Amidst the debris...

A desktop study on the environmental and public health impact of Syria's conflict

PAX

www.paxforpeace.nl

Colophon

October 2015
ISBN: 978-90-70443-86-3

PAX means peace. Together with people in conflict areas and concerned citizens worldwide, PAX works to build just and peaceful societies across the globe. PAX brings together people who have the courage to stand for peace. Everyone who believes in peace can contribute. We believe that all these steps, whether small or large, inevitably lead to the greater sum of peace.

If you have questions, remarks or comments on this report you can send them to info@paxforpeace.nl
See also www.paxforpeace.nl

Authors: Wim Zwijnenburg, Kristine te Pas.
Contact: zwijnenburg@paxforpeace.nl
Editors: Doug Weir, Wilbert van der Zeijden.
Satellite maps: Bowy den Braber.

I would like to thank the following people for their input and feedback: Pieter Both, Wilbert van der Zeijden, Ingrid Rijk, Emilia Wahlstrom, Rene Nijenhuis, Hassan Partow, Marjolein Wijninckx, Roos Boer, Aidan Short, Elliot Higgins, Charles Kelly, Sandra Jansen.

Cover photo: Destroyed buildings are pictured, after the cessation of fighting between rebels and forces loyal to Syria's President Bashar al-Assad, in Homs city, May 10, 2014. Picture taken May 10th, 2014. REUTERS/Ghassan Najjar

Table of contents

Table of contents **4**

1. Executive summary **6**
General recommendations on conflict and the environment 8

2. İntroduction **10**
War in Syria 11
Conflict and the environment 12
Methodology and scope 14

3. Syria's environment before the war: a baseline assessment **16**
Geography and demography 16
Economy 16
Agriculture 17
Oil and gas 17
Industry 18
Environmental issues prior to the war 18
Water pollution and scarcity 18
Air pollution 19
Waste management issues 20
Mining industry pollution 20
Environmental policy and governance 21
Conclusions 21

4. The environmental footprint of Syria's war **22**
Damage to oil production and processing areas 22
Historic cases of damage to oil refineries 22
Hazards related to oil refineries 23
In Syria: Damage to oil refineries 23
In Syria: Indirect impact of damage to oil refineries 25

Damage to industrial areas 26
Hazards related to industrial areas 26
In Syria: Damage to industrial areas 27
Damage to critical infrastructure 28
Hazards related to critical infrastructure 28
In Syria: Problems with water supply 29
In Syria: Problems with water management 29
In Syria: Damages to the electricity network 37
The collapse of waste management 37
Hazards related to the collapse of waste management 37
In Syria: Collapse of waste management 38
Conflict rubble 39
Hazards related to conflict rubble 39
In Syria: Conflict rubble 40
Looting 41
Hazards related to looting 41
In Syria: Looting 41
Conclusions 41

5. Weapons related contamination 48
Toxic munitions constituents – health risks and environmental fate 48
Metals 49
Explosive substances 49
Existing literature on the effects of weapon contamination 50
Munitions use Syria 50
Munitions use by government armed forces 51
Use of heavy weapons and explosives 51
Improvised explosive weapons: barrel bombs and rockets 52
Chemicals 52
Vulcano rockets 52
Munitions use by armed groups 52
Home made weapons and ammunitions 53
Explosions in ammunition sites 54
Military scrap metal 56
Public health and weapons related contamination 57

6. Conclusions 60

7. Recommendations 64
General recommendations on conflict and the environment 64
Specific recommendations for Syria 65
Recommendations weapons related contamination 67

Appendix I Hazard Identification Tool Syria 68

Appendix II Reported weapons use 72

Endnotes 76

1. Executive summary

Four years of war in Syria has caused one of the biggest refugee crises in history. About six million Syrians are displaced within Syria, three million have left the country. The intense fighting has damaged many residential and industrial areas in the towns and cities of Syria and civilians living in these areas face a range of threats.

Some of these threats come from environmental pollution generated or exacerbated by the conflict. Rubble, wastes, pollution from damaged industry and munitions residues may all present immediate and long-term threats to civilians and their environment. Nationally, governmental capacity to deal with the environmental consequences of the ongoing war is largely absent. And this does not bode well for the longer term security and safety of those civilians remaining in, or returning to Syria.

This desktop study does not provide a list of verified “hotspots” of environmental damage. The ongoing war in Syria does not currently allow for systematic field measurements in most areas of concern. What this desktop study does aim to do, is link known civilian exposure scenarios to known cases of possible or probable environmental pollution from the war in Syria. In doing so it considers pollution incidents in other conflicts and examples of peacetime military pollution. It also explores an experimental approach to assessing the toxic footprint of the constituents of conventional munitions.

This desktop analysis identifies four types of hazards - feasible scenarios in which the environmental impact of the conflict may have a direct and or long-term impact on the public health of the Syrian people.

1. Targeting of industrial facilities and critical infrastructure.

Concentrated environmental pollution can occur in and around damaged industrial facilities, critical infrastructure and military bases. Matching publically available information on the occurrence of attacks on industrial, military and other sites, and information on the types of activities on those sites, a range of environmental hazards are identified.

Additionally, this report flags the hazards connected to the looting of industrial sites, to artisanal oil production, PCB contamination from damaged power plants and loss of access to clean drinking water and human waste disposal from disruption to essential services.

2. Heavy damage to residential areas and exposure to hazardous building rubble.

Widespread destruction has occurred in residential and light industrial areas in Aleppo, Homs, Hama, Idlib, Deir ez-Zor and around Damascus. Pulverised building materials containing cement dust, house-hold waste, medical waste, asbestos and other hazardous substances can pose acute and long-term exposure hazards to civilians living in or returning to these areas. The management of the vast quantities of rubble the conflict has created will pose a significant challenge.

