate and significant threat to human or environmental health. Interim measures to limit exposure or spread of contamination are also implemented within two weeks of completing the initial assessment.
  - Detailed site investigations (including health and environmental assessments as well as cost of environmental degradation) and remediation for priority contaminated sites are completed within six months of completion of an initial assessment.
  - Remediation of contaminated sites is initiated within 12 months of such site being included in the priority list of sites for remediation.
  - More than 90 percent of remediated sites that are suitable are put to productive reuse within two years of completion of remediation and post remediation measures.
- **Polluters remediate polluted sites and pay for all costs** in more than 50 percent of remediation cases.

5.5 Roadmap for developing a national program

The following roadmap sets out potential steps for the Government of Iraq to follow towards developing a potential NPCSM. The steps are cross-cutting and relate to all four key stages of contaminated site management, namely, identification; planning and prioritization; implementation; and post-remediation monitoring. Interventions are proposed under three key themes, namely, legislation and policy; institutional capacity; and financing. These are followed by additional interventions relating to stakeholder engagement and the implementation of pilot projects.

56 Specific targets mentioned for each indicator are indicative and shall be finalized by the Government of Iraq as part of the overall NPCSM preparation process.

5.5.1 ENHANCING THE LEGAL AND POLICY FRAMEWORK

As discussed earlier, although the Protection and Improvement of the Environment Law 27 of 2009 includes requirements for preventing pollution and includes the "polluter pays" principle, neither this nor any other national legislation explicitly describes requirements or obligations for the management of contaminated sites. Moreover, there is no specific requirement to establish a national register of contaminated sites. The absence of national determinants of contaminated soil also represents a major constraint to the MoE's efforts to identify and manage contaminated sites. This lack of standards and guidelines on contaminated sites complicates efforts to develop a regulatory framework.

The Government of Iraq can draw on several international examples to enhance national legislation for contaminated site management. For example, the United States has a suite of legislations related to this issue, including the Resource Conservation and Recovery Act,[57] which gives the US Environment Protection Agency the authority to manage environmental pollution originating from underground storage tanks. This works in tandem with the Comprehensive Environmental Response, Compensation, and Liability Act (the Superfund Law)[58] to give federal authorities in the United States the power to remediate certain categories of contaminated sites and ensure the cooperation of responsible parties. The Superfund Law also established a National Priorities List, a list of national priority sites with known or threatened releases of hazardous substances, pollutants, or contaminants. This law further created a trust fund (financed by a tax on the chemical and petroleum industries) for the remediation of abandoned or uncontrolled hazardous-waste sites.

Similarly, South Africa has the National Environmental Management: Waste Act,[59] which includes specific, comprehensive "contaminated land provisions" that define contamination and specify requirements for reporting, assessing, and managing of suspected contaminated sites. The act also includes a requirement to establish a national contaminated land register. In parallel, the National Water Act specifies requirements for contaminated water resources.

Recommended actions

1 ***Establish a technical advisory group and a stakeholder platform to support and inform the design, development, and implementation of an NPCSM.***

The first step to comprehensively address the issues of contaminated hotspots is to establish the following:

- **A technical advisory group** comprising relevant government, academic, and internal experts. This group should lead the review and implementation of actions recommended in this roadmap.
- **A stakeholder platform** comprising various CSOs and other national and local stakeholders who are well positioned to contribute to hotspot management efforts.

2 ***Develop a contaminated site management policy (or incorporate relevant considerations into appropriate existing policy).***

This policy will form the foundation of the NPCSM on which all subsequent interventions will be based. It will include, among other things, objectives, targets, roles and responsibilities, and resource requirements.

3 ***Enhance existing provisions or promulgate legislation on contaminated site management.***

Conduct an in-depth review of existing regulations and identify opportunities to enhance or promulgate legislation on contaminated site management. This intervention will form the foundation for future actions aimed at strengthening the national approach to managing contaminated sites and should therefore be considered a high priority. **Legislative enhancements would benefit from the following steps:**

- Establish international benchmarks and identify national legislative gaps.
- Draft new or revised legislation and guidelines.
- Promulgate and implement revised legislation.

57 42 U.S.C. §6901 et seq. (1976) as amended (1986).
58 42 U.S.C. §9601 et seq. (1980).
59 NEMWA. Act 59 of 2008.

Establish international benchmarks and identify national legislative gaps

An international benchmark for best practice should draw on assessments from developed and developing nations. This benchmark will form the basis of a comprehensive gap analysis on Iraq's legislation for contaminated sites and can be used to inform a clear plan to address gaps or introduce enhancements.

At minimum, legislation should include provisions to establish:

- **An NPCSM that covers all categories of contaminated sites**, including orphan sites and those where contamination has resulted from conflict. This NPCSM should include a strategy to minimize risks to human health and the environment in the short term. It should draw on quantitative analysis to establish clear medium- and long-term objectives.
- **An inventory of contaminated sites** and associated minimum requirements and update it on ongoing basis.
- A mechanism for the adequate and sustainable financing of the NPCSM, including orphan sites and those where contamination has resulted from conflict.
- **A national definition for contaminated land, water, and ecosystems**, and associated remediation targets depending on future land and resource use.
- **National technical guidelines** on the approach to contaminated site management and implement them.

Draft new or revised legislation and guidelines

This will involve drafting new legislation and guidelines for contaminated site management or addressing gaps by amending existing legislation. This process will involve extensive consultation with a wide range of stakeholders from the Government of Iraq, the private sector, and others to ensure that revised legislation reflects, to the extent practical, the long-term interests of all.

Preparing clear technical guidance documents will facilitate communication and interpretation of the revised or new legislation and promote uniform implementation.

Promulgate and implement revised legislation

Full implementation of the amended or new legislation is likely to take time. However, appropriate legislation is a key catalyst for realizing the subsequent objectives set out below. Technical guidelines should be made available at the same time that legislation changes are made.

4

Develop national standards and guidelines for remediation.

National standards (screening levels) provide a consistent tool for defining, assessing, and prioritizing contaminated sites.

The following standards and guidelines are recommended:

- A national standard or screening levels for contaminants
- National guidelines for risk assessment.

National standards or screening levels for contaminants

Screening levels are chemical-specific concentrations for individual contaminants (in soil, groundwater, drinking water or other mediums) and are used to decide which sites are "clean" and no further action is required, versus those that require additional investigation and remediation.

In line with international best practice,[60] the national standard should consider the risks the site poses to human health and the environment health, as well as the proposed land use.

60 Refer to approaches employed by the USA EPA, South Africa (National Norms and Standards for the Remediation of Contaminated Land and Soil Quality, 2014), and China (Health & Environmental Risk Assessment approach).

National guidelines for risk assessment

National guidelines for risk assessment seek to embed a risk-based approach to carrying out site assessments, to developing management or remediation plans, and to estimating costs so as to ensure the protection of human health and the environment. Such guidelines allow for a site to be remediated to a level that matches the future intended land use, whether this be industrial, commercial, or high-density residential use.

5.5.2 ENHANCING INSTITUTIONAL CAPACITY AND PLANNING

The absence of a systematic approach to managing contaminated sites and a lack of sufficient trained personnel and technical facilities are key constraints to implementing an NPCSM in Iraq. Although the exact shortfall in capacity is unknown, a larger cohort of trained personnel with appropriate and diverse technical skills will be required at both the national and the governorate level to implement identification, planning, implementation, and post-remediation monitoring. Enhanced legislation for contaminated site management will also likely lead to an increase in the need for personnel to enforce such legislation.

Iraq's existing laboratory facilities are understaffed and lack adequate, fully operational equipment to support efforts to investigate and manage a large number of contaminated sites across the country.[61]

Chain-of-custody and quality assurance are also essential components of managing contaminated sites. Iraq's Central Environmental Laboratory does not yet hold any quality assurance certification (for example ISO 17025). Although private laboratories could be used for analysis of environmental samples, this is unlikely to be cost-effective in the long term.

Recommended actions

1 ***Carry out a comprehensive analysis of national capacity needs.***

The objective of this analysis is to identify gaps between existing human and laboratory resources and the resources that will be required to implement the NPCSM over the short, medium, and long term.

The analysis of human resources should consider the number and geographical distribution of personnel as well as the skills required. The potential for outsourcing certain functions to external service providers and minimum requirements for their accreditation should also be considered.

The analysis of laboratory facilities and equipment could draw on previous assessments but should also reflect the current situation and the NPCSM's specific requirements. Quality assurance at laboratories and relevant certification should also be included in this assessment.

2 ***Develop and implement a clear, time-bound resourcing plan to close gaps in internal capacity.***

This plan should be based on the findings of the above-mentioned capacity needs analysis and is likely to involve a combination of new recruitment and building capacity through training. A detailed budget should be included in the plan.

5.5.3 ALLOCATING BUDGET AND SECURING FINANCING

The total cost of implementing an NPCSM is difficult to estimate because it depends on a wide range of factors including the program's final contours, site-specific factors for remediation, and the overall approach for the management of contaminated sites. However, based on the key elements of the program detailed in this section and the information contained in the hotspots inventory developed by the MoE, implementation it is broadly estimated that the implementation of NPCSM could cost about US$422 million (Table 15).

61 UNEP 2018b.

Table 15: Indicative budget for implementing remediation program

Program component	Estimated cost (US$)
Program development, legal, and technical studies	2,000,000
Site inventory (100 sites). Assessment and plan preparation (75 sites)	10,000,000
Implementation of remediation plan and post-remediation monitoring (50 sites)	400,000,000
Laboratory equipment, GIS, IT, and other infrastructure (lump sum)	3,000,000
Capacity-building and training (lump sum)	2,000,000
Project management and operating costs (US$1 million per year for five years)	5,000,000
Total budget	**422,000,000**

Source: *Estimates by the ASA team.*

The following key assumptions were used in arriving at this cost:

- NPCSM implementation period: five years
- Program development, legal, and technical studies: 10 studies at US$200,000 each (based on cost of studies carried out in the current ASA)
- Inventory, site assessment studies, and health and environmental impact assessments: 100 sites at US$25,000 each (based on the costs incurred on assessments carried out in the current ASA)
- 75 percent of identified hotspot sites (based on the current inventory) would likely require detailed investigation and remedial plan preparation: 75 sites at US$100,000 (ASA team's professional judgement based on similar assessments internationally)
- 50 percent of identified hotspot sites will require remedial action: 50 sites at US$8 million each (broad cost estimate based on technologies reviewed).

The Government of Iraq would need to increase the MoE's budgetary allocation to enable it to implement the NPSCM. Alternatively, external financing may be sought.

National legislation requires polluters in the oil and gas sector to pay for the remediation of contamination resulting from their activities and allows for the establishment of an Environmental Protection Fund. However, the long-term sustainability of this source of funding, as well as its adequacy for implementing a systematic NPCSM, is uncertain. The extent to which these funds can be deployed for the remediation of sites contaminated due to conflict also needs to be evaluated.

The experience of the United States and other countries shows that it is important that sustainable funding mechanisms are established for contaminated site clean-up activities in order to accelerate remediation activities for the most urgent sites.[62] The financing mechanism may include economic incentives and funds. Economic and financial instruments, such as environmental taxes; clean-up subsidies; and loans, guarantees, and market licences can also be considered. In addition, the mechanism for managing these funds needs to address existing challenges, including a lack of understanding amongst officials of the costs of contaminated site management, and governance of the fund.

Experience in Europe and the United States also shows that the private sector could play a role in remediating and reactivating the nine destroyed industrial units (the "brownfield remediation" model). This approach would provide the twin benefits of addressing site contamination and contributing to the economy by way of industrial rejuvenation. As noted in Section 2.4 of this report, reactivating the four damaged industrial units (where it was possible to estimate) could contribute about US$1.17 billion per year to the economy. This is a strong factor for exploring the participation of the private sector in the remediation of contaminated sites.

62 The US government established a Superfund program that is funded through a combination of appropriations from the US Congress and a tax on certain industries, including the chemical, petroleum, and manufacturing sectors. The tax is used to create a trust fund, known as the Superfund Trust, which is used to pay for the cleanup of hazardous waste sites that are not covered by responsible parties.

Recommended actions

1 ***Review existing funding and benchmarking.***

The adequacy of existing national funding mechanisms for contaminated site management should be reviewed to confirm adequacy and identify gaps relating to implementing an NPCSM. **This review should consider:**

- The expected value of the fund over time versus the predicted costs of the NPCSM
- The long-term sustainability of existing revenue streams of the fund
- The governance of the fund
- Permitted activities supported by the fund
- The effectiveness of the "Polluter Pays" Principle
- Alternative options to increase the size and reliability of the Fund
- The potential role of the private sector in remediation activities and reactivating the destroyed industrial units.

This review should draw on experiences from other countries and benchmark in the context of Iraq.

2 ***Implement a revised funding strategy.***

Based on the outcome of the review process, the next step is to develop and implement a clear plan to address gaps and shortcomings in the existing funding strategy for contaminated sites management. This intervention may require revision of existing legislation or introduction of new legislation.

5.5.4 STAKEHOLDER CONSULTATIONS

Stakeholder consultations are critical for ensuring that knowledge and information is not missed, for providing engagement and transparency, for supporting the development of policy, regulations, and guidance, and for developing sectoral awareness and know-how.

Transparent regulatory procedures underpin the effective prioritization of resources while optimizing the mitigation of harm and delivery of wider value. Monitoring and reporting on environmental policy effectiveness will allow the government to manage and refine the guiding principles suggested in section 5.3 over the implementation period based on performance.[63]

Internationally, the principle of stakeholder consultation is generally embedded within environmental legislation and features prominently in the areas of Environmental and Social Impact Assessment. These assessments are typically conducted prior to government approval for projects that could have negative socioeconomic or environmental impacts. Stakeholders, including the general public, are normally informed of the assessment in the early stages and are offered an opportunity to review draft reports and mitigation plans in order to maximize the likelihood that any decisions by authorities regarding a proposed development project considers the interests of a broad range of stakeholder groups.

Similarly, engagement with stakeholders should be an important element of sustainable contaminated site management where sharing information can help with the development of targeted legislation, the identification and prioritization of contaminated sites, establishing remediation targets, and so on. Sharing of information can also be important to protect communities from harm until such time as contaminated sites can be remediated.

This may be particularly relevant where contaminated sites are still in active use (for example at industrial facilities), close to residential areas, or where communities are currently using contaminated resources (for example, contaminated water). As discussed, a key question is the extent to which the public will have access to information on contaminated sites. The international trend is to exercise a high level of transparency, which involves sharing information on contaminated sites through various public communication channels.

The United States' Superfund program encompasses extensive stakeholder engagement. Stakeholders, including communities, are proactively encouraged and supported in participating in all steps of the program. The goal of Superfund community involvement is to advocate and strengthen early and meaningful community participation during clean-up projects, and the public is involved in reporting suspected contaminated sites, preliminary site assessments, and reviewing proposed plans for remediation of specific sites.[64] Several mechanisms have been established specifically to aid meaningful involvement by the public including establishment of a Technical Assistance Services for Communities, which aims to assist communities to interpret information about sites. The US EPA also develops a Community Involvement Plan once a contaminated site has been added to the National Priorities List and must also maintain a publicly available repository of information. Similar approach may also be considered by GoI, as part of NPCSM Consultation with stakeholders was initiated as part of the initial site assessment carried out by the MoE. Although relatively limited, this served to demonstrate a collaborative, inclusive, and transparent approach to managing contaminated sites in the country. At this time, however, there is no regulation or framework outlining the nature of future stakeholder consultations within the context of contaminated site management in Iraq.

63 World Bank 2019.
64 https://www.epa.gov/superfund/superfund-community-involvement.

Recommended actions

1 ***Develop a national framework for stakeholder engagement.***

The objective of a national framework would be to ensure that an inclusive, transparent, and consistent approach is applied to all elements of the NPCSM. In addition to the approach adopted by the Superfund program (see above), the MoE and other relevant parties could draw on approaches employed in other countries to develop a framework that is effective in terms of information-sharing and gathering while not being overly bureaucratic and resource-intensive. To the extent practical, the framework could align with existing national requirements for stakeholder consultations. **The framework should include requirements and guidance on at least the following topics:**

- **The objectives of stakeholder engagement** within the context of the NPCSM
- **The requirements for stakeholder mapping** at different levels (national, regional, site, and so on) and different elements of the NPCSM (in other words, site prioritization, site-specific remediation strategies, and so on).
- **Minimum requirements for sharing information**, for example, the key steps of consultation, the type of information shared, stakeholder notification, the modes of communication, timing, review period feedback, and so on.
- **Reporting requirements**, for example, annual reporting on NPCSM progress.

5.5.5 PREPARING THE NPCSM AND DEMONSTRATION REMEDIATION PROJECTS

The policy, regulatory, institutional, and technical actions identified in the sections above for the establishment of an NPCSM would require a number of preparatory studies, technical inputs, and financial allocation by the Government of Iraq. Completing these actions and implementing the NPCSM would take a long time. In addition, many of these studies and assessments would require support from international agencies and experts.

Considering this, and as a first step to develop NPCSM, it is recommended that a project that aims to carry out all critical studies required for the NPCSM and implement demonstration projects at priority sites is initiated. The objective of the project would be to prepare the NPCSM based on inputs from preparatory studies and actions recommended in 5.5.1 to 5.5.4 above and experience from demonstration projects. The following components may be considered for such a project.

Component 1

Technical and regulatory studies and the development of an NPCSM.

Component 2

Laboratory and technical capacity-building of the MoE.

Component 3

Detailed assessment and remediation plans for very high-risk hotpot sites.

Component 4

Implementation of Remediation Plans in two or three very high risk hotspots sites

The advantage of such a project would be that it would allow for remediation plans to be implemented in a selection of high-priority hotspots while a long-term NPCSM is being prepared. In addition to the project will demonstrate pro-activity on behalf of the Government of Iraq and provides specific technical inputs for the development of NPCSM.

Since Iraq has limited experience in implementing remediation projects, information on the costs of, carrying out detailed assessment studies, remediation plan preparation studies (including Health and Environmental Impact Assessment), and implementing various technologies is unknown. In addition, intervention values for soil and other technical standards are not available in Iraq. Considering these factors, the detailed assessments (Component 3) and proposed demonstration projects (Component 4) suggested in the project above will provide valuable inputs to the preparation of NPCSM.

The project would also build Iraq's capacity to remediate and manage contaminated sites through a learning-by-doing approach. The demonstration remediation projects would enable various government agencies, and possibly academia, the opportunity to adopt or apply new guidelines or regulatory processes on actual remediation projects while practitioners can adopt and apply investigation and remediation tools and technologies at contaminated site, therefore enhancing in-country capacity regarding contaminated site remediation and management. The demonstration remediation projects can also help identify any problems or challenges that need to be addressed before a regulatory process or technology can be implemented on a large scale. This can help ensure that any issues are identified and addressed early on, which can save time and resources in the long run.

Demonstration remediation projects can also provide a safe and controlled environment in which to test new processes and approaches. This can help identify the strengths and weaknesses of different approaches and can inform decision-making about which approaches are most likely to be successful in the long term. The project would also help increase public understanding and awareness of contaminated site management processes, procedures, and remediation technologies, and can build support for their implementation.

5.6 Conclusion

Based on the analysis of hotspots, their potential to cause health and environmental impacts, and a review of legal, institutional, and technological aspects related to contaminated sites, the ASA recommends establishing a National Program on Contaminated Sites Management (NPCSM).

In the initial phase, the NPCSM is recommended for five years at an estimated cost of US$ 422 million. A roadmap comprising specific actions for policy, regulatory, institutional, and demonstration remediation projects is proposed. The actions recommended in the roadmap include developing a contaminated site management policy; promulgating legislation on contaminated sites; establishing standards for remediation; establishing an institutional mechanism supported by capacity-building measures; identifying financing mechanisms; and ensuring the participation of all government and community stakeholders in the NPCM.

A project to implement the actions recommended for the development of an NPCSM, along with demonstration remediation projects, has also been recommended. Implementation of the project and roadmap actions will help better manage contaminated sites in Iraq.

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Appendixes

Appendix A: General profile of pollution hotspots in Iraq

***Table A1:** General profile of pollution hotspots in Iraq*

Site number	Site description	Area (ha)		Population		Land use	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
Baghdad (6 sites)							
1	Lead Extraction Factory (08)	3.20	12.56	230	1,500	Industrial	Agricultural
2	Ibn Sina Company (01)	3.14	12.56	200	1,500	Industrial	Residential
3	Bader Company (02)	10.00	12.56	4,000	30,000	Industrial	Residential
4	That-Alsawary Company (03)	0.30	3.14	1,000	7,000	Industrial	Agricultural and village
5	Ibn Al-Waleed (04)	1.00	3.14	500	3,500	Industrial	Agricultural and village
6	Al-Harith Factory (06)	10.00	12.56	5,000	35,000	Industrial	Agricultural and village
	Subtotal	**27.64**	**56.52**	**10,930**	**78,500**	**Industrial**	
Ninevah (17 sites)							
7	Al-Qayyarah 1/2	1.70	3.14	15,000	100,000	Industrial	Agricultural and village
8	Al-Qayyarah 3	4.00	12.56	2,000	15,000	Industrial	Agricultural and village
9	Al-Qayyarah 4	0.30	0.80	250		Industrial	Agricultural and village
10	Al-Qayyarah 5	8.70	12.56	50		Industrial	Agricultural and village
11	Al-Qayyarah 17/18	0.30	3.14	50		Industrial	Agricultural and village
12	Ein Zalah Station (6/7/8/9)	1.20	3.14	20	500	Industrial	Agricultural and village
13	Alkask Refinery (10)	0.40	3.14	1,500	10,000	Industrial	Agricultural and village
14	Ninevah 11	0.60	3.14	100	1,000	Industrial	Agricultural and village
15	Alhukama Pharmaceuticals (12)	2.50	12.56	300	5,000	Industrial	Agriculture
16	Ninevah Pharmaceuticals (14)	250.00	12.56	5,000	35,000	Industrial	Agricultural and village
17	Ninevah 15	4.00	12.56	300	5,000	Industrial	Residential
18	Al Kindy General Company (16)	1.50	3.14	1,000	10,000	Industrial	Agricultural and village
	Subtotal	**275.20**	**82.44**	**25,570**	**181,500**		

Table A1: *General profile of pollution hotspots in Iraq (continued)*

Site number	Site description	Area (ha)		Population		Land use	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
Babil (1 site)							
19	Al Furat Company (01)	6.20	12.56	1,080	10,000	Industrial	Residential and agricultural
Diyala (1 site)							
20	Diyala Electricals (01)	0.30	3.14	1,200	10,000	Industrial	Residential
Al Anbar (5 sites)							
21	General Phosphate Company (01)	500.00	12.56	2,250	15,000	Industrial	Residential
22	Alamer Factory (03)	0.30	3.14	400	30,000	Industrial	Residential
23	Haditha Oil Refinery (04)	0.50	3.14	1,000	10,000	Industrial	Residential
24	Al Anbar Pesticides (05)	0.30	3.14	60	4,000	Industrial	Residential
25	Al Shahid Company (06)	0.56	3.14	550	30,000	Industrial	Residential
	Subtotal	**501.66**	**25.12**	**4,260**	**89,000**		
Kirkuk (24 sites)							
26	Sarolo Station 1	0.30	3.14	30	2,000	Industrial	Residential
27	Sarolo Station 2	0.25	3.14	30	2,000	Industrial	Residential
28	Sarolo Station 3	1.00	3.14	50	4,000	Industrial	Residential
29	Dawood Station- Kir 6	0.30	12.56	410	3,000	Industrial	Residential and agricultural
30	Bay Hassan Station - Kir7,8,9,10,12,13	12.00	12.56	420	3,000	Industrial	Residential
31	Baba Gurgur Station (14/19)	8.00	12.56	260	1,500	Industrial	Residential and agricultural
32	Bai Hassan Oilfield (15/17/23)	0.30	3.14	110	1,000	Industrial	Residential and agricultural
33	Serbsach (16)	0.25	3.14	20	200	Industrial	Staff and residential
34	Haljira Isolation station (18/20)	0.30	3.14	19	200	Industrial	Staff and residential
35	H-Showraw Station (24)	1.50	3.14	200	1,500	Industrial	Staff and residential
36	Hawija Pesticides (25)	0.30	3.14	31	500	Industrial	Staff and residential
37	Mulla Abdulla Station (26)	0.25	3.14	320	2,000	Industrial	Staff and residential
38	Qutan Gas Isolation (28)	0.40	12.56	500	4,000	Industrial	Staff and residential

Table A1: *General profile of pollution hotspots in Iraq (continued)*

Site number	Site description	Area (ha)		Population		Land use	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
Kirkuk (24 sites)							
39	Jabal Bur Gas Separation (30)	8.00	12.56	150	1,075,000	Industrial	Staff and residential
40	Khabaz Gas Station (31)	0.30	3.14	110	1,000	Industrial	Staff and agricultural
	Subtotal	**33.45**	**94.20**	**2660**	**1,100,900**		
Salah Al-Din (15 sites)							
42	Alaas Oilfield (02)	3.00	3.14	100	1,000	Industrial	Agriculture
43	Northern Fertilisers (03)	10.00	12.56	500	10,000	Industrial	Residential and agricultural
44	Al-Mansour Vegetable Oils (04)	1.00	3.14	500	5,000	Industrial	Residential and agricultural
45	Baiji Power Plant (05)	5.00	12.56	1,500	10,000	Industrial	Residential and agricultural
46	Salah Al-Din (06)	0.30	3.14	300	2,000	Open hotspot	Residential and agricultural
47	Al Seenia Oil Refinery (07)	0.30	3.14	500	3,500	Industrial	Residential and agricultural
48	Baiji Refinery (09)	15.00	12.56	3,000	173,677	Industrial	Staff and residential
49	Salah Al-Din 10	0.30	3.14	300	2,000	Open hotspot	Residential and agricultural
50	K2 Pumping Station (13)	0.30	3.14	50	500	Industrial	Staff and agricultural
51	General Company (14)	0.30	3.14	1,000	10,000	Industrial	Staff and residential
52	Al Fatha (15)	0.30	3.14	300	2,000	Open hotspot	Residents and agricultural
53	Al Sahl Valley (16)	0.30	3.14	300	2,000	Open hotspot	Residents and agricultural
	Subtotal	**136.10**	**78.50**	**9,350**	**231,677**		
	Grand total (69 sites)	**980.55**	**352.48**	**55,050**	**1,701,577**		

Source: *Based on hotspots mapping and analysis MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

Appendix B: Methodology for hotspots inventory and mapping using spatial tools

The overall approach to prepare the inventory and mapping of environmental hotspots through the ESA's EO clinic involved multistage, consistent process that is used to systematically screen candidate pollutions sites. At each stage in the process, more information is developed about the candidate sites and a subset of the sites are selected for further analysis in the subsequent process. Each stage is described in the following subsections.

1 Hazard site inventory

The first step in the process was to create an inventory of candidate pollution hotspot sites and to assemble various datasets that will be used in the screening, characterization, and detailed mapping process. A summary of the datasets is provided in Table B.1.

Table B.1: *Datasets hotspot inventory*

Dataset	Source	Description
Candidate sites	Iraqi MoE	Spreadsheet with coordinates (latitude/longitude) of locations of suspected pollution, type, and name of facility (if known) based on MoE's knowledge of conflict events.
Converted to point geospatial data by consultant.	0.00	46.17
Industrial and military land use polygons	OSM	Polygon geospatial data of industrial and military site boundaries/ footprint, based on OSM community contributions.
Landsat time series	Google Cloud	Full time series of Landsat 5, 7, 8, Surface Reflectance (1984–present).
Sentinel-2 time series	Google Cloud	Full time series of Sentinel-2 a, 2b, Surface Reflectance (2015–present).
Ikonos, Quickbird, GeoEye, WorldView	Maxar SecureWatch	Selected images (2000–present) available and exploitable in the web application.
SPOT and Pleiades	Airbus OneAtlas	Selected images (2013–present) available from web application.
Global Urban Footprint	German Aerospace Center	Worldwide mapping of settlements (2015) using TerraSAR-X/ TanDEM-X data.
Sentinel-2 10m land cover	Environmental Systems Research Institute	Worldwide mapping of land use/land cover using Sentinel-2 (2020).

Source: *Based on inventory and mapping by MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

Other reports such as "Iraq Reconstruction and Investment: Part 2: Damage and Needs Assessment of Affected Governorates (January 2018)", which estimated damages by sectors of activities based on ground-based and remote-based data, and UNEP's report "Assessment of Environmental 'Hot Spots' in Iraq", which provided detailed damage assessment on five priority sites were also referred.

An initial compilation of the existing sites and pollution type prepared by the MoE indicated that most sites are located in Ninevah (75) and very few sites in Al Anbar, Babil, and Diyala. This list also formed the basis for the inventory. To expand the candidate sites, the team extracted industrial and military land-use features from the OSM database for Iraq, which were reviewed jointly with the EO clinic team. Subsequently, an inventory of more than 215 sites was established. The inventory contained a point coordinate for each site and, if available, the name of the site and potential pollution hazard suspected at the site.

Since several sites were in proximity, spatial analysis using QGIS was completed to group adjacent sites. A 2×2 square kilometer buffer (400 ha) was applied to the original list of 215 sites, and sites found in relative proximity (usually within 2 km) were grouped. The result was that 215 sites were consolidated into 121 polygons for assessment. An initial selection (prioritizing hydrocarbon and waste pollution types) meant that CCDC was applied to 54 polygons (containing 136 individual sites in total). Polygons for assessment ranged from 400 ha (for those containing a single site) to 4,000 ha (for the polygons containing larger numbers of sites). Only two groups had more than eight sites and were found in the large oil fields in the Ninevah governorate.

***Table B.2:** Output of the inventory component per vector dataset*

	Sites	Polygons for assessment
Format	Point shapefile	Polygon shapefile
Coordinate system	EPSG:32638–WGS 84/UTM zone 38N	EPSG:32638–WGS 84/UTM zone 38N
Description	215 sites	121 polygons (54 selected for CCDC assessment)

***Source:** Based on inventory by MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

2 Hazard site screening

Typically, very little is known about pre-conflict land use and land cover, the extent and timing of disturbance and damage, and post-conflict change at candidate pollution sites. What is known bears considerable uncertainty. The rationale for the site screening is to use the long-time series of free and open satellite EO data to provide consistent information for each site. Furthermore, the full time series and change detection methods of the site screening can be used to identify periods of abrupt change that may be due to natural or human-caused processes. **To establish a site screening method across the candidate sites, the following aspects were considered:**

- **Land cover and land use:** Conditions vary, with some sites in urban/developed areas and others in remote rural areas, with land cover varying from bare soils, developed, to vegetated wetlands or croplands.
- **Land surface phenology:** Conditions vary seasonally, with variability across the region.
- **Type of infrastructure:** The infrastructure and substances will affect the type of impacts that could be detected, for example hydrocarbons vs chemicals.
- **Type of incident:** The damage and impact vary depending on the incidents, e.g., explosives, accidents, and aerial bombings.

The UNEP report "Assessment of Environmental 'Hot Spots' in Iraq" helped to investigate these considerations and to select suitable satellite EO image parameters (bands and spectral indexes) to detect changes at specific sites. In addition, the approach was informed by investigating changes in land cover and land use in arid and semi-arid regions. CCDC, a temporal segmentation algorithm introduced by Zhu and Woodcock (2014), was selected. This algorithm can use the full time series of Landsat (1984–present) or Sentinel-2 (2016–present) and offers flexibility to select the spectral bands and indexes that are sensitive to the change that is of interest in the context of land surface characteristics and phenology.

The CCDC algorithm assembles dense time-series of observations for each pixel to predict reflectance values for a given band. These observations can be used to better characterize the temporal trajectories for each pixel through time as well as identifies when a series of new data points diverge from this prediction, triggering a temporal break.[65] The predicted reflectance values account for both intra-annual (like phenological changes) and inter-annual changes, providing a decomposition between seasonal and long-term changes in the reflectance of a band or index. **The equation for this reflectance prediction contains eight change coefficients:**

$$\hat{\rho}_{i,x} = a_{0,i} + \sum_{k=1}^{3}\left\{a_{k,i}\cos\left(\frac{2\pi}{T}x\right) + b_{k,i}\sin\left(\frac{2\pi}{T}x\right)\right\} + c_{1,i}x$$

where

***x*:** Date

***i*:** The ith Landsat Band (i = 4, 5, 6, and 7)

***k*:** Temporal frequency of harmonic component (k = 1, 2, and 3)

***T*:** Number of days per year (T = 365.33 25)

$a_{0,i}$: Coefficient for overall value for the ith Landsat Band

$a_{k,i}$, $b_{k,i}$: Coefficients for intra-annual change for the ith Landsat Band

$c_{1,i}$: Coefficient for inter-annual change (slope) for the ith Landsat Band

$\hat{\rho}_{i,x}$: Surface reflectance for the ith Landsat Band at x Julian date from model prediction.