3. Contamination from the intense use of weapons

The lack of data from conflict-affected areas on the levels of environmental contamination from residues of conventional weapons is troubling. The prolonged and intensive use of explosive weapons in populated areas during the Syrian conflict underscores the necessity to better document the risks heavy metals and energetic materials may pose to civilians in conflict. Similarly, uncontrolled explosions of munitions depots in or near residential areas can cause massive dispersion of heavy metals and other military toxics. Military toxics also pose a hazard to those working in DIY munitions factories and on scrap metal collection sites.

4. The breakdown of environmental services

The collapse in government waste management services can pose an immediate threat from communicable diseases. The absence of services can also lead to air and soil pollution from the uncontrolled burning of wastes. Long-term concerns include the groundwater pollution associated with poorly managed landfill sites and the mixing of waste streams such as industrial or medical waste that should be isolated.

General recommendations on conflict and the environment

Strengthen discourse and mandate on environment and conflict:

The damage to Syria's environment and the immediate and long-term risks that this damage may pose to Syria's civilian population, clearly demonstrate that environmental protection during conflict is a humanitarian issue. Yet environmental damage during conflict suffers from low prioritisation throughout the UN system. This is most clearly reflected in UNEP's currently weak mandate on conflicts, and states should consider how the UN Environmental Assembly (UNEA) , UNEP's new universal governing body could be used to strengthen UNEP's mandate in this field.

Increase cooperation between relevant actors:

Civil society and a range of other humanitarian and military actors should be encouraged to play a greater and more coordinated role in recording and monitoring wartime environmental damage and the risks it poses to lives and livelihoods. This could be done by increased mainstreaming of environmental action, exchange of information and by funding research on environmental impact of conflict.

Develop mechanisms of response and assistance:

Complex conflicts involving state and non-state actors make determining strict liability and accountability for environmental damage and its humanitarian consequences challenging. Meanwhile the environment and its inhabitants remain unassisted. States and other actors should consider the example of Syria as part of the developing initiative aimed at strengthening protection of the environment in relation to armed conflict. In doing so, states and civic society should consider how norms could be developed that help minimise damage and how new systems of response and assistance could improve the protection of the civilians and the environmental upon which they depend.

Improve legal measures to protect the environment:

States debating how protection for the environment could be strengthened in relation to armed conflicts in the UN Sixth Committee should highlight how the principles and standards established in both International Environmental Law and Human Rights Law could be used to inform progress on the topic. ♦

Map 01
Syria

SYRIAN ARAB REPUBLIC
TURKEY
CYPRUS
IRAQ
LEBANON
ISRAEL
JORDAN
MEDITERRANEAN SEA
AL LĀDHIQUIAH
IDLIB
HALAB
AR RAQQAH
AL ḤASAKAH
DAYR AZ ZAWR
ḤAMĀH
ḤIMṢ
DIMASHQ
DARĀ
AS SUWAYDĀ
AL QUNAYTIRAH
Al Lādhiqīyah (Latakia)
Ḥalab (Aleppo)
Ḥimṣ (Homs)
Dimashq (Damascus)
Bayrūt (Beirut)
Ṭarṭūs
Ar Raqqah (Nicephorium)
Dayr az Zawr
Al Ḥasakah
Al Qāmishlī
Ra's al 'Ayn
Tall Tamir
Tall al Abyaḍ
Akçakale
Jarābulus
Barak
Manbij
Al Bāb
Kilis
Gaziantep
Maydān Ikbiz
Tarsus
Adana
Mersin
Yumurtalik
Karataş
Iskenderun (Alexandretta)
Uluçinar
Kirikhan
Reyhanli
Antakya (Antioch)
Iqlīb
Ar Ḥā
Ma'arrat an Nu'mān
Khān Shaykhūn
Bāniyās
Ar Rastan
Ṭarābulus (Tripoli)
Bsharri
Jubayl
Ba'labakk
Zahlah
Sidon
An Nabaṭīyah
Ṣūr (Tyre)
Haifa
Nazareth
Irbid (Arbela)
Jarash
Al Mafraq
Busrā ash Shām
Dar'ā
As Suwaydā'
Al Qunaytirah
Az Zabadānī
Dūmāh
An Nabk
Al Qaryatayn
Tiyas
Tadmur (Palmyra)
Sab' Ābār
Aṭ Ṭanf
Trebil
Maḥaṭṭat al Jufūr
Ar Ruṭbah
Al Qā'im
Abū Kamāl
Buṣayrah
Al 'Ashārah
As Sukhnah
Aṣ Ṣuwār
Al Ṭibnī
Madīnat ath Thawrah
Ash Shaddādah
Sinjār
Tall Kūjik
Tall Abū Ẓahir
Tall 'Afar
Ceylanpinar
Viranşehir
Urfa
Mardin
Nusaybin
Dubūr al Bid
Cizre
Silopi
Zākhū
National capital
Provincial capital
Town, village
Airport
International boundary
Provincial boundary
Expressway
Main road
Secondary road
Railroad
Oil pipeline
0 25 50 75 100 km
0 25 50 75 mi

2. Introduction

Wars leave a toxic footprint in their wake. Considering the scale and duration of the ongoing Syrian conflict, it is beyond doubt that the targeting decisions, the widespread damage to populated areas, the vast quantity of weapons and munitions expended and the breakdown of environmental services and governance will have caused grave environmental damage in Syria, with the significant potential to negatively impact the health of civilians. It is a dimension of warfare that is often overlooked, but one with long-lasting effects that will interfere with post-conflict recovery in Syria.

This study provides an indication of the breadth and scale of pollution caused, or exacerbated, by the war in Syria. In doing so it seeks to contribute to providing a starting point for rigorous post-conflict analyses on the full scale of environmental damage in the country, which we hope will inform decisions on the clean-up of explosive and toxic remnants of war and other risk mitigation measures. Furthermore, this study demonstrates how the protection of the environment links with the protection of civilians. In this regard, it appeals to states, relevant international institutions and non-governmental organisations to fully mainstream environmental assessment in conflict assessment and post-conflict reconstruction efforts.

Identifying appropriate responses to the current build-up of environmental hazards in Syria begins with the methodical collection and assessment of data on practices and incidents. This study aims to contribute to that mapping and calls on all stakeholders to share more widely the information available. In particular data should be made available to the relevant authorities and organisations operating in affected areas. In addition, funding and expertise should be made available for remediation efforts and comprehensive risk management practices. One day the

hostilities in Syria will end. But from a citizens' perspective, recovery – the restoration of a life free from danger and fear, will also need determined action to responsibly and adequately deal with the environmental hazards the conflict has created.

War in Syria

Since the outbreak of hostilities in Syria in 2011, its citizens have witnessed violence and destruction on an enormous scale. At the time of writing, the fighting in Syria has caused the deaths of more than 210,000 people[1], and a dire humanitarian crisis, with more than four million[2] Syrians forced to leave their homes to find safe refuge. Pro-democracy protests in mid-March 2011 – part of the wave of 'Arab Spring' protests seen throughout the Arab world - first erupted in the southern governorate of Daraa, spreading quickly to other parts of the country. Government security forces responded with increasingly brutal force, killing and detaining protesters, while launching large-scale military and policing operations in restive towns and cities nationwide.

Syrian army defections and the formation of armed opposition groups, fuelled by the increasingly violent government crackdown on anti-regime protests, developed into an entrenched armed conflict. Ultimately developing into a full-blown civil war, which comprises several sub-conflicts - even pitting rebel groups against one another. The national Syrian Arab Army (SAA) and its allied militias have increasingly resorted to the use of heavy calibre, explosive weapons and cluster munitions in populated areas, and even used chemical weapons.

The use of explosive weapons in populated areas puts civilians and civilian objects at great risk. Explosive weapons, such as mortar bombs, artillery shells, barrel bombs, aircraft bombs and missiles, are conventional weapons that detonate to affect an area with blast and fragmentation. This area-effect means that civilians are exposed to a high risk of harm[3]. Data indicate that worldwide approximately 90 percent of those killed and injured when explosive weapons are used in populated areas are civilians[4]. In addition to large numbers of people killed and injured directly from explosive weapon use, still more are affected by the damage that explosive weapons do to essential infrastructure such as schools, hospitals, housing, and water and sanitation systems. Living under bombing and bombardment also causes severe psychological distress, which often continues to impact the lives of those affected even if they have fled the area or the conflict has ceased. The use of explosive weapons in populated areas is a also key cause of displacement[5]. The risk of explosive remnants of war can remain for decades after a conflict has ended

The use of chemical weapons in the Ghouta area outside Damascus in August 2013 ultimately led to international pressure that forced the Syrian government to give up its chemical weapons arsenal, as well as its stockpile of precursor chemicals, and accede to the Chemical Weapons Convention (CWC). There are strong indications nonetheless that government forces have subsequently used chlorine gas against civilians, most recently as June 2015[6].

The use of heavy calibre weapons and other explosive weapons in populated areas and the targeting of civilians are not limited to the Syrian government forces. Rebel forces, using a wide variety of conventional – often improvised – weapons, have also carried out serious abuses, including indiscriminate attacks on civilians. In recent months, the ongoing conflict between Syrian pro-regime forces and armed opposition groups was further complicated by the rapid

territorial gains of the so-called Islamic State (IS) jihadist army in Syria and Iraq. IS, in its attempt to create and hold a caliphate state encompassing much of Syria and northern Iraq, has used a range of tactics considered contrary to International Humanitarian Law (IHL), including the indiscriminate shelling of besieged towns, mass executions, slavery and the use of mustard gas[7].

Conflict and the environment

From the jungles of Vietnam polluted with Agent Orange, to the burning oil fields of Kuwait and Iraq, military conflicts have long-term environmental consequences that can threaten public health. In industrialised or industrialising countries, the technological environmental risks of conflict can be manifold. There is a growing recognition of this problem among states, humanitarian relief practitioners and UN agencies. For example, the UN Environment Programme (UNEP) has conducted a series of Post-Conflict Environmental Assessments in countries such as Afghanistan, Iraq, Lebanon, South-Sudan and Gaza, identifying a range of environmental concerns. Conscious of the weak protection currently afforded to the environment under IHL, the International Law Commission (ILC) is currently undertaking a four year study on protection of the environment in relation to armed conflict[8], while in 2011, the Nordic governments and Red Cross Societies pledged to explore both the gaps in existing law and means through which they could be remedied.

The Pledge process concludes in December 2015 and a follow up is currently under discussion, while the third of the ILC's three reports will be published in summer 2016. Unlike previous debates over strengthening environmental protection before, during and after armed conflict, the current debate has not been triggered by a specific conflict. Instead it represents four decades of concern over the limitations of IHL and a growing understanding of the links between environmental protection and the protection of civilians. Recognition from states is also growing, with an increasing number of interventions on the topic, both in the UN General Assembly's First Committee, such as those made in 2013[10], and the Sixth Committee, where the ILC's project has been debated[11].

Among civil society organisations, especially those working in conflict-affected areas, there is a growing awareness of the link between conflict-related pollution and the humanitarian consequences of conflict. Humanitarian demining organisations such as Norwegian People's Aid (NPA) have engaged on this subject as they are dealing with the long-term impact of explosive remnants of war and other munitions residues in their field operations[12], and this is being picked up as an issue by the broader demining community as an area of concern[13]. Similarly, environmental organisations such as Green Cross International are increasing their work linking the environment with security and human health[14].