CCDC has been implemented in Google Earth Engine.[66] Note that Zhu et al. (2020) provides an update to the CCDC method, which they refer to as the Continuous Monitoring of Land Disturbance (COLD) algorithm. While the Google Earth Engine implementation is expressly referred to as CCDC, it is actually an implementation of COLD algorithm. Hence, reference to CCDC means Google Earth Engine implementation of the COLD algorithm.

65 Zhu et al. 2020.
66 Gorelick et al. 2017.

The CCDC algorithm uses harmonic modelling to distinguish intra-annual change, like phenology, from gradual changes like inter-annual greening. A series of consecutive values that diverge from the harmonic is identified as an abrupt disturbance, which would not be expected by the intra- and inter-annual change modelled in the harmonic.

The harmonic is generated during an initialization period, where a minimum of 12 clear pixel values (not cloud or snow contaminated observations) occurring over the period of at least one year are used to fit eight model coefficients using the Least Absolute Shrinkage and Selection Operator, or LASSO. The spatial distribution of available pixels can vary due to cloud cover and other factors, meaning that different pixels in a scene may have different initialization periods.

The CCDC algorithm can calculate harmonics for single bands, for a combination of multiple bands, and for spectral indices. Zhu et al. (2020) compared temporal segmentation accuracy with various Landsat band combinations and indices and found the highest overall disturbance detection accuracy using Green, Red, NIR, SWIR1, and SWIR2 together. This band combination had the highest accuracy across several disturbance types, including forest harvesting, fire, mechanical, and hydrological disturbances.

Each new data point in the time series is compared to the expected harmonic value using normalized change vector magnitude, which enhances the ability to identify change in a single band when multiple bands are used as inputs. Because this approach uses a $\chi 2$ test between bands and/or indices, the segmentation results for a given band or index will change depending on the combination of bands and/or indices in the model.

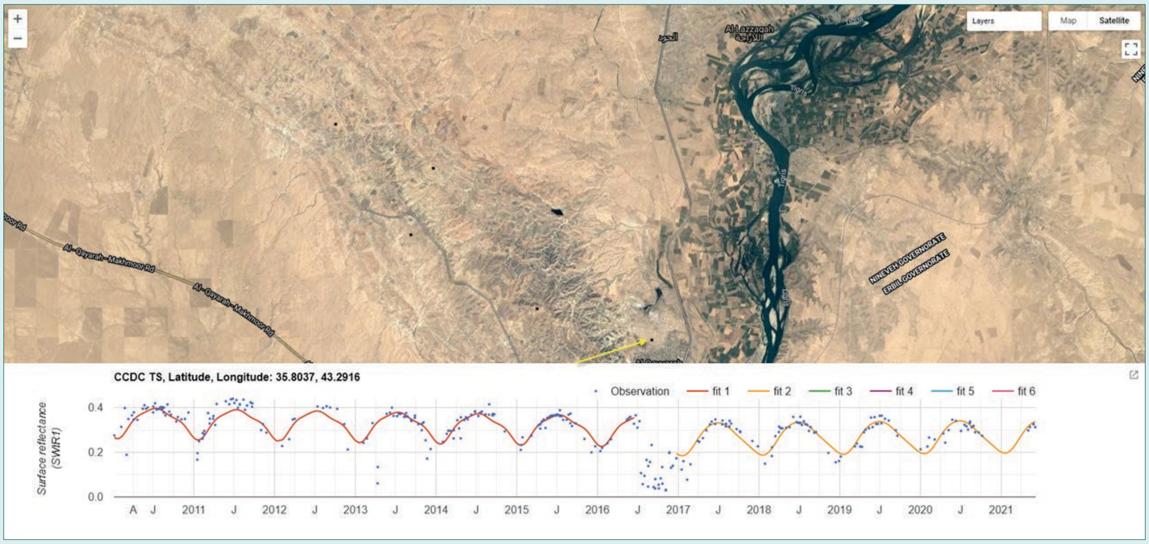
If a data point exceeds a dynamic probability threshold, it is considered an outlier. A user defined parameter identifies the number of consecutive outliers needed to classify an abrupt disturbance—the optimal number was empirically determined to be six. Outliers that occur in isolation, or in series less than the consecutive outlier threshold, are considered to represent ephemeral change and are omitted from further fitting.

The CCDC algorithm produces a variety of model outputs, including the date of each temporal break, the start and end date of each initialization period and segment, the modelled change probability, Root Mean Square Error, and change magnitude for each segment, in addition to the eight harmonic coefficients representing intra- and inter-annual change.

The area under consideration presented several challenges for the implementation of CCDC, as the algorithm had to handle a land cover characteristically open and sparsely vegetated, with deserts in some regions. Nevertheless, CCDC detected phenological changes that were depicted by distinct sinusoidal curves, or harmonics, each fit to a time-series model (see Figure B.1).

An illustration of a break in CCDC harmonic models fit using Landsat time-series is also presented in Figure B.1 using SWIR1 response. This example was captured during the 2016 armed conflict. Below the map, the graph depicts two harmonic (Fourier) models fitted before and after 2016. The lowest SWIR1 values in late 2016 and early 2017 occurred over areas that were reportedly burned or at an oil spill site, likely caused by its bombing or an oilfield explosion. The normal range of SWIR1 values here occurs between 0.2 and 0.4 (pre-2016), and appeared to recover post-2017, with a return to a normal phenological and seasonal cycle, showing high SWIR1 in June and low in January, however, with slightly lower values overall compared to pre-conflict conditions.

Figure B.1: *Phenological changes and break in harmonic models detected by CCDC and fit to a time-series model*



Source: *Based on hotspots mapping by MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.*

For the parametrization of the CCDC algorithm, input variables were selected to capture the type of events that would best characterize hydrocarbon pollution. **Parameters were set as follows:**

- Input variables (breakpointBand) were green, SWIR1, SWIR2, Tassel Cap Brightness, and Wetness.
- The minimum number of observations that qualify as consecutive outliers (minObservations:) used to trigger a break in the harmonic was set to eight (default is six) to reduce the number of disturbance flag not related to pollution events.
- The timeframe for the CCDC analysis was set to 2000–present. (Note that the Landsat archive allows to go further back in time (from 1984) and could be adjusted accordingly if the need would arise.)
- All other parameters were set to their default values.

The CCDC algorithm was run over 54 polygons containing 136 sites. An important element of the screening operation is the geo-processing of the outputs of the algorithm to enable visualization of the potential anomalies and disturbances that could be associated with the conflict and pollution events. The output included three main raster files composed of 20 bands, one for each year from 2001 to 2021, and information at each pixel include: date (fractional year) of harmonic model breaks; magnitude of change in SWIR1 values; and change probability. The latter was used to exclude low probability (<0.16) breaks.

3 Hazard site characterization

Following screening using open satellite EO data, more detailed site characterization is required to further develop knowledge of the physical, environmental, and socio-economic setting, as well as the history of the site and change. VHR satellite images with resolution below 1.5 m can support site characterization, with the archive of VHR images being from roughly 2000 for Maxar data and from 2013 for Airbus data. Recently, cloud-based services have been developed to provide cost-effective and easy access to images. Maxar SecureWatch and Airbus OneAtlas are both web applications that provide tools to identify, view, and exploit images in the cloud. In addition, these web services enable direct streaming of the images into GIS software such as QGIS or ArcGIS.

Given the large number of sites and years to be characterized, an efficient approach is needed to provide consistent information across sites. A Grid-Based Assessment approach was adopted, whereby a regular square grid is draped over the site and each grid cell is assessed for information pertinent to hazard characterization. This regular grid enables rapid calculation of statistics, such as proportion of land cover and land use types or proportion of a site with visible signs of damage or pollution. The grid also helps with sampling design for field investigations.

A 2 km grid over the polygon of interest was considered, which could contain one or multiple sites. Each 100×100 m grid cell was visually assessed for each of the VHR image dates and classified with the following information.

Land use classes

- Residential
- Commercial
- Industrial
- Military
- Agriculture
- Dense vegetation
- Sparse vegetation
- Bare ground
- Water
- Wetland.

Status

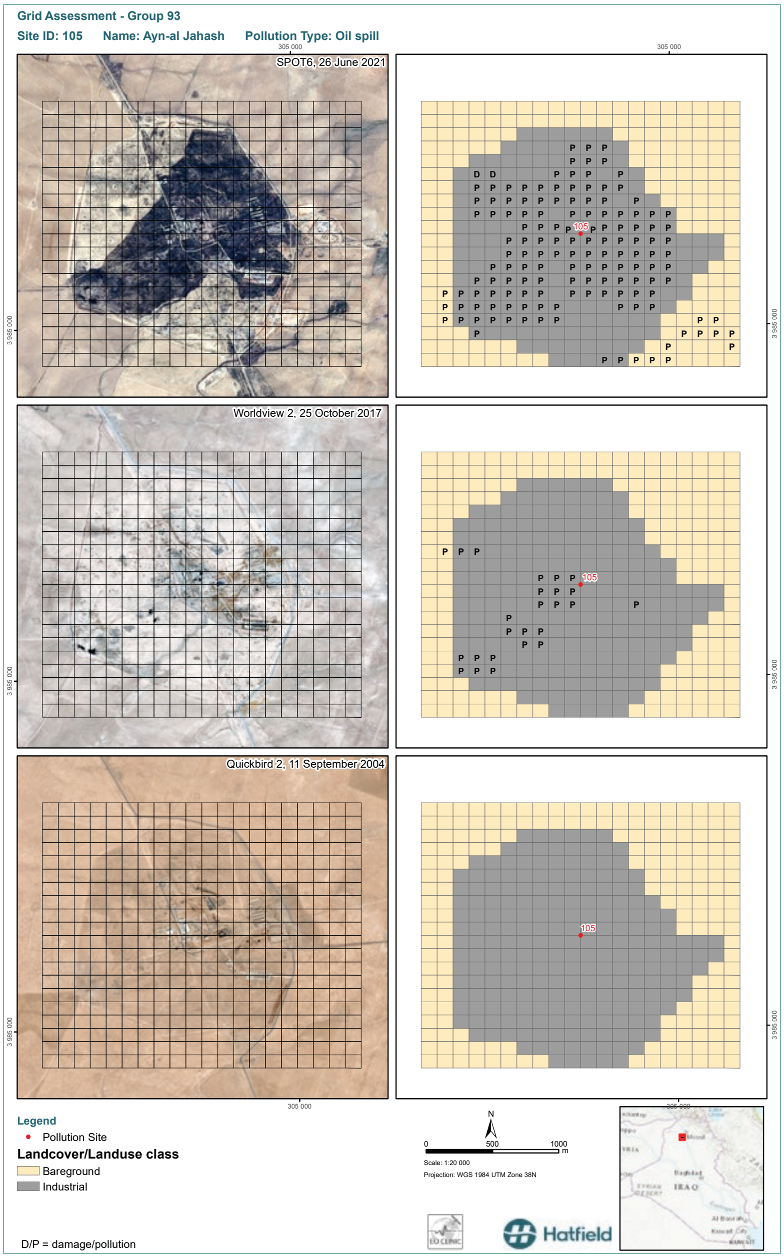
- **Damage:** Indicates if the cell has visible signs of damage to infrastructure
- **Pollution:** Indicates if the cell has visible signs of surface pollution or fire.

Type

- **Receptor:** indicates if the cell land use is related to potential pollution receptor
- Neutral.

The Grid-Based Assessment process was completed for 20 polygons which contained 75 individual sites. VHR data available for these polygons was searched and viewed via Maxar SecureWatch and Airbus OneAtlas. For each polygon, three cloud-free images covering three dates were selected. The selection of dates was informed by the changes that were identified using Sentinel-2 and Landsat-8 images and the outputs from the CDC algorithm. The Grid-Based Assessment grids were created as vector GIS datasets and used to create a series of one page map templates along with the corresponding source VHR images (see Figure B.2).

Figure B.2: One-page map templates with Very High Resolution images



Source: Based on MoE, Hatfield Consultants LLP, CLS, and GeoVille 2022.

4 Detailed site mapping

Detailed mapping involved:

- Extracting and characterizing a wide selection of relevant features, namely land use, land cover, buildings, physical barriers, transport network, and hazard-related ones by following geospatial intelligence techniques at 1:2,000 analysis scale.
- Delineating key receptors such as livestock, aquatic species, and human population by mapping pastoral land use, water bodies, and settlements and work sites, respectively.
- Identifying pathways of direct exposure by mapping distances/proximity to the pollution site, bioaccumulation by including drainage networks and water sources in maps, and transport from site by identifying drainage networks or other means of transport.

The extraction rules of geometric features followed the internationally accepted standard for reference mapping in a context of defense and security, while using geometric positionality and careful assessment of thematic accuracies. Each hotspot map was based on a geospatial dataset, composed of multiple GIS-compatible layers, and contained feature geometries and attribute information. The geospatial dataset was also visualized through a comprehensive map that included annotations, descriptive texts, statistics, and photos. This presentation enables users to understand the situation even without any prior GIS experience.

Appendix C: Site inspection checklist

As part of the intial assessment of hotspots, a detailed site inspection checklist was developed to enable the collection of basic information such as the name of the site, GPS coordinates and possible pathways of contamination. This checklist is presented below.

PROJECT: Initial Assessment of Environmental Hotspots in Iraq

FACILITY / SITE NAME:

FACILITY ADDRESS:

DATE:

INSPECTION BY: MoE

These inspections can provide useful information on:

- Suitable and appropriate locations for investigation
- The groundwater and surface water environments
- Potentially sensitive receptors (targets) including issues that require further investigation, e.g., ecology surveys
- Potential sources of contaminants
- Nature of contamination
- Potential migration routes (pathways).

During the walkover survey the consultant may mark locations of features described on a map or photograph them and give them a reference number. If this is undertaken, please add photograph number and map references to this table. Describe features in as much detail as possible.

__Table C1:__ Preliminary contamination observations

Was there visible evidence of contamination? (Yes/No)	
Type of expected contamination (Please list the contaminants expected on site, for example, hydrocarbons, sulfur, explosives, etc.)	
Estimated area contaminated (hectares)	
Estimated depth of contamination (m)	
Cause of contaminant release (if known)	

Features	Description	Photo no.
1. Describe present land use and building types. Take photographs.		
2. Note the presence of any suspected Asbestos Containing Materials in building structures or in waste materials on the ground. Take photographs.		
3. Describe surrounding properties/land use especially any waste sites or industrial premises, rubbish dumping area, note the collection and how it gets rid of it. Take photographs.		
4. Estimate the distance to the nearest residential house (if applicable).		
5. Describe any soils and rocks exposed nearby to the site in road cuttings, quarries, etc. Take photographs.		
6. Describe the types and condition of any vegetation on site and nearby. Take photographs.		
7. Describe site topography.		
8. Describe any damage to existing structures or buildings on site or adjacent to the site. Take photographs.		
9. Note the location (distance) of streams, ponds, and rivers nearby, and any signs of previous flooding.		
10. Examine all nearby surface waters for evidence of contamination. Note any sheen, color, odors.		
11. Locate any ground water wells on site/nearby and coordinate them.		
12. Note any odors, sheen, or discoloration in underground water.		
13. Note any discolored ground on site or other evidence of ground contamination.		
14. Note the presence of any above- or below-ground tanks and, if safe, inspect for evidence of ground contamination, contained liquids, and associated hazardous solid waste.		
15. Note the presence of transformers and any electrical equipment.		
16. Note any abandoned equipment such as air-conditioning units.		
17. Examine nearby areas for evidence of contamination that could migrate onto the site.		