PAX, together with the International Coalition to Ban Uranium Weapons (ICBUW), founded the Toxic Remnants of War Project[15] in 2012. Its aim was to explore the generation and risks from conflict pollution in greater detail. Over the past few years, PAX has conducted research on the potential impact of depleted uranium munitions and other military sources of contamination on public health and the environment in Iraq. During the course of this work, it became clear that depleted uranium is just one a wide range of pollution problems associated with conflict. The toxic remnants of war (TRW), ranged from toxic substances used in munitions to the toxic legacies of targeted industrial sites and the breakdown of societal mechanisms to assess and mitigate environmental hazards. TRW can therefore be defined as: *"Any toxic or radiological substance*

"Protection of the **natural environment** is one element necessary to give proper effect to the **protection** of **civilian** populations in times of **armed conflict**. Conscious of the profound effects **damage** to the environment, caused during armed conflicts, has or may have on the **health and survival** of civilians and civilian populations, and cognizant of the **fact** that the **scope** and extent of legal protections of the **natural environment** merits analysis and where appropriate **clarification**[9]".

Nordic Plegde to the International Red Cross and Red Crescent Societies - 2011

resulting from conflict or military activities that forms a hazard to humans and ecosystems"[16]. Sources of TRW can be classified as either direct or indirect. Direct TRW are the immediate result of military activity, such as the decision to target a petrochemical site, by which pollutants are released into the environment. Another example of direct TRW could be munitions residues, spread out over urban or rural areas during heavy fighting. These could include heavy metals such as tungsten, lead or even depleted uranium, as well as energetic materials that make up explosives, such as RDX, PBX and TNT and highly toxic rocket propellants. Another ubiquitous and understudied contaminant are pulverised building materials, which may contain asbestos and other pollutants[17].

Indirect sources of TRW result from sequences of events or conditions connected to conflicts and instability. Large-scale armed conflicts often weaken state authority, reducing the regulation and governance of potentially hazardous activities, or waste collection and water treatment. Weakened governance also creates the conditions in which industrial sites and stockpiles may be damaged or abandoned. Uncontrolled sites provide opportunities for harmful activities such as looting, which may expose individuals to toxic substances.

Methodology and scope

Amid the prolonged violence, and without the opportunity to undertake research on the ground, it is impossible to conduct a comprehensive assessment of the environmental hazards and the potential public health effects across Syria, which may have resulted from toxic or radiological substances released into the local environment by weapons use and other military activities. That does not mean that Syria is a black box from which no information can be collected and analysed. This study aims to provide a risk identification overview. It is an initial compilation of available data that could provide the basis upon which more rigorous post-conflict analyses can be built.

This study focuses on environmental damage as a result of attacks on densely populated areas, industrial areas and critical infrastructure. All of which may have resulted in direct and indirect environmental damage with potential threats to public health. Cases studied include:

- Damage to industrial areas and facilities as a consequence of deliberate targeting or the collateral effects of on-site fighting.
- Damage to critical infrastructure, such as water treatment systems, electricity plants and sewage systems.
- Pollution caused by the constituents of munitions and explosives and related production facilities.
- Pollution caused by conflict rubble.
- The breakdown of environmental services and governance.

The study also applies a novel approach to considering some of the potential risks created by the toxic footprint of conventional weapons in densely populated areas. Although this study will refrain from quantifying the potential risk to civilian health from these weapons

residues, we believe that there is sufficient evidence from the peace-time regulation of firing range emissions to warrant this new approach to assessing the toxic footprint of conventional weapons and warfare.

Data collection for the baseline study was conducted by open-source data from UN, EU and official Syrian government documents, as well industrial sources and environmental assessments undertaken prior to the conflict. Data on the impact of the conflict was collected through newspaper and online articles and using social media data on fighting taking place in industrial areas. Data on weapon contamination was provided by investigative journalist Eliot Higgins[18]. Battle damage assessment makes use of data from UNOSAT's website[19]. Additional satellite data were provided by the United Nations Operational Satellite Applications Programme (UNOSAT) for the assessment of damage to industrial sites in Aleppo and Homs. Supporting information on the industrial facilities was retrieved from Wikimapia and where possible verified by online open sources.

In sum, this report is first and foremost an illustrative case-study that identifies potential environmental risks caused by the conflict and which highlights the need for commitment from the international community to address these concerns. Traditionally, environmental concerns are low on the list of priorities for post-conflict assessment and rebuilding. Yet, greater consideration of the environmental impact of military activities during their planning and execution, as well as increased mainstreaming of the environment during post-conflict activities could help reduce the environmental footprint and civilian health consequences of conflicts. Improved monitoring of conflicts, and more rapid identification of environmental hotspots, would support improved awareness-raising on environmental problems, encouraging swifter measures to protect civilian and environmental health. ♦

3. Syria's environment before the war: a baseline assessment

Assessing the potential environmental impact of the Syrian conflict requires an understanding of the pre-conflict environmental conditions in the country. This chapter will provide a general baseline assessment of pre-conflict environmental conditions and governance, based on publically available sources. A more detailed baseline assessment would require governmental monitoring data, which was unavailable at the time of writing.

Geography and demography

Deserts make up most of the eastern part of Syria, with roughly one third of the country fertile land. Around 55 percent of the country comprises natural pastures, steppe, desert and mountainous areas. Natural resources include petroleum, phosphates, chrome and manganese ores, asphalt, iron ore, rock salt, marble, gypsum and hydropower[20].

In 2011, the population of Syria was 21.5 million[21], of whom approximately one third lived in rural areas. Prior to the 2011 uprising, Syria also hosted a large number of refugees – an estimated 1.8 million - mostly from Iraq. Most inhabitants are Arabs, while 9.7 percent belong to Kurdish, Armenian or other minorities[22].

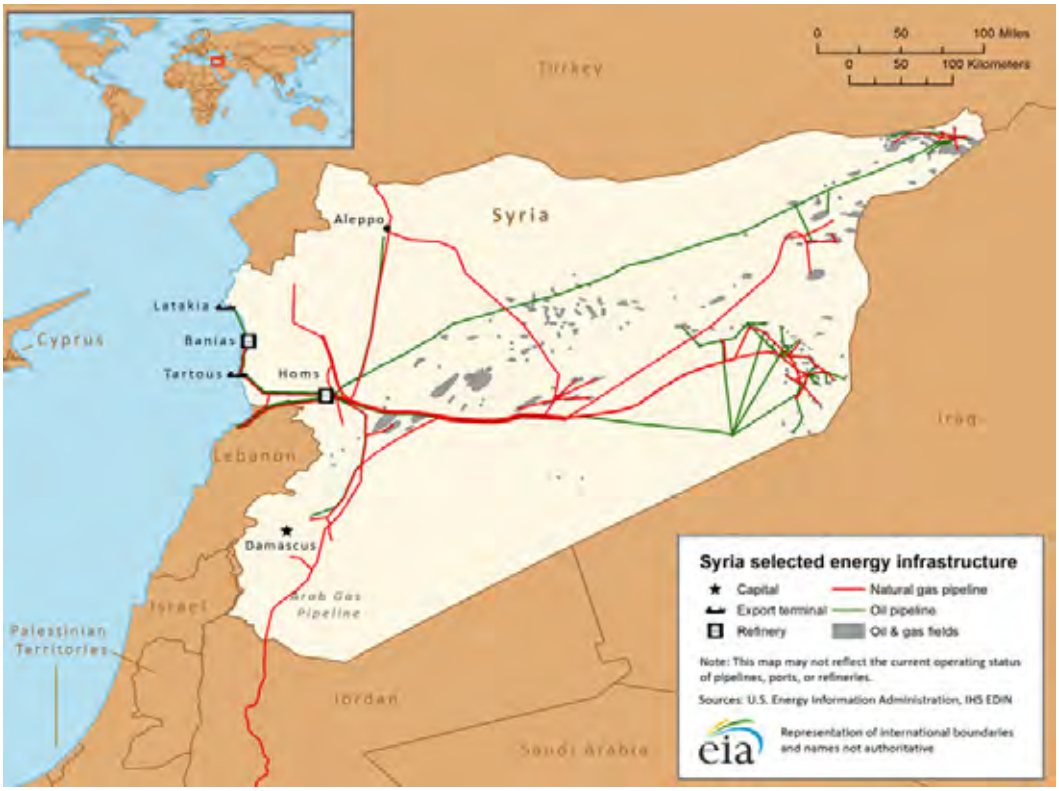
Economy

Syria was classified as a *Lower Middle Income Country*, with a per capita income in 2010

of US$2,808, which was low by regional standards[23]. The most important sectors were agriculture (22 percent of the economy), industry (25 percent), retail (23 percent) and tourism (12 percent)[24]. Although Syria's economy appeared relatively healthy before 2011, the economy faced serious challenges. Oil prices were affected by the global economic crisis, the financial and capital markets were weak and there were high rates of unemployment in combination with a rapidly growing population[25].

Agriculture

The country has five agricultural zones, distinguishable by their dominant crops: grains (e.g. wheat), industrial crops (e.g. cotton), vegetables (e.g. tomatoes, sugar beet), permanent crops (e.g. olives, fruit trees) and fodder crops (e.g. barley)[26]. Around 60 percent of the total agricultural land is located in the northern governorates - Aleppo, Ar-Raqqa and Al-Hasakeh. The latter accounted for 75 percent of total wheat production and is therefore nicknamed 'the breadbasket'[27].



Oil and gas

Syria has two principal oil-producing regions. The first region is around Sweidiyeh in the north-eastern Hasakah Province, which has been operated by the state-owned Syrian Petroleum Company (SPC) since the 1950s and 1960s. Prior to the hostilities, production had been steady at around 200,000 barrels per day. A second region was discovered in the 1980s in the Euphrates Valley, between Deir ez-Zor and the Iraqi border. Production in this region

topped at about 400,000 barrels per day in the 1990s, but has declined over the following decades to approximately 100,000 barrels per day in 2011.

In March 2011, Syria produced around 385,000 barrels per day, of which two thirds was processed in the Homs and Baniyas refineries to produce gasoline, diesel and fuel oil for the local market, while around one third was exported. At the same time, around 70,000 barrels of *mazout* (gas oil or diesel) were imported per day, for domestic heating, transport and agriculture[28]. The majority of Syria's natural gas fields are in the central and eastern parts of the country. Most of the gas was used by commercial and residential customers and in power generation, but Syria also reinserted about 19 percent of daily gross gas production into oil-recovery efforts between 2003 and 2012.

İndustry

The country's main industrial activities are the manufacturing of petroleum, textiles, beverages, tobacco, cement, food processing, phosphate rock mining, oil seed crushing, and car assembly[29]. Since the late 1980s, Syria has invested heavily in the development of its industrial pharmaceutical and biotechnology sectors[30]. The pharmaceutical industry was significant in being one of the most important pillars of economic and social development in Syria. With 63 factories and a higher concentration of companies than any other Arab country, the industry covered 90 percent of domestic demand[31].

Environmental issues prior to the war

In spite of some animal and plant species having gone extinct, pre-conflict assessments in Syria reported a rich biodiversity. The country had 26 protected areas where mammals could not be hunted but no designated natural parks. Although there were plans to establish national protected areas to ensure the protection of fragile ecosystems. Deforestation had accelerated due to the expansion of human settlements, yet government reforestation projects had demonstrated some progress by 2009. The intensification of agricultural activities and irrigation works had degraded and destroyed wetlands, while rivers are heavily polluted by industrial and agricultural emissions. Marine resources had also been degraded due to industrial and municipal sewage waste disposal and coastal pollution[32].