Table C1: *Preliminary contamination observations (continued)*

Features	Description	Photo no.
18. Note the presence of any underground structures, services, mine workings, tunnels, etc.		
19. Make a list of all chemicals and fuels used/stored on site. Is there an inventory on site and Material Safety Data Sheets?		
20. Are all fuel, oil, chemical and waste stores within clearly marked and designated areas on-site with appropriate bunding/containment?		
21. Are small containers/canisters of fuel, oil, or chemicals fit for purpose?		
22. Confirm arrangements for waste disposal and segregation/ recycling. Do they keep waste transfer notes and records of waste produced site?		
23. Confirm arrangements for dealing with environmental incidents. Are there spill kits available and other procedures in place?		
24. Have there been any environmental incidents on-site? If yes, review incident report and summarize.		
25. Are service plans available to show water pipes, drains, electricity, gas, etc?		
26. Note any evidence of leaching from landfill sites/ dumping areas.		
27. Note potential sources of contamination such as pipelines, fuel tanks, or underground utilities.		
28. Note any evidence of buried services (water, gas, cable, pipelines).		
29. Note any evidence/presence of leakage on site (water, gas, pipelines).		
30. Note any exposed manhole and observe any sheen or evidence of NAPL.		
31. Note any evidence/presence of scrap or metals not been used and could be risk of NORM.		
32. Describe the site in terms of ground slopes and changes.		
33. Describe any evidence of animal activity.		
34. Note any anecdotal information in past uses of the site.		
35. Note any evidence of gases releases (i.e., flare, smokestack, rubbish burned, generators or heavy-duty engine/turbine).		
36. Note types of sewage. Is it all connected or separate? Note if any oil/water separators are available within sewage system.		
37. Note the approximate number of people affected by contamination.		
38. Who may benefit from remediation in this area (if applicable)?		
39. Is the facility currently operational?		
40. What is the estimated number of people in the nearby vicinity?		

Source: *Discussions with MoE and other Government of Iraq entities.*

Appendix D: Source, pathway, and receptor for pollutants across hotspots

Table D1: *Source, pathway, and receptor for pollutants across hotspots*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Ninevah			
Al-Qayyarah NIN_01	Oil well 46: High viscosity hydrocarbon Approximately 1.7 ha of contaminated land.	Current / future site users Current adjacent site users Groundwater Surface water.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al-Qayyarah NIN_02	NA	NA	NA
Al-Qayyarah NIN_03	Oil well 39: Hydrocarbons. 2.6 ha at source 1.07 ha of surface staining	Current / future site users Adjacent site users Groundwater Surface water course.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al-Qayyarah NIN_04	Hydrocarbon Approximately 150 m^2 at the loading site and a pathway to the north of the pit, approximately 1 m in width and 120 m in length.	Current / future site users Adjacent site users Buildings and services Existing / future vegetation Groundwater Surface water course Fish farm / lake about 240 m northwest. The fish farm is supplied by a groundwater extraction well. Ecological receptors	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Potential contamination of groundwater extraction well.
Al-Qayyarah NIN_05 and NIN_17	Hydrocarbon Approximately 66,000 m^2 of pathway contamination Approximately 21,000 m^2 of pits size contamination. Hydrocarbon sheen observed on top of water surface.	Current / future site workers Surface water course: a pond near a pit of NIN-05 (sampled) of approximate area of 300 m^2 Groundwater.	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Runoff into surface waters.
Al-Qayyarah NIN-18	Explosions of oil well no. 78 during the war with ISIS. Well pad 78: hydrocarbons. Approximately 850 m^2	Current / future site users Groundwater	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

Table D1: *Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Ninevah			
Ein Zalah Station NIN_06	NA	Current / future site users Groundwater Vegetation including crops Further receptors may be identified in site sheets.	NA
Ein Zalah Station NIN_07	NA	Current / future site users Groundwater Vegetation including crops Further receptors may be identified in site sheets.	NA
Ein Zalah Station NIN_08 and NIN_09	Oil leakage: hydrocarbons 50×50 m near a damaged tank. There is a contaminated pathway from the shelled tank towards the valley, of approximate distance 270 m slopped towards the valley. Discharged/leakage from a tank towards unlined pit covering a distance of approximately 200 m. Used diesel tank for generator. More few leaks within fuel tanks in the facility which are approximately 1×1 m ~ 1×2 m in size There is asbestos scattered and broken near to the tank.	Current / future site users Groundwater Vegetation, including crops.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Root uptake leading to phytotoxicity.
Alkask Refinery NIN_10	Oil leakage: hydrocarbons, 4,000 m^2 Chemical storage on site.	Current / future site users Vegetation agricultural land in the south of the site Groundwater Surface water course Ecological receptors.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL There is a river in the south. The refinery discharge water to the river after physical treatment. Flare within the boundary of the refinery and there are gas odors due to the flare and oil spills.

***Table D1:** Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Ninevah			
Chemical Contaminated Site NIN_11	Chemical contamination: electrical transformer stores Mainly electrical scrap and minor oil stain leaked from transformers.	Current / future site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Alhukamaa Pharmaceutical Company NIN_12	Chemical contamination: rubble, damaged tools and scrap 250 km^2.	Groundwater	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Ninevah Pharmaceutical Industrial Company NIN_14	Chemical contamination: contaminated with chemical materials as a result of spills from inside the chemical material storage. Materials have also expired.	Current / future site users Current adjacent site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Chemical Contaminated Site NIN_15	Chemical contamination: explosives, area not fully cleared from mines. Also partially contaminated. 200×200 m^2 There is a lot of broken up asbestos Pesticides known to have been stored on site. Oil manhole Old transformer.	Future site users Current adjacent site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al Kindy General Company NIN_16	The source of the surface water contamination is unknown, and it is thought that it could potentially originate from off site.	Flora and fauna Current / future site users Current adjacent site users Groundwater	Surface runoff Oral, dermal and ingestion of contaminated water leaching from surface water / percolation to aquifer / lateral migration of contaminants.

Table D1: *Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Baghdad			
Ibn Sina Company BAG_01	Chemical contamination: liquid fertilizer, sludge, and asbestos within building structure.	Current / future site users Adjacent site users Vegetation including crops Groundwater Surface water course—Tigris river 300 m south and east of the station.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminates through food Root uptake leading to phytotoxicity Leaching from soils and percolation to groundwater likely to be in hydraulic continuity with Tigris.
Bader Company BAG_02	Chemical contamination: Poly Chlorinated Biphenyl from transformer / generally weapon powder and TNT and Research Department eXplosive.	Current/future site users Adjacent site users Surface water course—nearby river but no sign of contamination.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust.
That Alsawary Company BAG_03	Chemical contamination: several plants producing asphalt materials, aluminum production plants, concrete additives, rock wool production plant, calcium carbonate plant and discontinued carbide plant (resins production plant and oil recycling plant). Polychlorinated Biphenyl from transformers There are AST and UST for asphalt materials.	Future site users if any Vegetation including crops Groundwater Surface water course.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Runoff to surface water.
Ibn Al Waleed BAG_04	Chemical contamination: scrap (mainly vehicles), spills of hydrocarbon due to leaks in fuel tanks	Current/future site users Vegetation including crops Adjacent site users Groundwater	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al Harith Factory BAG_06	Chemical contamination: The presence of clear contamination with asbestos in the destroyed buildings. Very large quantities of factory scrap, in addition to large quantities of military equipment scrap. Water contaminated with chemicals inside a buried underground tank. Oily pollution in two tanks. Traces of pollution resulting from the discharge of water from the treatment unit into the river (blackish color with the smell of organic substances).	Current / future site users Vegetation - agricultural areas (palms, fruit trees and seasonal crops) natural plant cover. Groundwater: Water well present on site. Notes from site walkover indicate that groundwater may be close to the surface. Surface water course: Tigris River along the eastern side. Ecological receptors: Existence of agricultural and fish and livestock breeding.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

__Table D1:__ Source, pathway, and receptor for pollutants across hotspots (continued)

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Baghdad			
Baghdad Lead Extraction Facility BAG_08	Chemical contamination: heavy metals, asbestos, Poly Chlorinated Biphenyl, tar, and hydrocarbons.	Current / future site users Adjacent site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Babil			
Al Furat Company BAB_01	Chemical contamination including sulfur, chlorine, carbon disulphide, asbestos, and Polychlorinated Biphenyl from transformer.	Current / future site users: operational Adjacent site users Vegetation including crops Groundwater Surface water course: Main drainage channels of farms 50 m east of the station	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminates through food Root uptake leading to phytotoxicity Leaching from soils and percolation to groundwater.
Baghdad			
Diyala Electrical Industries Company DIY_01	Chemical contamination: hydrocarbons Heavy metals, leakage oil from transformers Sheen present in groundwater samples indicating contamination The ground around diesel tanks, oil barrels, and transformers was contaminated.	Current / future site users Adjacent site users Groundwater	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al Harith Factory BAG_06	Chemical contamination: The presence of clear contamination with asbestos in the destroyed buildings. Very large quantities of factory scrap, in addition to large quantities of military equipment scrap. Water contaminated with chemicals inside a buried underground tank. Oily pollution in two tanks. Traces of pollution resulting from the discharge of water from the treatment unit into the river (blackish color with the smell of organic substances).	Current / future site users Vegetation - agricultural areas (palms, fruit trees and seasonal crops) natural plant cover. Groundwater: Water well present on site. Notes from site walkover indicate that groundwater may be close to the surface. Surface water course: Tigris River along the eastern side. Ecological receptors: Existence of agricultural and fish and livestock breeding.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Baghdad Lead Extraction Facility BAG_08	Chemical contamination: heavy metals, asbestos, Poly Chlorinated Biphenyl, tar, and hydrocarbons.	Current / future site users Adjacent site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

Table D1: *Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Babil			
Al Furat Company BAB_01	Chemical contamination including sulfur, chlorine, carbon disulphide, asbestos, and Polychlorinated Biphenyl from transformer.	Current / future site users: operational Adjacent site users Vegetation including crops Groundwater Surface water course: Main drainage channels of farms 50 m east of the station	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminates through food Root uptake leading to phytotoxicity Leaching from soils and percolation to groundwater.
Diyala			
Diyala Electrical Industries Company DIY_01	Chemical contamination: hydrocarbons Heavy metals, leakage oil from transformers Sheen present in groundwater samples indicating contamination The ground around diesel tanks, oil barrels, and transformers was contaminated.	Current / future site users Adjacent site users Groundwater	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al Anbar			
State Company for Phosphate in Al-Qaaim City ANB_01	Chemical contamination: explosives, chemicals. Metal scrap.	Future site users Adjacent site users.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present.
Alamer factory ANB_03	Chemical contamination chemicals.	Future site users Adjacent site users. Future site users Adjacent site users.	Oral, dermal and inhalation exposure with dust / fibers, ingestion and inhalation of contaminated materials.
Haditha Oil Refinery ANB_04	Oil spill: hydrocarbons. It is understood based on information from the Ministry of Environment that the site is generally well managed and in a good state of repair. While hydrocarbon contamination has been identified within an oil pit, this is understood to be located away from the most sensitive receptors. Oil within such pits tends to be highly weathered, longer-chain hydrocarbons with a high viscosity, so reducing the risk of these hydrocarbons leaching into the surrounding soil and/or groundwater.	Current / future site users Adjacent site users Vegetation Groundwater Surface water course: pond with visual sign of contamination Ecological receptors.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Runoff to surface water.

***Table D1:** Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Al Anbar			
Pesticides Factory Al-Falluja City ANB_05	Chemical contamination: chemicals used for pesticides and herbicides. Asbestos and Polychlorinated Biphenyl from transformer.	Current / future site users: factory still in operation at reduced output due to bomb damage Buildings and services Existing/ future vegetation Groundwater: one groundwater extraction well on-site and used for domestic purposes Surface water course Ecological receptors.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al Shahid Company ANB_06	Chemical contamination: storage of chemicals on site. Poor storage noted.	Current/ future site users: operational factory.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present.
Kirkuk			
Sarolo Station KIR_01, KIR_04 and KIR_05	Work of Kar company: hydrocarbons Spill inside the station due to overload, lack of maintenance, and leaks but no historical record for the environmental incidents in place Old (pipes, flanges, valves, and tanks) Visible oil spills at surface.	Current/ future site users Groundwater Surface water course: need to determine distance to Zab river.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Sarolo Station KIR_02	Evaporation pit / Kar company: hydrocarbons, leakage from old pipes, valves, and old transformers, several spills in different locations. The site also contains asbestos roofing.	Current/ future site users Vegetation, including agricultural crops Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Sarolo Station KIR_03	Work of Kar company: a large leak of crude oil as a result of maintenance work and broken pipes, pollution outside the station fence. Obvious contamination of crude oil. It was noted by the site team that there had been frequent environmental incidents.	Current and future site users Vegetation Groundwater: hydrocarbon observed at surface in unlined pits. Surface water course: A large stream heading towards the little Zab river overflows during the winter season.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / naphthalene are flares to burn gas.

***Table D1:** Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Kirkuk			
Dawood Station for Oil Refining KIR_06	Oil waste: hydrocarbon pollution. Oily water not treated. Unlined pit.	Current / future site users Adjacent site users Vegetation Groundwater Surface water course.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Bai Hassan North Degassing Station KIR_07	Ruptured pipeline: hydrocarbon pollution. Blackish ground due to spills. Free phase hydrocarbons visible at the surface.	Current site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Bai Hassan North Degassing Station KIR_08	Ruptured pipeline: hydrocarbon pollution.	Current site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Bai Hassan North Degassing Station KIR_09	Pit near hydrocarbon waste tank.	Current site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Bai Hassan North Degassing Station KIR_10	Evaporation pool in API station.	Current / future site users Vegetation Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

Table D1: *Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Kirkuk			
Bai Hassan North Degassing Station KIR_10	Evaporation pool in API station.	Current / future site users Vegetation Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Bai Hassan North Degassing Station KIR_12	Testing tank pit.	Current / future site users Vegetation Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Bai Hassan North Degassing Station KIR_13	Evaporation pool in API station.	Current / future site users Vegetation Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Baba Gurgur Station KIR_14	Maintenance work and cleaning: hydrocarbons 2,500 m and it spreads to the south about 8 km. Significant area of contamination.	Current / future site users Adjacent site users Vegetation Groundwater Surface water.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL There are flares.
Baba Gurgur Station KIR_19	Discharging works: hydrocarbon, spills, using uncovered pit for waste oil, asbestos used as pipe isolation.	Current / future site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

Table D1: Source, pathway, and receptor for pollutants across hotspots (continued)

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Al Anbar			
Bai Hassan South Oilfield KIR_15, KIR_17 and KIR_23	Oil waste flaring pit for hot flares: Hydrocarbons 40 drums x 200 L demulsifier Electrical transformers existed, flaring.	Current/ future site users: site is operational Adjacent site users: flaring noted to be in direction of residential Vegetation Groundwater Surface water course Ecological receptors.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Windblown dust / hydrocarbons.
Serbach Station KIR_16	Work of Kar company: hydrocarbons and asbestos found in roofing over the carpark.	Current / future site users Vegetation: strategic agricultural area Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Haljira Gas Isolation Station KIR_18 and KIR_20	Leakage of crumbling pipes, hydrocarbons 10 x 2 m, and some old transformers.	Current / future site users: operational site Groundwater	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Showraw Station and Kat Factory KIR_24	Maintenance work and cleaning above-ground tank, number 29, containing raw materials and product. One new transformer. Chemicals	Current / future site users Groundwater: there are five water wells with a depth of 200 m. Surface water course: in the southwest there is a large stormwater drain.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Hawija Pesticides Stores KIR_25	Chemical contamination: sulfuric acid, urea, and pesticide.	Current / future site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater.
Mulla Abdulla Station (IT1) KIR_26	Oil leakage: 2,500 m and it spreads to the south about 8 km.	Current / future site users Adjacent site users Vegetation Groundwater Surface water course.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

Table D1: *Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Al Anbar			
Qutan Gas Isolation Station - Babakkar Oilfield KIR_28	Oil leakage: hydrocarbon pollution resulting from the oil waste collection effluents A pit with a diameter of 25 m.	Current / future site users Adjacent site users Groundwater Vegetation: agricultural land.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Gas flaring.
Gas and Oil Separation Plant in Jabal Bur KIR_30	Hydrocarbons: 1,500 m^2 and it spreads to the south about 8 km Unlined oily pits The ground near the source is contaminated (oil separators) 4 transformers, production date is 1984.	Current / future site users Adjacent site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Gas flaring.
Khabaz Gas Station KIR_31	Hydrocarbons: 2,500 m^2 Electrical transformers existed.	Current / future site users Agricultural and grazing areas Groundwater There are flares in village direction.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Salah Al Din			
Ajil Oil Field SAL_001_H, SAL_011_H, SAL_012	Oil leakage: hydrocarbon. Multiple leaks some extending over significant areas (multiple hectares).	Current / future site users Adjacent site users Vegetation Groundwater Surface water course: Tigris river (agricultural land is separating between the river and the field) Ecological receptors There are flares.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of contaminated produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Alass Oil Field SAL_002_H	Oil leakage: historical contamination (hydrocarbons) 2,500 m^2 oil pit for taking oil out and selling	Groundwater Ecological receptors	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

***Table D1:** Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Salah Al Din			
Northern Fertilizers Company SAL_003_H	Damage to tanks: fertilizers units' products destroyed because of the war with ISIS. Radioactive element: co-60	Future site users Groundwater	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
AL Mansour Factories for Vegetable Oils SAL_004_H	The discolored ground near the broken transformer Old waste stream and near an oil tank All locations have been sampled.	Future site users Groundwater.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Baiji Power Plant SAL_005_H	Oil leakage: historical contamination (hydrocarbons) 2,500 m^2 Oil spill due to bombing.	Current / future site users Vegetation Groundwater Surface water course Ecological receptors	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Salah Al-Din - SAL_06, SAL_006_H	Only maintenance work and cleaning taking place at the site. Historical contamination: hydrocarbons Source not unknown 600 m^2.	Future site users Groundwater.	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al Seenia Oil Refinery SAL_007_H	Oil leakage: unlined pit Hydrocarbons Asbestos 50 x 50 m^2 Caustic soda Anti corrosive Dispersed Trisodium phosphate Oil pumps Motor oil.	Current / future site users Adjacent site users Vegetation Groundwater: agriculture well.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL There are flares.