Syria faced serious environmental challenges even before the war, such as water pollution and scarcity, air pollution, soil degradation and inappropriate solid waste treatment and disposal[33]. Environmental pollution threatened the health of the Syrian population. A 2009 European Commission study on its environment had concluded that Syria was attempting to catch up with international environmental standards but these efforts were put on hold soon after the uprising started in March 2011[34]. In the absence of a well-developed national monitoring system, it is difficult to comprehensively assess pre-war environmental conditions, making it difficult to quantify damage resulting from the conflict.

WATER POLLUTION AND SCARCITY

Prior to the conflict, Syria's water resources were under growing pressure from population growth, urbanisation, the impacts of climate change and an expanding agricultural sector. There was a growing shortage of water due to persistent droughts and desertification[35]. Between 2006 and

Water sits low at the Barada river spring basin near Syria's border with Lebanon, April 13, 2009. Massive overuse, pollution, mismanagement and inadequate infrastructure have aggravated water shortages over the past decade in Syria.

2010, Syria went through five successive years of drought, with the year 2007-2008 reportedly the worst drought in 40 years. This had a serious impact on the agricultural sector, especially in Al-Hasakeh, Ar-Raqqa and Deir ez-Zor. Around 1.3 million people were affected and an estimated 800,000 famers and herders lost almost all their livestock[36]. Subsequently, an estimated 300,000 farmer families migrated to the cities, leaving large areas of agricultural land unattended. Many resettled in informal urban housing areas, leaving them more vulnerable to environmental hazards caused by poor air quality and contaminated of drinking water[37].

In addition to water scarcity, water quality in Syria was relatively poor, especially in areas with high economic activity. The reuse of untreated waste water in agriculture led to polluted surface and ground water. This affected the quality of drinking water, and contaminated river water used for irrigation. The resulting health risks[38] were understood by the government and its 10th Five-Year Plan set out to establish 200 water treatment plants, that would reach about 50 percent of the population[39].

Few urban areas and no rural areas were connected to sewage water treatment. Existing treatment facilities often did not meet international standards and many waste water pipes were leaking. There were water quality standards but permitted levels of pollution were relatively high. Agri-industrial wastewaters that were generated by Syria's large olive oil industry caused soil and water pollution. Waste water from the processing of olive oil was habitually used for irrigation, often containing additives which could cause a reduction in soil fertility, when spread in large quantities[40].

AIR POLLUTION

Air pollution was a growing concern in industrialised areas on the coast (Tartous, Banyas and Latakia), the midlands (Hama, Homs) and large cities such as Damascus and Aleppo. Reports

noted complaints about its effects on people's health, especially with regard to cardiovascular and respiratory diseases[41]. The limited data available on air quality showed high levels of sulphur dioxide, nitrogen oxides and carbon monoxide in Damascus as well as Aleppo prior to the conflict. Lead emissions were also high, for example from the recycling of used car batteries in lead smelters located near the cities of Aleppo and Damascus[42]. Other major sources of air pollution included emissions from a fertilizer complex, cement plants, crude oil extraction and petroleum refining, electric power plants, inefficient domestic heaters and poor quality fuels. Many of the industrial plants were old and had not been updated to modern environmental standards. Air quality monitoring stations were established in Damascus, Aleppo, Homs and Latakia in 2009, however were still at an early stage of implementation when the conflict began.

WASTE MANAGEMENT ISSUES

The waste treatment sector was considered to be weak. The data available provide a useful indication of the situation, but a lack of proper registration systems means that this is incomplete. Although domestic solid waste, which accounted for 85 percent of the volume of all solid waste, was collected in all Syrian towns and the majority of rural villages by municipalities or private companies, an estimated 80 percent was disposed of at open dump sites located on the outskirts of towns. This caused air pollution due to released dioxin and other gases[43] during open air incineration, a common practice to reduce waste volumes. Prior to the conflict, nearly all dump sites in Syria were basic and largely uncontrolled, due to a lack of material, knowledge and financial resources[44].

Generally, hazardous and non-hazardous wastes were not disposed of separately but instead were commonly mixed with domestic waste, threatening water, soil and air quality. Hazardous waste formed about 1 to 3 percent of total volume of wastes but was identified as one of the most important sources of pollution in Syria due to inadequate handling[45]. In 2010, Syria's medical centres had no waste segregation implemented, creating a potential risk for health care workers, waste handlers, patients and the general community.

In Syria, medical waste was composed of five percent radioactive waste, 15 percent chemical waste, and 80 percent infectious waste[46]. Prior to the conflict, there was only one landfill dedicated to receiving hazardous waste, which was located in Damascus. The Syrian government had begun to evaluate the quantity of domestically generated industrial waste and had planned to establish one landfill for hazardous waste in each governorate, and two in Aleppo in 2010[47]. It is unclear whether these plans had been implemented at the start of the conflict in 2011.

MINING INDUSTRY POLLUTION

Syria's mining industry is modest but has a substantial role in the region. Ranging from quarries extracting raw materials for cement production, to phosphate mines in the centre of the country. According to the US Geological Survey, Syria currently has 13 cement plants, and a small number of other mining or processing plants for asphalt, gypsum, marble, salt, iron, sulphur and volcanic tuff[48].

Environmental concerns over the impact of the mining industry, especially extraction quarries have been noted in the media, after communities expressed concerns over health problems and the Ministry of Environment reported increased air pollution affecting agricultural land use[49]. Past environmental impact assessments[50] of Syrian quarries and cement factories have identified a numbers of pollutants of concern.

ENVIRONMENTAL POLICY AND GOVERNANCE

The primary environmental authority in Syria is the Council for Environmental Protection and Sustainable Development, which was established by Law No. 50 in 2002. It is responsible for national policy making and for coordinating environmental activities and the adoption of environmental legislation and regulations. Both representatives of all sectoral ministries, as well as important NGO representatives, are represented in the Council. As the first independent environmental ministry in the Arab states, the Ministry of State for Environmental Affairs was established in 1991 with the task of protecting Syria's environment. It later merged with the Ministry of Local Administration to form the Ministry of Local Administration and Environment (MoLAE).

In 2002, Law No. 50 – the Environmental Protection Law – was adopted as a central legal tool for protecting the environment, in which the tasks and authorities of the MoLAE were laid down. It includes strict regulations to protect the environment in sectors such as forestry, agriculture, fisheries, industry, water utilisation and transport. Yet in areas such as air quality and water quality implementation of legislation has proved inadequate. In some areas, the legislation itself has been weak and a poorly functioning judicial system has made the prosecution of breaches of the law impossible.

Syria is party to several multilateral environmental agreements. One of particular importance to this report is the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes, which Syria signed and ratified in 1992[51]. Syria is also member of the Stockholm Convention on Persistent Organic Pollutants, the Rotterdam Convention, the Convention for Protection of Marine Environment of the Mediterranean and Coastal Region, the Convention on Wetlands of International Importance and a number of other UN conventions.

Syria's *National Environmental Strategy and Action Plan* (NEAP) was prepared in 2003 by the MoLAE, with support of the United Nations Development Programme (UNDP) and World Bank. It described the state of the environment on a national scale, identified environmental priorities for the country, such as water issues and land degradation, and set up a general framework for environmental planning until 2010. According to the *National Plan of the Syrian Arab Republic,* which was prepared for the UN Conference on Sustainable Development in 2012, the government claimed to have initiated a range of projects aimed at improving solid waste management, water, sanitation and other development projects, but it is unclear how effective delivery had been prior to the conflict.

Conclusions

From this limited assessment of the state of Syria's environment, it can be concluded that even before the outbreak of hostilities, general environmental quality was low due to improper water management, inadequate handling of wastes, lack of regulatory control of emissions from the industrial sector, the rapid development of a range of industries and a weak national system of environmental governance. As a consequence, the findings of the impact of the war on Syria's environment should be placed in a certain perspective, as the state of the protection of the environment was already poor. It could therefore be argued that, were it possible, even recovery to pre-conflict conditions in the post-war period would not fulfil all the requirements of responsible environmental management. ♦

4. The environmental footprint of Syria's war

During prolonged and complex conflicts such as the Syrian civil war, little attention is usually paid to the potential long-term impact of military activities on the environment, and the consequences they may have for the civilian population. The targeting of oil infrastructure and other industrial facilities, the collapse of waste management, the exposure of civilians to hazardous military substances, the accumulation of conflict rubble – are all cause for concern, but they typically remain under-addressed.

Drawing on examples and studies from previous conflicts, this chapter examines the environmental and public health threat these sources pose, and provides data on when and where such incidents are likely to have occurred during the ongoing conflict in Syria.

Damage to oil production and processing areas

HISTORIC CASES OF DAMAGE TO OIL REFINERIES

Attacks on oil facilities are commonplace in conflict and can lead to severe environmental damage. Arguably the most notorious historic case were the oil fires in Kuwait during the 1991 Gulf War, when retreating Iraqi forces set 736 Kuwaiti oil wells on fire. The oil wells burned for more than nine months, with severe consequences for the environment. Thick smoke blocked out the sun, locally reducing temperatures, and the fallout of oil, soot, sulphur and acid rain affected areas up to 1,900km from the wells. Land, ground and surface water was contaminated by releases of petroleum compounds harming vegetation, animals and people. People in smoke-affected areas were exposed to high concentrations of soot, particulate matter and particle-bound pollution. The oil fires released almost half a billion tons of CO_2 and are considered to have contributed

considerably to the current progression of climate change[52].

During the 1999 Kosovo conflict, fires in oil refineries and oil depots as a result of NATO air strikes led to widespread environmental damage. For example, air strikes on the oil refinery in Pancevo in the Former Republic of Yugoslavia (FRY) caused dense black clouds of smoke, with local falls of black rain. According to a UNEP study on the environmental consequences of the Kosovo conflict, an estimated 80,000 tonnes of oil and oil products were burned. Another case of environmental damage as a consequence of air strikes on an oil refinery took place in Novi Sad in the FRY, where an estimated 73,000 tonnes of crude oil and oil products reportedly burned or leaked causing widespread air and localised soil contamination[53].