***Table D1:** Source, pathway, and receptor for pollutants across hotspots (continued)*

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Salah Al Din			
Baiji Refinery SAL_009_C	Several large areas of hydrocarbon contamination have been identified. 50 x 50 m^2 (nearby storage tanks) 750 x 35 m^2 (area to collect the oil waste and rainwater) 100 x 1,500 m^2 (volume approximate = 203,000 m^3).	Current / future site users Adjacent site users Vegetation: The water generated from the treatment unit is drained into the al-Nouri canal. Al-Nouri canal: A spring water stream connected to the Tigris river, used by the people to irrigate crops and livestock, with a direct impact on the Tigris River Groundwater: NAPL appeared in manhole due to leakage in the destroyed tanks. Surface water course: Tigris River adjacent to the refinery Ecological receptors.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Salah Al-Din SAL_10, SAL_010_IC	Chemical contamination: historical contamination (hydrocarbons) and the source not unknown 600 m^2.	Future site users Groundwater.	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
K2 Station SAL_013	Hydrocarbons: 30 x 30 m^2.	Current / future site users Buildings and services Existing / future vegetation Groundwater Surface water course Ecological receptors.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Salah Al-Din - SAL_06, SAL_006_H	Only maintenance work and cleaning taking place at the site. Historical contamination: hydrocarbons Source not unknown 600 m^2.	Future site users Groundwater.	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

__Table D1:__ Source, pathway, and receptor for pollutants across hotspots (continued)

Site name and hotspot ID	Potential source	Potential receptor	Possible pathway
Salah Al Din			
General Company for Communication Equipment and Power SAL_014_C	Chemicals: 2,500 m^2 The chemical store contains quantities of damaged and dangerous chemicals: Sodium and potassium cyanide about 700 kg. Data gap (no cyanide testing completed) Sodium hydroxide Copper sulphate Nickel chloride.	Current / future site users Adjacent site users Vegetation Groundwater: three ground water wells used to water plants.	Oral, dermal and inhalation exposure with impacted soil, soil vapor and dust / fibers, ingestion of home-grown produce, inhalation of vapors from groundwater and / or NAPL if present Root uptake leading to phytotoxicity Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.
Al Fatha SAL_015_H	Historical contamination: hydrocarbons. Source unknown. 600 m^2 or more.	Vegetation Groundwater Surface water course: Open area, next to Tigris river Ecological receptors.	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Runoff into surface water and impact to ecological receptors.
Al Sahl Valley SAL_016_H	Historical contamination: hydrocarbons Source unknown 600 m^2 or more.	Groundwater Surface water course Ecological receptors	Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL Leaching from soils / percolation to aquifer / lateral migration of dissolved phase / NAPL.

__Source:__ Site Assessment by MoE and RSK Environment LLC 2022.

Appendix E: Summary of preliminary assessment of Health, Economic, Agriculture and Livelihood impacts of hotspots

(Table on following page)

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Table E1: *Estimate of burden of disease due to hotspots*

Typology	Direct area	Indirect area	Direct population	Indirect population	Relative risk: mortality		Relative risk: morbidity		Mortality impact		Morbidity impact		Mortality valuation		Morbidity valuation		Total
					Chem: Sulfuric Acid-Carcinogens Oil: PAH-Lead		Chem: Sulfuric Acid-Carcinogens Oil: PAH-Lead		Direct Pop	Indirect population	Direct population	Indirect population	Direct population	Indirect population	Direct population	Indirect population	
	ha	ha	#	#	Low death per 100,000	High death per 100,000	Low Years Lived with Disability (YLD) per 100,000	High YLD per 100,000	#	#	YLD Lost	YLD Lost	US$	US$	US$	US$	US$
Al Anbar																	
Chemical	501	22	3,260	79 ,00	0.0025	0.42	0.031	1.31	0.01	0.00	0.04	0.02	5,709	824	216	124	6,872
Oil	1	3	1,000	10,000	0.03	8.63	0.0073	49.19	0.09	0.00	0.49	0.00	35,985	1,251	2,483	4	39,722
Babil																	
Chemical	6	13	1,080	10,000	0.0025	0.42	0.031	1.31	0.00	0.00	0.01	0.00	1 891	104	71	16	2,083
Oil					0.03	8.63	0.0073	49.19	-	-	-	-	-	-	-	-	-
Baghdad																	
Chemical	27	53	10,430	75,000	0.0025	0.42	0.031	1.31	0.04	0.00	0.14	0.02	18 266	782	690	117	19 855
Oil	1	3	500	3 500	0.03	8.63	0.0073	49.19	0.04	0.00	0.25	0.00	17 992	438	1 242	1	19 673
Diyala																	
Chemical	0	3	1,200	10,000	0.003	0.42	0.031	1.31	0.01	0.00	0.02	0.00	2,102	104	79	16	2,301
Oil					0.030	8.63	0.0073	49.19	-	-	-	-	-	-	-	-	-

Table E1: Estimate of burden of disease due to hotspots (continued)

Typology	Direct area	Indirect area	Direct population	Indirect population	Relative risk: mortality		Relative risk: morbidity		Mortality impact		Morbidity impact		Mortality valuation		Morbidity valuation		Total
					Chem: Sulfuric Acid-Carcinogens Oil: PAH-Lead		Chem: Sulfuric Acid-Carcinogens Oil: PAH-Lead		Direct Pop	Indirect population	Direct population	Indirect population	Direct population	Indirect population	Direct population	Indirect population	
	ha	ha	#	#	Low death per 100,000	High death per 100,000	Low Years Lived with Disability (YLD) per 100,000	High YLD per 100,000	#	#	YLD Lost	YLD Lost	US$	US$	US$	US$	US$
Kirkuk																	
Chemical	0	3	31	500	0.003	0.42	0.031	1.31	0.00	0.00	0.00	0.00	54	5	2	1	62
Oil	33	91	2,629	1,100,400	0.030	8.63	0.0073	49.19	0.23	0.33	1.29	0.08	94,604	137,651	6,528	406	239,188
Ninevah																	
Chemical	259	44	6,700	56,000	0.0025	0.42	0.031	1.31	0.03	0.00	0.09	0.02	11,734	584	443	88	12,848
Oil	17	38	18,870	125,500	0.03	8.63	0.0073	49.19	1.63	0.04	9.28	0.01	679,030	15,699	46,856	46	741,631
Salah Al-Din																	
Chemical	17	35	3,800	37,000	0.0025	0.42	0.031	1.31	0.02	0.00	0.05	0.01	6,655	386	251	58	7,350
Oil	120	44	5,550	194,677	0.03	8.63	0.0073	49.19	0.48	0.06	2.73	0.01	199,715	24,352	13,781	72	237,920
																Total	**1,329,505**
Chemical													-	-	-	-	51,370
Oil																	1,278,134

Note: The Value of Statistical Life for Iraq (US$416,971) is used for premature mortality and the Gross Domestic Product (US$5,048) per capita is used for the Years Lived with Disability (YLD) lost in 2021 prices.

__Table E2:__ Estimate of economic impacts (loss of industrial production)

Industry	Annual production (tons per year)	Price per ton (2021)*	Annual turnover (US$ million)	Cost of production lost (US$ million per year)
1. Alhukama Pharmaceuticals, Ninevah**	Not available		11.58#	11.58
2. Ninevah Pharmaceuticals**	Not available		11.57#	11.57
3.General Phosphate Company, Al Anbar	1,500,000	767.00	1,150.50	1,150.50
4. Al-Mansour Vegetable Oils	1,200	1,876.25	2.25	2.25
			Total cost of lost industrial production	**1,175.90**

* Acid Plant Database 2023.[67]
\# Kadhim et al. 2022.
** Directory of Pharmaceutical and Medicine Manufacturing Companies in Iraq 2023.[68]

Source: *Analysis by ASA team.*

__Table E3:__ Estimate of loss of agriculture yield (wheat)

Governorate	Agriculture area (ha)	Wheat harvest yield (ton per ha)		Wheat harvest opportunity (tons)		2021 wheat harvest prices (US$/ton)		Forgone wheat (US$)		
Al Anbar	5.73	3.30	20	18.92	114.68	346.90	462.50	6,564	53,043	0.03
Babil	8.15	3.30	20	26.91	163.08	346.90	462.50	9,334	75,426	0.04
Baghdad	77.76	3.30	20	256.62	1,555.28	346.90	462.50	89,020	719,354	0.40
Diyala	0.81	3.30	20	2.66	16.11	346.90	462.50	922	7,451	0.00
Kirkuk	567.81	3.30	20	1,873.79	11,356.29	346.90	462.50	650,005	5,252,567	2.95
Ninevah	681.13	3.30	20	2,247.74	13,622.66	346.90	462.50	779,726	6,300,815	3.54
Salah Al-Din	227.60	3.30	20	751.09	4,552.05	346.90	462.50	260,548	2,105,436	1.18
Total	**1,569.01**			**5,177.72**	**31,380.14**			**1,796,119**	**14,514,093**	**8.16**

Source: *Analysis by ASA team.*

67 Acid Plant Database, DKL Engineering, Inc. (Accessed August 24, 2023), http://www.sulphuric-acid.com/sulphuric-acid-on-the-web/acid%20plants/State%20Company%20for%20Phosphates.htm.
68 Directory of Pharmaceutical And Medicine Manufacturing Companies In Iraq, Dun & Bradstreet (Accessed August 24, 2023), https://www.dnb.com/business-directory/company-information.pharmaceutical_and_medicine_manufacturing.iq.html.

Table E4: Estimate of loss of livelihood (industrial jobs)

	Al Anbar	Babil	Baghdad	Diyala	Kirkuk	Ninevah	Salah Al-Din	Total
Number of industrial jobs	3,260	80	12,930	200	31	4,200	10,500	**31,201**
Total employment days (310) per year	1,010,600	24,800	4,008,300	62,000	9,610	1,302,000	3,255,000	**9,672,310**
GDP per capita (2021) (US$)	5,048	5,048	5,048	5,048	5,048	5,048	5,048	**5,048**
GDP per capita per day (2021) (US$)	13.83	13.83	13.83	13.83	13.83	13.83	13.83	**13.83**
Total expenditure per year (US$)	13,976,736	342,987	55,435,338	857,468	132,908	18,006,838	45,017,096	**133,769,372**
Marginal Propensity to Consume (MPC)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	**0.30**
Multiplier, K = 1/(1-MPC)	1.43	1.43	1.43	1.43	1.43	1.43	1.43	**1.43**
Change in real GDP (US$)	**19,966,766**	**489,982**	**79,193,340**	**1,224,955**	**189,868**	**25,724,055**	**64,310,137**	**191,099,103**

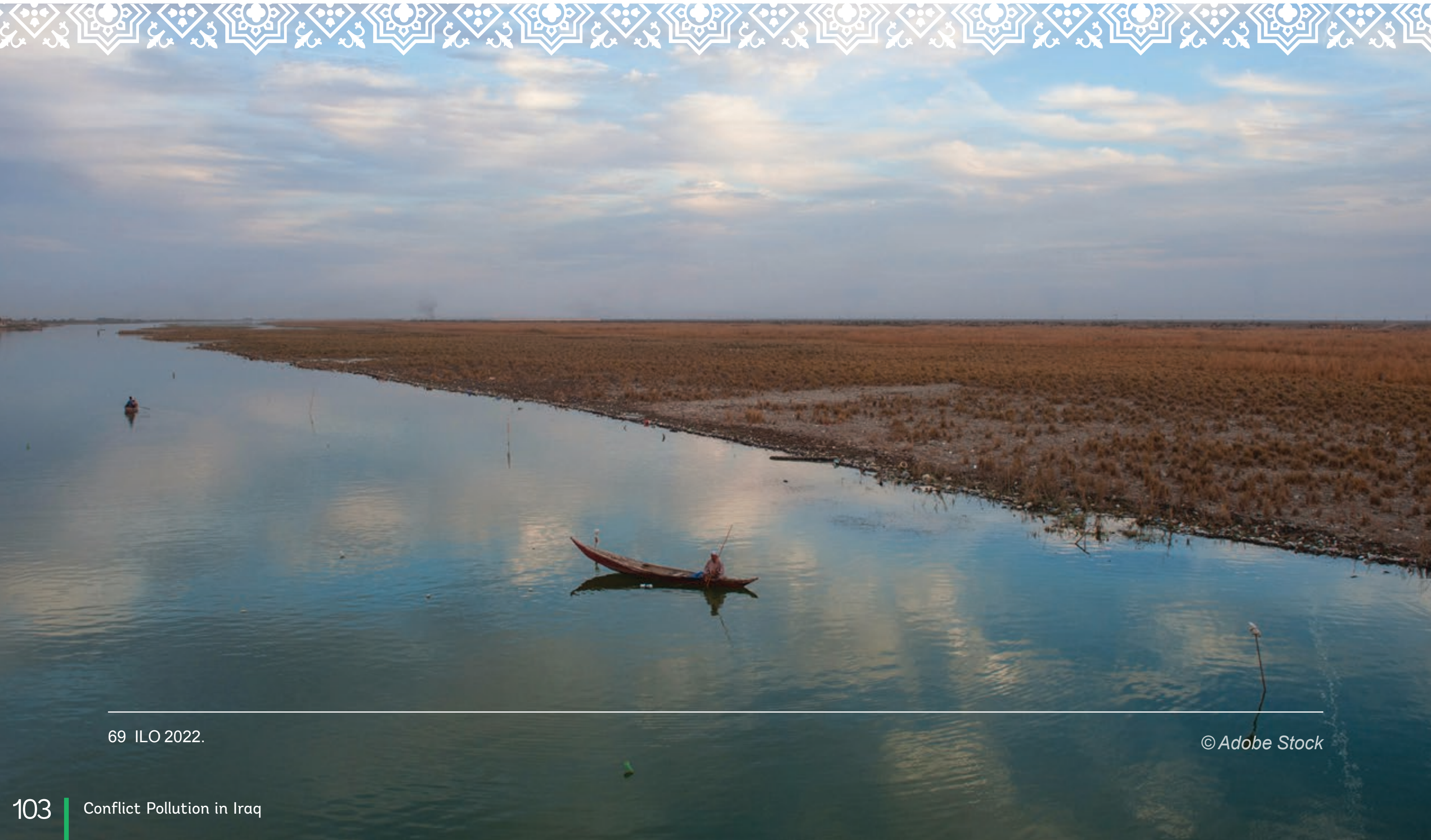
Source: *Analysis by ASA team.*

Table E5: *Estimate of loss of livelihoods (agricultural jobs)*

	Al Anbar	Babil	Baghdad	Diyala	Kirkuk	Ninevah	Salah Al-Din	Total
Number of agricultural jobs (0.79 ha)*	5	6	62	1	452	543	181	**1,250**
Total employment days (310) per year	1,416	2,014	19,206	199	140,241	168,29	56,214	**387,520**
GDP per capita (2021) (US$)	5,048	5,048	5,048	5,048	5,048	5,048	5,048	**5,048**
GDP per capita per day (2021) (US$)	13.83	13.83	13.83	13.83	13.83	13.83	13.83	**13.83**
Total expenditure per year (US$)	19,587	27,852	265,628	2,751	1,939,558	2,326,633	777,451	**5,359,461**
MPC#	0.30	0.30	0.30	0.30	0.30	0.30	0.30	**0.30**
Multiplier, K = 1/(1-MPC)	1.43	1.43	1.43	1.43	1.43	1.43	1.43	**1.43**
Change in real GDP (US$)	**27,981**	**39,788**	**379,469**	**3,930**	**2,770,798**	**3,323,762**	**1,110,645**	**7,656,373**

* *Average jobs per hectare estimated from International Labour Organisation (2022).*[69]
\# Carroll et al 2017.

Source: *Analysis by ASA team.*



69 ILO 2022.

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Appendix F: Risk assessment summary

Table F1: *Summary of risk assessment*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
		Ninevah		
Al-Qayyarah NIN_01	The site used to be a well pad. The oil well was burned and concreted. Currently it is located in a residential area within Al-Qayyarah. The ground comprises burnt soil / hydrocarbon and two highly viscous hydrocarbon pits. A natural tar spring is about 400 m to the north.	Across the entire facility, scrap metal has been observed. However, no evidence of asbestos was found. Soil samples contain a high concentration (10x DIV) of aromatic hydrocarbons. Additionally, it appears that nearby surface water contains elevated concentrations of fluoranthene (5x DIV for water).	Moderate	*Likely:* There is visible evidence of hydrocarbon contamination, which has been confirmed through chemical testing. Hydrocarbons appear highly viscous, weathered heavy-end rather than more volatile fractions. *Medium severity:* Chronic damage to human health.
Al-Qayyarah NIN_02	Site sheets required for assessment currently withheld.	NA	NA	NA
Al-Qayyarah NIN_03	Damaged / burned oil well and four pits to north trapping the contamination (highly viscous hydrocarbon).	Despite visible evidence of hydrocarbon contamination, the gathered soil samples do not show any contamination above the LLD. The surface water that has been sampled contains chrysene (100x DIV).	High	*Highly likely:* There is visible evidence of hydrocarbon contamination which has been confirmed through chemical testing. *Medium severity:* Chronic damage to human health.
Al-Qayyarah NIN_04	The site is a non-lined crude oil pit. The pit is about 3 m higher than the surrounding ground.	The site consists of a large hydrocarbon pit. Around this pit several locations were sampled that do not show any contamination. The surface water contained high concentration (50x DIV) of SVOC.	High	*Highly likely:* There is visible evidence of hydrocarbon contamination. *Medium severity:* Chronic damage to human health
Al-Qayyarah NIN_05 and NIN_17	Site comprises multiple oil pits and oil wells within Al Qayyarah oil field. Mountainous area with valley.	The site consists of large hydrocarbon pits and contamination pathways. On several locations aromatic hydrocarbon contamination (10x DIVs) was sampled. The surface water in pools that has been sampled contains high concentrations (100x DIV) of SVOC (perylene and pyrene).	Moderate	*Highly likely:* Visible and chemical evidence of contamination. *Mild severity:* Pollution of non-sensitive water resources

***Table F1:** Summary of risk assessment (continued)*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Ninevah				
Al-Qayyarah NIN-18	NA	NA	Moderate / low	*Likely:* Hydrocarbon contamination identified. *Mild severity:* Pollution of non-sensitive water resources.
Ein Zalah Station NIN_06	Site sheets required for assessment currently withheld Potential risk likely to be the same as that at NIN_08 and NIN_09.	NA	NA	NA
Ein Zalah Station NIN_07	Site sheets required for assessment currently withheld Potential risk likely to be the same as that at NIN_08 and NIN_09.	NA	NA	*NA*
Ein Zalah Station NIN_08 and NIN_09	Oil industry facility containing storage oil tanks, pumps, heavy-duty generators and office buildings. Mountains located in the north and sloped / valley towards south.	The location is littered with asbestos. Additionally, both on- and offsite high concentrations (50x DIV) of hydrocarbons can be found in spills.	Moderate	*Highly likely:* Visible evidence of extensive hydrocarbon contamination supported by chemical test results. *Mild severity:* Pollution of non-sensitive water resources.
Alkask Refinery NIN_10	Industrial area including oil tanks, offices, and oil pipes.	Close to the water discharge unit pits with high concentrations (50x DIV) of aromatic hydrocarbons can be found in spills. Additionally, at the riverbanks evidence of hydrocarbon pollution has been observed.	Very high	*Highly likely:* It appears that the contamination is leaking in the river. *Severe severity:* Short-term risk of pollution of sensitive water resource used by local communities as a source of domestic water.
Chemical Contaminated Site NIN_11	Site used to store disused transformers.	Localized aromatic hydrocarbons spills from leaking transformers show very high concentrations (100x DIV). Due to the number of transformers on site there is a significant risk of more spills as the transformers degenerate.	Moderate / low	*Likely:* Visible evidence of localized contamination supported by chemical test results. *Mild severity:* Pollution of non-sensitive water resources.
Alhukamaa Pharmaceutical Company NIN_12	The company drains industrial water to the surrounding land because there is no treatment unit. (The whole facility was destroyed in 2016.)	The soil is slightly contaminated with nickel and cadmium (1x DIV).	Low	*Low likelihood:* No visible or olfactory evidence of contamination, but testing did identify marginally elevated nickel and cadmium. *Mild severity:* Pollution of non-sensitive water resources.

Table F1: *Summary of risk assessment (continued)*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Ninevah				
Ninevah Pharmaceutical Industrial Company NIN_14	Out-of-service factory. The factory is almost totally destroyed. Large quantities of expired material / chemicals identified on site.	There are many old, expired components in the facility that may ultimately lead to spillage. The soil is slightly contaminated with nickel and cadmium (1x DIV).	Moderate / low	*Low likelihood:* no visible or olfactory evidence of contamination, but testing did identify marginally elevated nickel and cadmium. *Medium severity:* Potential chronic damage to human health should surrounding residents come into contact with onsite contaminated material.
Chemical Contaminated Site NIN_15	Site is deserted and largely destroyed, with a lot of rubble.	There is a lot of asbestos on the site that could lead to health risks. The soil underneath a transformer that is located inside is highly contaminated with aromatic hydrocarbons (50x DIV). Due to the fact that this contamination is inside a separate room, it is not expected that this contamination will spread or lead to any health risks to the community.	Moderate	*Highly likely:* Visible evidence of contamination supported by chemical test results. *Medium severity:* Potential chronic long term affects on human health.
Al Kindy General Company NIN_16	Destroyed with remaining rubble.	There are a lot of destroyed buildings and rubble on the site. No visible contamination can be detected. Lab analyses show that the soil is not contaminated. The analyzed water sample, however, shows severe concentrations of Indeno (1,2,3-cd) pyrene (>100x DIV). This could cause serious health problems if flora or fauna come into direct contact with this water. It is also likely to spread during rainy periods.	Moderate / low	*Low likelihood:* No visible evidence of onsite contamination has been identified. Contamination of surface water identified during lab testing is thought to originate from offsite sources. *Medium severity:* Long-term risk of pollution of sensitive water resource, which local communities use as a source of domestic water. There is chronic risk to human health if they use that water.
Baghdad				
Ibn Sina Company BAG_01	Production of liquid fertilizer. Four buildings were destroyed in the 1991 uranium enrichment plant.	The soil in general seems to be enriched in antimony (5–10x DIV). It is unclear whether this is natural or that this is part of a substance used in this facility.	Moderate	*Likely:* Asbestos building materials identified on site and potentially within the made ground. Antimony found but source not known. *Medium severity:* Chronic damage to human health receptors.
Bader Company BAG_02	An operational mortar bomb facility approximately 188,000 m^2 in area. Relatively modern, no clear sign of contamination.	The soil samples contain an elevated concentration (1x DIV) of lead. Both groundwater and surface water nearby show no sign of contamination.	Moderate / low	*Low likelihood:* Relatively modern facility, no clear sign of contamination. Testing has identified elevated levels of lead. *Medium severity:* Chronic damage to human health receptors.

Table F1: *Summary of risk assessment (continued)*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Baghdad				
That Alsawary Company BAG_03	Rocket fuel and chemicals supplying a battery plant. Currently the factory is not working.	The factory is scattered with scrap metal, debris, and rubble. Locally there are spills or leakages that cause aromatic hydrocarbon contamination in soil (10x DIV). The surface water close to the facility is not contaminated above the LLD. However, one sample could not be tested due to presence of NAPL.	Moderate / low	*Likely:* Hydrocarbon contamination identified, although contamination levels appear to be relatively low. Risk to offsite receptors is therefore considered low. *Mild severity:* Pollution of non-sensitive water resources.
Ibn Al Waleed BAG_04	Used as military base and looks relatively well maintained. There are some areas of scrap material.	Lab results indicate elevated levels of lead (1x DIV). Despite visible confirmation of hydrocarbons, lab results did not show indication of a diesel spill. Groundwater is not contaminated.	Moderate / low	*Low likelihood:* Levels of contamination appear to be relatively low and therefore risk to offsite receptors is considered low. There is some risk to the staff if they interact directly with the soil. *Medium severity:* Contamination identified on site has the potential to cause chronic damage to human health receptors.
Al Harith Factory BAG_06	Tank repair factory	Despite the visible observations and odors of chemicals and contamination, neither soil nor surface water show analytical evidence of contamination.	Moderate / low	*Low likelihood:* Limited visible and olfactory evidence of contamination. Chemical tests did not identify the presence of contamination in the samples analyzed. *Medium severity:* Potential pollution of sensitive water resources, ecological receptors, and chronic damage to people both on- and offsite. Notwithstanding the above, the site is confirmed to be in good repair.
Baghdad Lead Extraction Facility BAG_08	Recycling depleted batteries to lead.	Scrap metal, asbestos, and tar storage. Soil samples contain a high concentration (>100x DIV) of lead, high concentrations of other metals (>5x DIV) and aromatic hydrocarbon contamination.	High	*Likely:* Visible and olfactory evidence of contamination and high concentration (>100x DIV) of lead in soil samples. *Severe severity:* Short-term risk of pollution of sensitive water resources, ecological receptors, and people both on and off the site.

Table F1: *Summary of risk assessment (continued)*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Babil				
Al Furat Company BAB_01	Sulfur noted on the ground and the road of the station. Chlorine tank is discharged directly to the channel of wastewater treatment plant.	Across the facility scrap metal, asbestos, sulfur, and chlorine deposits have been observed. The soil in seems to be generally contaminated with mercury and antimony (5x–10x DIV).	Very high	*Highly likely:* Contamination identified within the made ground include ng asbestos, sulfur, and chlorine deposits. The soil in general seems to be contaminated with mercury and antimony (5x–10x DIV). *Severe severity:* There is the possibility of short-term acute risk to human health.
Diyala				
Diyala Electrical Industries Company DIY_01	The site itself is covered in hardstanding but areas of visible contamination were found away from the hardstanding.	The soil is locally contaminated with aromatic hydrocarbons (>10x DIV), and antimony and molybdenum (5x DIV). Water in the water treatment facility has very high concentrations of pyrene, perylene, and other sVOC components (>100x DIV). The fact that the facility has several manholes without oil separators makes it likely that water from the treatment may spill or leak into the sewer / groundwater / irrigation water, leading to significant health risks for surrounding communities.	Moderate	*Likely:* Areas of contamination noted, but it is unclear if this contamination will impact offsite receptors. The nearest residential receptors are 200m away. *Medium severity:* Chronic damage to human health receptors.
Al Anbar				
State Company for Phosphate in Al-Qaaim City ANB_01	The factory was used to produce: • Triple phosphate fertilizers • Compound fertilizers • Urea • Phosphoric acid • Sulfuric acid. Factory destroyed but old tanks and infrastructure visible.	The factory was completely destroyed by due to bombing. As a result, there is a lot of scrap metal on the site. Chemical testing of soil and water samples did not identify contamination above the LLD.	Low	*Low likelihood:* Based on historical use and current status of the factory, some contamination should be expected on the site even if none has been identified by soil testing. While there is a risk that this contamination will impact nearby residential communities, the distance (1km) makes this risk unlikely. *Medium severity:* There is a risk of chronic damage to human health.

Table F1: Summary of risk assessment (continued)

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Al Anbar				
Alamer factory ANB_03	Alamer Factory is located in an area of arid desert where there is no vegetation cover surrounding the site except for some desert plants. This company specializes in military heavy production (military equipment). Indoor chemical storage areas show signs of contamination on flooring.	Onsite chemical storage warehouses had poor storage practices and visible contamination on the flooring. Some chemicals were unidentifiable. Chemical testing of soil and water samples did not identify contamination above the LLD, with the exception of silver within a single soil sample (>1x DIV).	Low	*Low likelihood:* Based on historical use and current status of the factory, some contamination should be expected on the site even if not identified by chemical testing. While there is a risk of this contamination impacting current site users and residential / farming communities, the distance (700m) makes this risk unlikely. *Medium severity:* There is a risk of chronic damage to human health.
Haditha Oil Refinery ANB_04	Oil pit without liner (discharged directly to the ground). Water treatment unit designed to treat TPHs 2,000 ppm now receives 8,000 ppm and discharges to the ground directly too. Oil refinery receives crude oil to use to produce naphtha, kerosene, and fuel.	Despite observations of hydrocarbon contamination, the analyses do not show evidence that the soil is contaminated. Testing of water from the water treatment indicated very high concentrations of pyrene, perylene, and other sVOC components (50–100x DIV).	Moderate	*Likely:* Evidence of hydrocarbon contamination including presence of VOC in surface waters. However, the samples and contamination are located within an oil pit away from the most sensitive receptors. *Medium severity:* Long-term chronic impact to human health likely to residence nearby, especially those within the refinery boundary.
Pesticides Factory Al-Falluja City ANB_05	Al-Falluja City Pesticide factory.	Despite the odor of pesticides, the soil sample and water samples tested show contaminants below LLD. The investigation did not test for the most likely COPC including herbicides, pesticides, asbestos, and Polychlorinated Biphenyl.	Moderate / low	*Likely:* Contamination due to historical use. *Mild severity:* Pollution of non-sensitive water resources.
Al Shahid Company ANB_06	This company works in metal smelting and forming (copper and brass mainly). It operates six smelters that run on liquid fuel. The company also contains an electroplating unit for copper plates. The company was operating during the time of the visit.	Locally the soil is slightly enriched with copper (1x DIV). No other contaminants were detected by the soil analyses. The water sample taken shows no evidence of contamination. One water sample was not tested due to presence of NAPL.	Moderate / low	*Likely:* Contamination due to historical use. Poor storage of chemicals on site with the potential for future release. *Minor severity:* Site staff identified as receptor. Non-permanent human health effects easily prevented by use of personal protective clothing.

***Table F1:** Summary of risk assessment (continued)*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Kirkuk				
Sarolo Station KIR_01, Sarolo Station KIR_04, and KIR_05	Wet oil unit	In several locations, evidence of hydrocarbon spills can be identified. The soil that was sampled is contaminated with aromatic hydrocarbons (>10x DIV).	Moderate	*Likely:* There is evidence of hydrocarbon contamination on the site (>10x DIV). The hydrocarbon leaks are noted to be confined to natural storage pits. *Medium severity:* Chronic damage to human health for the small number of site staff.
Sarolo Station KIR_02	Degassing station and oil product.	There is a spill of approximately 20 m^2 where the soil is severely contaminated with aromatic hydrocarbons, although this has not been identified in the chemical test results. Testing indicates that the soil is enriched in silver (>5x DIV) though this is interpreted to be naturally occurring.	High	*Highly likely:* There is a hydrocarbon spill of approximately 20 m^2. *Medium severity:* Significant damage to the ecosystem, crops, and pollution of non-sensitive water resources. However, unlikely to be a direct threat to human health due to the remote nature of the site.
Sarolo Station KIR_03	An industrial site that includes gas compression and isolation units, as well as wet oil treatment units. The surrounding land is polluted. The surrounding land is polluted industrial sites, which includes isolation and gas compression units, in addition to wet oil treatment units.	Evidence of hydrocarbon spills is visible in several locations. However, lab results show there is exceedance of the LLD, except for silver.	Moderate	*Highly likely:* There is visible evidence of hydrocarbon contamination. *Mild severity:* Pollution of non-sensitive water resources, but direct threat to human health unlikely due to the remote nature of the site.
Dawood Station for Oil Refining KIR_06	Degassing station Dawood oilfield. Two-phase separators and tanks for oil storage. Previous oil spills were caused by broken tankers and pipelines. Spills are handled by Health, Safety and the Environment Division (North Oil Company).	The soil is locally severely contaminated with aromatic hydrocarbons (>100x DIV). The well water was analyzed and is contaminated with benzene, toluene, xylene, and aromatic hydrocarbons. Due to the fact that residents and agricultural lands are close by there might be a risk to their health.	Moderate	*Low likelihood:* Contamination identified. Contamination stored in unlined pit, therefore there is a chance it will leach into the underlying groundwater and affect offsite receptors. *Medium severity:* Chronic damage to human health.

Table F1: Summary of risk assessment (continued)

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Kirkuk				
Bai Hassan North Degassing Station KIR_07	The station has the following units: • Degassing unit • Wet oil unit • Gas compressor unit • 40 production wells • 7 injection wells. The total production is 40,000 barrels per day. The current production is 31,000 barrels per day.	The soil is locally severely contaminated with aromatic hydrocarbons (10x to >100x DIV). There are somewhat higher concentrations of arsenic in the soil (1x DIV) which might be a natural occurrence.	High	*Highly likely:* Hydrocarbon contamination identified and proven through chemical testing. *Medium severity:* Pollution of non-sensitive water resources connected to sensitive water resources such as the Zab river.
Bai Hassan North Degassing Station KIR_08		Soil sample taken. However, lab testing could not be undertaken due to presence of free phase hydrocarbons.	High	*Highly likely:* Hydrocarbon contamination identified and proven through chemical testing. *Medium severity:* Pollution of non-sensitive water resources connected to sensitive water resources such as the Zab river.
Bai Hassan North Degassing Station KIR_09		The soil is locally highly contaminated with aromatic hydrocarbons (50x DIV). There are somewhat higher concentrations of arsenic in the soil (1x DIV), which might be a natural occurrence. No groundwater data available.	High	*Highly likely:* Hydrocarbon contamination identified and proven through chemical testing. *Medium severity:* Pollution of non-sensitive water resources connected to sensitive water resources such as the Zab river.
Bai Hassan North Degassing Station KIR_10		Despite visible evidence of contamination, the soil sampled does not show evidence of being contaminated. However, there are higher concentrations of arsenic in the soil (1x DIV), which might be a natural occurrence. The groundwater from a farm well used for irrigating crops shows high concentrations of various SVOC such as Indeno (1,2,3-cd)pyrene (>50x DIV).	High	*Highly likely:* Hydrocarbon contamination identified and proven through chemical testing. *Medium severity:* Pollution of non-sensitive water resources connected to sensitive water resources such as the Zab river.

Table F1: *Summary of risk assessment (continued)*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Kirkuk				
Bai Hassan North Degassing Station KIR_12		The soil is locally severely contaminated with aromatic hydrocarbons (10x to >100x DIV). There are somewhat higher concentrations of arsenic and barium in the soil (>1x DIV), which might be a natural occurrence.	High	*Highly likely:* Hydrocarbon contamination identified and proven through chemical testing. *Medium severity:* Pollution of non-sensitive water resources connected to sensitive water resources such as the Zab river.
Bai Hassan North Degassing Station KIR_13		The soil is locally severely contaminated with aromatic hydrocarbons (10x to >100x DIV). There are somewhat higher concentrations of arsenic and barium in the soil (>1x DIV), which might be a natural occurrence.	High	*Likely:* Hydrocarbon contamination identified and proven through chemical testing. *Mild:* Pollution of non-sensitive water resources.
Baba Gurgur Station KIR_14	Degassing station, wet oil proccing, and gas compressor with gas drying units.	A spill originating from the factory is spreading down the slope. The soil is severely contaminated with aromatic hydrocarbons (>100x DIV) and TPH (>5x DIV). Due to the sloping terrain, the spill has spread approximately 8 km to the south, most likely passing villages, agricultural lands, and surface water that may risk exposure to the contamination. Despite the visible evidence and odor of hydrocarbons, surface water only shows contamination of hexachlorobenzene (>5x DIV), which is often used as pesticide.	High	*Highly likely:* Hydrocarbon contamination over a significant area is likely to come into contact with a number of receptors. *Medium severity:* Such contamination has the potential to cause chronic damage to human health and significant environmental impacts.
Baba Gurgur Station KIR_19	Wet oil treatment plant.	The soil is, in certain places, contaminated with aromatic hydrocarbons (>10x DIV).	Moderate / low	*Likely:* There is visible evidence of hydrocarbon contamination that has been confirmed through chemical testing. *Mild severity:* Pollution of non-sensitive water resources.

***Table F1:** Summary of risk assessment (continued)*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Kirkuk				
Bai Hassan South Oilfield KIR_15, KIR_17, and KIR_23	Degassing station, wet oil processing, and gas compressor with gas drying units. Oil visible at surface in pit and drainage ditches.	A pathway of oil is spreading outside the facility. The soil in close proximity of this location is severely contaminated with aromatic hydrocarbons (10x–>100x DIV). There are somewhat higher concentrations of arsenic in the soil (1x DIV). which might be a natural occurrence. The contaminations are spreading through a manmade pathway and may contaminate surface water and residential areas (within 500 m).	High	*Highly likely:* There is visible evidence of hydrocarbon contamination that has been confirmed through chemical testing. *Medium severity:* Such contamination has the potential to cause chronic damage to human health and significant environmental impacts.
Serbach Station KIR_16	Gas isolation station. Pipeline leakage.	The soil is severely contaminated with aromatic hydrocarbons (>100x DIV). In some locations old spills have been covered up with clean soil. No water has been sampled or identified.	Moderate	*Highly likely:* There is visible evidence of hydrocarbon contamination, which has been confirmed through chemical testing. *Mild severity:* Significant damage to crops and pollution of non-sensitive water resources are possible.
Haljira Gas Isolation Station KIR_18 and KIR_20	Hanjira gas isolation station.	There are locations that show clear visual evidence of hydrocarbon contamination. The sampled soil shows elevated aromatic hydrocarbon concentrations (> 100x DIV).	Moderate	*Highly likely:* There is visible evidence of hydrocarbon contamination, which has been confirmed through chemical testing. *Mild severity:* Pollution of non-sensitive water resources.
Showraw Station & Kat Factory KIR_24	This is an asphalt production plant that includes several departments. No contamination was observed on the site, which appears to be well maintained including lined ponds.	Based on the sampled soil and the sampled water from a well used for reverse osmosis. there is no contamination above the adopted DIV with the exception of silver in soil samples.	Low	*Low likelihood:* No visible or olfactory sign of contamination. *Mild severity:* Pollution of non-sensitive water resources including stream and water abstraction wells (used for reverse osmosis).
Hawija Pesticides Stores KIR_25	Yellow corn plant, seed purification, and storage. The factory was damaged by bombing.	Based on the sampled soil and the sampled water from the well, there is no contamination on this site. However, fieldworkers noted seeing and smelling chemicals.	Moderate / low	*Likely:* Visible and olfactory signs of contamination identified on site. *Mild severity:* Pollution of non-sensitive water resources.

Table F1: Summary of risk assessment (continued)

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Kirkuk				
Mulla Abdulla Station (IT1)KIR_26	The first station of the Iraqi-Turkish oil line. The station stores and pumps oil received from the concentration station, which is located adjacent to Mulla Abdulla Station. The date of establishment is 1975.	The soil samples collected indicate exceedance of 1x DIV for arsenic and TPH, though there is a 10x exceedance relating to total aromatics.	Very high	*Highly likely:* Significant area of hydrocarbon contamination likely to impact multiple receptors. *Severe:* There is a possibility of short-term acute risk to human health.
Qutan Gas Isolation Station—Babakkar Oilfield KIR_28	Qokan gas isolation station / Babakkar oilfield	The contamination on this hotspot exists from a single pit of aromatic hydrocarbon spill. The soil close to this storage pit exceeds the DIV at least 10 times. The site is littered with old pipes and insulation.	High	*Highly likely:* Hydrocarbon pollution is present, with evidence of historic surface runoff increasing likelihood of direct contact with residents. *Medium severity:* Chronic damage to human health posed to nearby residents.
Gas and Oil Separation Plant in Jabal Bur KIR_30	Degassing station since 1956, destroyed in 1991 and 2003. The plant's production is 12,000 barrels per day. The total number of producing wells is 41 and the number of operating during the visit is 6 wells. Plant sends gas to a gas compressor station in North Oil Company. Waste oil is sent to two unlined pits outside the fence of the station.	A spill that originates from the factory is spreading down the slope. The soil is contaminated with aromatic hydrocarbons (>10x DIV).	High	*Highly likely:* Hydrocarbon contamination over a significant area is likely to come into contact with a number of receptors. *Medium severity:* Such contamination has the potential to cause chronic damage to human health and significant environmental impacts.
Showraw Station & Kat Factory KIR_24	This is an asphalt production plant that includes several departments. No contamination was observed on the site, which appears to be well maintained including lined ponds.	Based on the sampled soil and the sampled water from a well used for reverse osmosis. there is no contamination above the adopted DIV with the exception of silver in soil samples.	Low	*Low likelihood:* No visible or olfactory sign of contamination. *Mild severity:* Pollution of non-sensitive water resources including stream and water abstraction wells (used for reverse osmosis).
Khabaz Gas Station KIR_31	Gas isolation plant that produces 26,000 barrels per day. Wet oil unit to separate water from oil so that the oil is ready for export. A unit to compress the gas and send it to the North Gas.	Contamination and oil spills found at several locations, and soil severely contaminated with aromatic hydrocarbons (5x–>100x DIV). Analyzed surface water is severely contaminated with SVOC (perylene, pyrene; 100x DIV) and hexachlorobenzene (1x–5x DIV).	Moderate / low	*Likely:* Hydrocarbon contamination identified and confirmed through chemical testing. *Mild:* Pollution of non-sensitive water resources. Significant damage to crops

__Table F1:__ Summary of risk assessment (continued)

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Kirkuk				
Ajil Oil Field SAL_001_H, SAL_011_H, SAL_012	Ajil oil field produces 10,000–15,000 barrels per day, which includes production in the Alas field. The total number of wells: 90 wells, including a field (Ajil, Alas, and Al-Nakhila). CPF to separate the associated gas and send it to the North Oil Company at a rate of 70–100 cubic meters per day.	Soil samples show evidence of aromatic hydrocarbon contamination (>50x DIVs). Sampled groundwater from wells in agricultural land show dangerously high concentrations of SVOC (chrysene, Indeno(1,2,3-cd) pyrene; 100x DIV). Other SVOCs are found in lower concentrations.	Moderate	*Highly likely:* Visible hydrocarbon contamination at surface confirmed by chemical test results. Satellite imagery indicates extensive contamination. *Medium severity:* Pollution of sensitive water resources. Significant damage to crops.
Alass Oil Field SAL_002_H	83 oil wells, of which eight are productive. Opportunity for site visits were limited because the area is unsafe (ISIS and UXO).	Samples show evidence of aromatic hydrocarbon contamination (>50x DIVs) in the soil close to an isolated oil pit. The pit is located in between mountains on an isolated spot, so there are no residents or staff in this area to be exposed to this contamination.	Moderate	*Highly likely:* Visible contamination confirmed by laboratory testing. *Mild severity:* Pollution of non-sensitive water resources.
Northern Fertilizers Company SAL_003_H	Company established in 1990, in operation until 2014, when it was destroyed in an ISIS attack. The site is littered with scrap metal and rubble. Main location: Salah al-Din Governorate, Baiji District. Produces nitrogen (urea-based) fertilizers and petrochemical products. A report from the national security says there is a radioactive element in a reactor device ((301D) high pressure reactor (co 60) Intensity (mbq) 400–2000). The second reactor was not found in its place (high pressure stripper).	The soil is enriched in lead and other metals (5x DIV). Earlier research claimed the presence of two radioactive reactors, of which only one is still present. The site is abandoned, there are no residential areas nearby, and there is no contact with surface water, so there is no health or spreading risks for these contaminations.	Moderate	*Likely:* Visible contamination confirmed by laboratory testing. *Mild severity:* Pollution of non-sensitive water resources.
AL Mansour Factories for Vegetable Oils SAL_004_H	AL Mansour Factories for Vegetable Oils was destroyed in the war with ISIS.	Aromatic hydrocarbons leaked out of a transformer (> 100x DIV). Sampled groundwater from wells at the site shows high concentrations SVOC (chrysene, Indeno(1,2,3-cd) pyrene; 50x DIVs). Other SVOCs are present in lower concentrations.	Moderate	*Highly likely:* There is evidence of groundwater contamination based on chemical test results. *Mild severity:* Pollution of non-sensitive water resources.

Table F1: *Summary of risk assessment (continued)*

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Kirkuk				
Baiji Power Plant SAL_005_H	The plant was destroyed by bombing. The station has six units with a capacity of 169 megawatts per unit, and a total capacity of about 1,000 megawatts.	The soil is contaminated with aromatic hydrocarbons (>10x DIV).	Moderate / low	*Likely:* Historical spills caused by bombing. *Mild severity:* Pollution of non-sensitive water resources.
Salah Al-Din SAL_06, SAL_006_H	This site is located in an open area between the North Fertilizers Company and Baiji Oil Refinery. The site is not surrounded by any buildings, infrastructure or factories. It has been sampled because it is an historical contamination without a known cause.	The soil is contaminated with aromatic hydrocarbons (>10x DIV).	Moderate / low	*Likely:* Visible evidence of groundwater contamination supported by chemical testing. *Mild severity:* Pollution of non-sensitive water resources.
Al Seenia Oil Refinery SAL_007_H	The refinery was built in 1976 and consists of several units capable of producing fuel oil, gas oil, naphtha, kerosene, and other chemicals. Production capacity is 30,000 barrels per day. Only three units are operation Oil spills, bombed oil storage tanks during war, and leakage from old pipelines were observed.	The sampled soil shows evidence of aromatic hydrocarbon contamination (>100x DIVs). Sampled groundwater from an agricultural well close by and a (waste disposal point) show dangerously high concentrations of SVOC (chrysene, Indeno(1,2,3-cd) pyrene; 100x DIVs). Other SVOCs are present in lower concentrations.	Moderate	*Likely:* Multiple sources of contamination observed on site and proven by chemical testing. However, nearby residents are upgradient of the site, reducing the likelihood that contamination will migrate in this direction. *Medium severity:* There is potential for long-term chronic damage to human health.
Baiji Refinery / North Oil Company SAL_009_C	The refinery consists of several production units producing different kinds of fuel and chemicals. 70% of the refinery, including two refineries with a capacity of 10,000 barrels per day and 9 storage tanks, were destroyed by war. Four storage tanks were partially destroyed and are currently under construction.	The sampled soil locally shows evidence of aromatic hydrocarbon contamination (>100x DIVs) in the soil. Sampled water on site show dangerously high concentrations of SVOC (chrysene, Indeno(1,2,3-cd) pyrene; >100x DIVs). Other SVOCs are present in lower concentrations, as is aromatic hydrocarbon contamination.	Very high	*Highly likely:* Multiple sources of contamination identified, observed on site, and proven by chemical testing. *Sever severity:* Nearby residents at risk from contamination that has migrated off site. VOCs present an acute risk to human health.
Salah Al-Din SAL_10, SAL_010_IC	The site is an open area not surrounded by any buildings, infrastructure or factories. It has been sampled because it is an historical contamination without a known cause.	The soil is contaminated with aromatic hydrocarbons (>100x DIV).	Moderate / low	*Low likelihood:* Visible evidence of groundwater contamination supported by chemical testing. *Mild severity:* Pollution of non-sensitive water resources.

Table F1: Summary of risk assessment (continued)

Site name and hotspot ID	Notes	Chemical results and conclusions	Risk rating	Justification
Kirkuk				
K2 Station SAL_013	Land between K2 and K3 pumping station. The refinery was established in 1966.	The site contains small spills that show visible evidence of aromatic hydrocarbon contamination. The sampled soil, however, is not contaminated. It is likely that the spills are small and local and pose no immediate risk to surrounding communities or staff (if not directly contacted).	Low	*Likely:* Surface oil spills identified on site but extent is limited. *Minor severity:* Site staff identified as the most likely receptors.
A General Company for Communication Equipment and Power SAL_014_C	The factory was established in 1980 and includes: • A digital meter factory • An electrical transformer repair factory • A paint factory (currently out of service) • Storage for chemicals • A treatment unit of a paint factory • Metal columns and towers factory.	The site contains factories with multiple occupations. A strong chemical odor was detected near an old paint-production facility. The soil here was severely contaminated with metals such as copper, silver (100x DIV), antimony (50x DIV), lead and chromium (> 10x DIV).	High	*Highly likely:* There are a number of contaminating land uses. Chemical testing has identified high levels of metals in the soil. *Medium severity:* The most relevant receptor is considered to be residential in close proximity to the site. Chronic damage to human health is a possibility.
Al Fatha SAL_015_H	Historical contamination and the source not unknown. An oil pipe crosses over the Tigris River.	Visible areas show leaks in the pipes over the river, contaminating the riverbanks and most likely the river itself. Samples are severely contaminated by aromatic hydrocarbons (>100x DIVs). River water shows contaminations with chrysene (>10x DIV) and perylene (> 50x DIV) close to the riverbanks.	Very high	*Highly likely:* Visible evidence of hydrocarbon contamination supported by chemical testing of soil and water samples. *Severe severity:* Short-term risk of pollution of sensitive water resources.
Al Sahl Valley SAL_016_H	Al Sahl is a valley where oil pipelines are in a mountainous area that slopes down approximately 2 km to the Tigris river. Here, hydrocarbon waste accumulates as a result of leakage in the pipelines from maintenance operations and terrorist attacks. The potential source is Biji Refinery.	Visible areas show ongoing leaks from oil pipelines that make their way down to the river. Samples are contaminated with high concentrations of aromatic hydrocarbons (>50x DIV). Water samples show contaminations with chrysene (>10x DIV) and perylene (>100x DIV).	High	*Likely:* Visible evidence of hydrocarbon contamination supported by chemical testing of soil and water samples. Attempts to stop the contamination have been made but do not appear to have been effective. There is a possibility contamination will reach the Tigris river. *Severe severity:* Short-term risk of pollution of sensitive water resources.

Source: *Site Assessment and Analysis by MoE and RSK Environment LLC 2022.*

Appendix G: Participants of stakeholder consultations

Stakeholder no.	Name	Position and organization
Consultations in Baghdad (March 19, 2023)		
1	Mohammed Amjad Ahmed	Baghdad Environment Department
2	Jasim Ali Nawar	Ministry of Environment – Technical Department
3	Hanan Mahmood Sulyman	Falowja Environment Department
4	Ahmed Kamil Dawood	Anbar Environment Department
5	Ihab Moayed Shihab	Haditha Refinery
6	Abdul Ghafoor Md Abdul Ghafoor	Ministry of Oil
7	Ahmed Khalaf Khamees	Ministry of Oil
8	Mostafa Salim Rasheed	Ministry of Environment
9	Waleed Ali Hussein	Ministry of Environment
10	Abdul Rahman Majeed Abdul Jalil	Ministry of Environment
11	Monther Noaaman Thabet	Haditha Sub-District office
12	Husham Ahmed Hashim	Aby Ghraib Sub-District Office
13	Dhafer Hobi Abdullah	North Refinery Company – Haditha Refinery
14	Raad Faisal Abbas	Mayor of Al Taji District – Baghdad Governorate
15	Raed Mohammed Khalaf	Mayor of Al Tarmiya District – Baghdad Governorate
16	Ammar Al Aaraji	Mayor of Al Rasheed District – Baghdad Governorate
17	Ahmed Ali	World Bank Representative
18	Nada Mohammed Ibraheem	Iraqi Organisation for Women And Future
19	Israa Gareen Qasim	Al Israa for Human Rights Care
20	Ikhlas Abdullah Khalaf	Al Israa for Human Rights Care
21	Sameem Salam Jali	Soqya Foundation – Anbar
22	Omar Fadhil Salih	Al Haq Foundation For Human Rights – Anbar
23	Dhuha Alaa Al Falahi	Al Aghsan Foundation – Anbar
24	Anas Ibraheem Hamad	Dream Organisation – Baghdad
25	Waleed Ali Hussein	Ministry of Environment – Technical Department
26	Mustafa Salim Rasheed	Ministry of Environment – Technical Department
27	Mais Bahri Sabbar	Baadna B Khair Organisation – Anbar
Consultations in Kirkuk (March 12, 2023)		
1	Dr. Mohammed Khodir Mohammed	Kirkuk Environment Department
2	Nishtiman Fattah Ammeen	Kirkuk Governor Office
3	Hasan Abid Lateef	Al Dibis District Mayor

__Appendix G:__ Participants of stakeholder consultations (continued)

Stakeholder no.	Name	Position and organization
4	Montasir Naji Abdullah	Salah Al-Din Environment Directorate
5	Ammar Saleem Mahjoob	Ninewa Environment Directorate
6	Alyaa Sarmad Abid Alwahab	Ministry of Environment – Minister Office
7	Waleed Ali Hussein	Ministry of Environment – Minister Office
8	Laith Mohammed Khalaf	Baiji Refinery
9	Dhafer Howayesh Abdullah	Baiji Refinery
10	Colonel Jazey Sameer Mahmood	Kirkuk Environment Protection Police
11	Monther Md Abid Alkareem	Kirkuk Environment Protection Police
12	Mohammed Jabbar Khudhair	Kirkuk Environment Protection Police
13	Mohammed Ahmed Najim Addin	Northern Environment Department
14	Ribwar Mohammed Ismaeel	Intelligence Department
15	Husam Abid Al Mutalib	Ministry of Environment – Technical Affairs Dept.
16	Mohammed Salman Hasan	North Oil Company – Operation Department
17	Talib Hussein Khalil	North Oil Company – Operation Department
18	Riyadh Adham Abdullah	North Oil Company, HSE Department – Environment
19	Najdat Khalid Shafeeq	North Oil Company – Operation Department
20	Tahseen Yaseen Tawfeeq	North Oil Company, HSE Department – Environment
21	Mazin Faiq Mahmood	Kirkuk Environment Department
22	Salih Jasim Mohammed	Head of Farmers Associations in Al Dibis District
23	Rokan Awad Khaleel	North Oil Company – Oil Pipes Section
24	Ali Abdul Malik	Kirkuk National Security Department
25	Karbaesh Majeed Aswad	North Oil Company – Environment Department
26	Shkoofa Mohamed Ubaid	Green Kurdistan Organisation
27	Hawary Hashim Sayed	Kokar Foundation
28	Mohammeed Habib Najeeb	Kokar Foundation
29	Husam Abid Almutalib Hashim	Ministry of Environment – Technical Affair Dept.
30	Waleed Ali Hussein	Ministry of Environment – Minister Office
31	Saad Salih Mahdi	Nahno Al Salam for Voluntary Work Organisation
32	Yaseen Faraj Yaseen	Ta'alo Nasna'a Al Farah Organisation
33	Omar Qusai Khairullah	Ta'alo Nasna'a Al Farah Organisation
34	Omar Hamid Mohammed	Ta'alo Nasna'a Al Farah Organisation
35	Mokhtar Hashim Mohammed	Nahno Al Salam for Voluntary Work Organisation
36	Halo Ali Hama	Kokar Foundation

Appendix H: GoI Project team

Stakeholder no.	Name	Position and organization
Ministry of Environment, Government of Iraq		
1	Waleed Ali Hussein	Senior Chief Engineer, Technical Director, Air Quality and Noise Monitoring and Assessment Department
2	Hussam Abdel Muttalib Hashim	Chief Engineer, Oil Pollution Division
3	Emad Ali Saleh	Senior Chief Engineer, Industrial and service activities monitoring Department
4	Amer Abdel Karim Nasser	Chief Chemist, Contaminated Sites Division
5	Ali Sami Khashan	Associate Chief Biologist, Contaminated Sites Division
6	Mustafa Salem Rashid	Chief Engineer Assistant, Carcinogenic Factors Division
7	Rasha Raad Salman	Chief Engineer Assistant, Carcinogenic Factors Division
8	Rafal Adel Nasser	Senior Engineer, Carcinogenic Factors Division
9	Mahmoud Khaled Mahmoud	Chief Chemist, Hazard Waste Division
10	Aliaa Sarmad Abdel Wahab	Chief Engineer Assistant, Industrial and service activities monitoring Department
11	Mohammed Adel Assaf	Chief Chemist, Following Department
12	Mohamed Ahmed Najmuddin	Senior Chief Engineer, Technical Department, Directorate of Environmental Protection and Improvement in the Northern Region
13	Ammar Selim Mahjoub	Chief Chemist, Technical Department, Ninevah Environment Directorate
14	Sabah Muhammed Salim	Senior Chief Chemist, Contaminated Sites Division, Ninevah Environment Directorate
15	Mazen Faeq Mahmoud	Engineer, Contaminated Sites Division, Kirkuk Environment Directorate
16	Miqdam Adel Mahmoud	Chemist, Contaminated Sites Division, Salah al-Din Environment Directorate
17	Jassim Ali Nawar	Senior Chemist, Technical Department, Directorate of Environmental Protection and Improvement in the Central Region
18	Mohamed Amjad Ahmed	Engineer, Contaminated Sites Division, Baghdad Environment Directorate
19	Ahmed Kamel Daoud	Assistant Chief Chemist, Contaminated Sites Division, Anbar Environment Directorate
20	Salem Jassim Dahesh	Assistant Chief Chemist, Contaminated Sites Division, Diyala Environment Directorate
21	Harith Jalil Razzouqi	Senior Chief Chemist, Contaminated Sites Division, Diyala Environment Directorate
22	Adnan Yas Khudair	Senior Chief Engineer, Contaminated Sites Division, Babil Environment Directorate
23	Moath Walid Ibrahim	Engineer, Contaminated Sites Division, Babil Environment Directorate
Other organizations		
24	Tahseen Yassin Tawfik	Senior Chief Engineer, Health Safety Environment Department, North Oil Company (external to MoE)
25	Muhammad Mukhlif Aswad	Technical, Health Safety Environment Department, Ninevah Fields Authority
26	Dhafer Howish Abdullah	Associate Chief Biologist, Health Safety Environment Department, North Refineries Company
27	Laith Hamad Khalaf	Associate Chief Biologist, Health Safety Environment Department, North Refineries Company
28	Hussam Thabet Nofan	Technical Manager, Following Department, Haditha Refinery
29	Hisham Abdel Nabi Khalifa	Chief Engineer, Health Safety Environment Department, Haditha Refinery

References

Carroll C, Slacalek J, Tokuoka K, and White MN. 2017. "The Distribution of Wealth and the Marginal Propensity to Consume." Quantitative Economics 8: 977–1020. https://doi.org/10.3982/QE694.

CL:AIRE (Contaminated Land: Applications in Real Environments). 2010. "A Framework for Assessing the Sustainability of Soil and Groundwater Remediation, March 2010." CL:AIRE, London. https://www.claire.co.uk/component/phocadownload/category/16-surf-uk-bulletins?download=61:surf-uk-framework-final-march-2010.

Dutch Ministry of Housing, Spatial Planning, and the Environment. 2000. "Dutch Target and Intervention Values." https://support.esdat.net/Environmental%20Standards/dutch/annexs_i2000dutch%20environmental%20standards.pdf

Gorelick N, Hancher M, Dixon M, Ilyushchenko S, Thau D, and Moore R. 2017. "Google Earth Engine: Planetary-scale geospatial analysis for everyone." Remote sensing of Environment 202: 18–27. https://doi.org/10.1016/j.rse.2017.06.031.

IAEA (International Atomic Energy Agency). 2018. "Radiological conditions in selected areas of southern Iraq with residues of depleted uranium." Radiological Assessment Reports Series. Vienna: IAEA. https://www.iaea.org/publications/8287/radiological-conditions-in-selected-areas-of-southern-iraq-with-residues-of-depleted-uranium.

ILO (International Labor Organization). 2022. "Iraq Labor Force Survey, 2021." International Labor Organization. https://www.ilo.org/beirut/publications/WCMS_850359/lang--en/index.htm.

Kadhim Z, Suaad A, and Awf A. 2022. "The Reality of the Cultivation and Production of Oil Crops and the Manufacture of Vegetable Oils in Iraq: A Review of Selected Applied Studies". Review article.

MoE (Ministry of Environment, Iraq), Hatfield Consultants LLP, CLS, and GeoVille. 2022. "Mapping Pollution Hotspots in Iraq." [Unpublished internal report produced for European Space Agency Earth Observation Clinic and The World Bank].

MoE (Ministry of Environment, Iraq) and RSK Environment LLC. 2022. "Analysis of Pollution in Environmental Hotspots of Iraq." [Unpublished internal report produced for The World Bank].

MoE (Ministry of Environment, Iraq) and Hatfield Consultants LLP. 2022. "Capacity Building Support for Mapping and Data Management of Environmental hotspots in Iraq." [Unpublished internal report produced for The World Bank].

MoE and RSK Environment LLC. 2023. "Stakeholder Consultations and Environmental Hotspots in Iraq." [Unpublished internal report produced for The World Bank].

Rudland DJ, Lancefield RM, and Mayell PN. 2001. Contaminated Land Risk Assessment: A Guide to Good Practice: C552. London: CIRIA.

Swartjes FA, Rutgers M, Lijzen JPA, Janssen PJCM, et al. 2012. "State of the art of contaminated site management in The Netherlands: Policy framework and risk assessment tools." Science of The Total Environment 427: 1–10. https://doi.org/10.1016/j.scitotenv.2012.02.078.

UNEP (United Nations Environment Programme). 2005. "Assessment of Environmental hotspots in Iraq." UNEP. https://www.unep.org/resources/report/assessment-environmental-hot-spots-iraq#:~:text=It%20is%20estimated%20that%20Iraq,and%20open%20to%20public%20access.

UNEP (United Nations Environment Programme). 2007. "UNEP in Iraq: Post-conflict Assessment, Clean-up and Reconstruction." UNEP. https://www.unep.org/resources/report/unep-iraq-post-conflict-assessment-clean-and-reconstruction.

UNEP (United Nations Environment Programme). 2018a. "Rapid Institutional Capacity Needs Assessment of Iraq's Ministry of Health and Environment." UNEP.

UNEP (United Nations Environment Programme). 2018b. "Iraq Contaminated Site Assessment Workshop Report." UNEP. https://www.unep.org/resources/report/iraq-contaminated-site-assessment-workshop-report.

UNMAS (United Nations Mine Action Service). 2021. "Iraq Programme Report 2021." UNMAS. https://iraq.un.org/en/186841-iraq-programme-report-2021.

WFP (World Food Programme). 2021. "Agricultural value chain study in Iraq – Dates, grapes, tomatoes and wheat." WFP. https://www.wfp.org/publications/agricultural-value-chain-study-iraq-dates-grapes-tomatoes-and-wheat-2021.

World Bank. 2010. "International Experience in Policy and Regulatory Frameworks for Brownfield Site Management." Washington, DC: World Bank. https://openknowledge.worldbank.org/entities/publication/59fc90d0-8c67-519e-b15e-d9fae4babcd9.

World Bank. 2018. "Damage and Needs Assessment of Affected Governorates." Part 2 of "Iraq Reconstruction & Investment." Washington, DC: World Bank. https://openknowledge.worldbank.org/entities/publication/8ba990ba-26d9-59aa-bfd6-6591250bb588.

World Bank. 2019. "Kosovo: Healing Land for the Future." Washington, DC: World Bank. https://openknowledge.worldbank.org/entities/publication/6798af5b-8dfa-552b-a23e-ebc94fa03cfd.

Zhu Z and Woodcock CE. 2014. "Continuous change detection and classification of land cover using all available Landsat data." Remote sensing of Environment 144: 152–171. https://doi.org/10.1016/j.rse.2014.01.011.

Zhu Z, Zhang J, Yang Z, Aljaddani AH, et al. 2020. "Continuous monitoring of land disturbance based on Landsat time series." Remote Sensing of Environment 238: 111116. https://doi.org/10.1016/j.rse.2019.03.009.