HAZARDS RELATED TO OIL REFINERIES

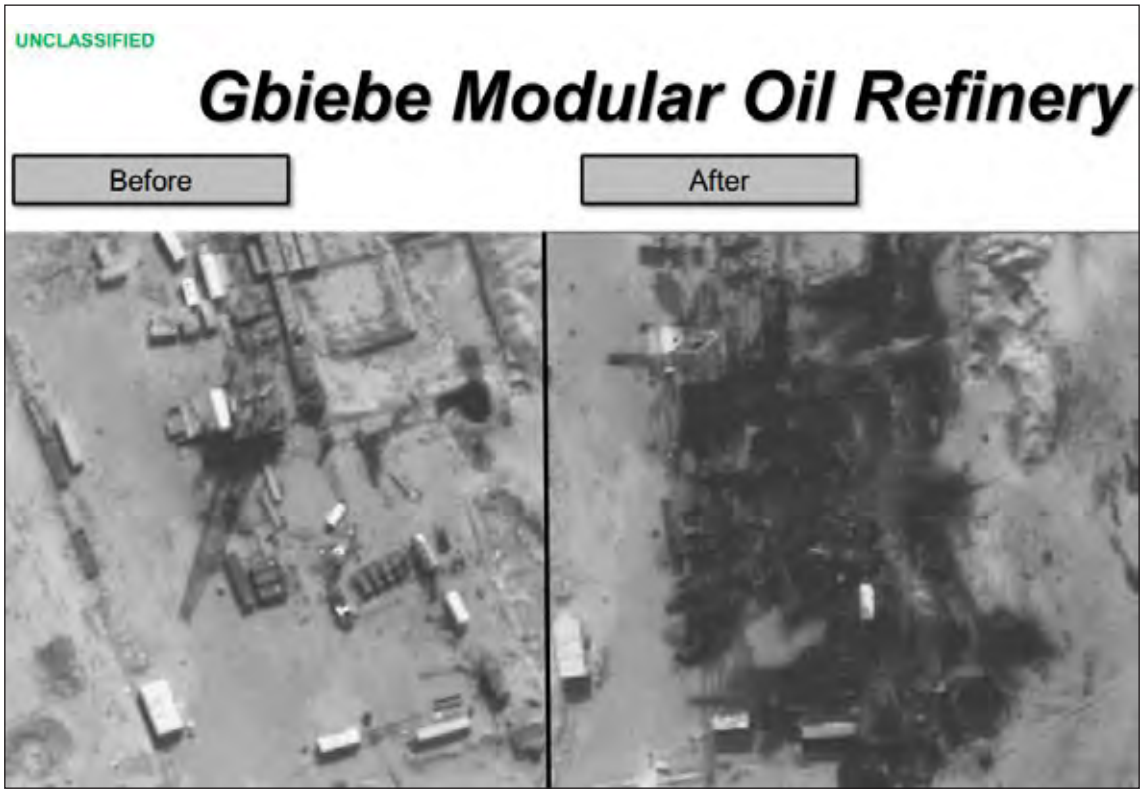
Oil products are a mixture of many different chemicals, making predicting their environmental fate and effects difficult. The oil in spills will partially degrade, a fraction will volatilise while the remainder adhering to soil and sediments. In general, short-chained aromatic compounds such as benzene, toluene, ethylene and xylene ("BTEX") are highly mobile and volatilise easily. Longer-chained compounds such as large alkanes have a very low solubility, often remaining attached to local soil and sediments. In general, the short-chained and aromatic compounds pose a greater threat to humans and the environment as they move into soil and air, exposing people via inhalation. The threat depends on the quantity released, the composition of the oil and the age of the released oil products. Groundwater pollution may occur where oil products leak from damaged storage tanks or facilities onto the soil surface. Ground and surface water pollution threatens agricultural land and the people who use ground and surface water for irrigation, drinking and domestic purposes[54].

Long-term exposure to some of the oil-related substances (BTEX and polycyclic aromatic hydrocarbons – PAHs) may lead to various health problems, such as respiratory disorders, liver problems, kidney disorders, and cancer, depending on the duration and intensity of exposure[55]. Oil pollution can be especially problematic for local ecological receptors, as certain animals such as birds are very sensitive to exposure to petroleum compounds.

Oil fires release harmful substances into the air, such as sulphur dioxide, nitrogen dioxide, carbon monoxide, PAHs and lead[56]. The nitrogen and sulphur compounds are associated with acid rain, which can have a negative impact on vegetation[57] and lead to the acidification of soils. Furthermore, these substances can cause severe short-term health effects, especially to people with pre-existing respiratory problems[58]. The largescale release of PAHs can have a potentially severe long-term environmental impact. PAHs are very persistent organic compounds, some of which are potential carcinogens and can cause respiratory problems. When released by fires, they can be transported over a large area before deposition in soils[59].

IN SYRIA: DAMAGE TO OIL REFINERIES

Attacks on oil refineries and depots have the potential to generate significant air pollution from persistent fires, as well as local soil, surface water and groundwater contamination. The risks to civilians and to the environment depend on local environmental conditions, land use and population density[60]. One may assume that attacks on oil refineries and oil depots in Syria could have led to local environmental pollution. This section provides a limited overview of the current



Slide presentation from Department of Defense Press Briefing by Rear Adm. Kirby in the Pentagon Briefing Room.

situation, as there are still numerous data gaps on oil production and operations at different sites.

Syria has two oil refineries, one in Homs and the other in Baniyas. The oil refinery in Homs is situated around seven kilometres west of the city and has repeatedly come under attack. The first large attack was on 8th February 2012, setting two fuel depots fire[61]. Other attacks on this refinery took place in March 2013, also causing fires in the facility[62]. Later that year, on 9th October 2013, and while the plant was working at barely 10 percent capacity, an attack on the refinery caused a large fire in one of its fuel storage tanks[63]. A month later, the facility was attacked again, causing considerable material damage and a fire in one of the reservoirs[64].

Since September 2014, a coalition led by the US has conducted air strikes that have targeted many oil installations controlled by IS in northern and eastern Syria[65]. The Pentagon had said in a statement that oil installations such as mobile or small-scale refineries and tanker trucks would be targeted, rather than oil fields, in order to minimise the long-term environmental damage from the attacks[66]. Army General Lloyd J. Austin III, Commander of U.S. Central Command, stated on 17th October 2014 that: *"By striking these types of facilities, we reduce their ability to generate the funds and the fuel required to sustain their operations…and we are having the desired effects"*[67].

Yet it also became clear during a press briefing by Rear Admiral Kirby in the Pentagon on 25th September 2014 that the possible environmental damage from the airstrikes was not high on the list of concerns of those planning the attacks. A reporter asked what the environmental risks of the strategy were, to which Kirby replied: "*I'm not an environmental expert. I can't dispel the fact that in some of these targets there may still be some fires burning as a result of what was hit. Again, we're working our way through the analysis right now […] I cannot completely ignore*

the possibility that there might still be some oil fires burning because of this"[68].

The take over by the Islamic State of Palmyra, and its gas and oil wells has severely limited the regime's access to this energy source. However, a deal struck between the Syrian government and the Islamic State on maintenance of oil production facilities ensured continuous operation of facilities, both in Deir ez-Zor, which was attacked by US air strikes and Raqqa[69].

On the basis of the information available, it is unclear whether coalition air strikes have led to significant environmental damage from spills and fires. Compared to Iraq's light crude oil, Syria's heavy crude oil has a higher proportion of potentially noxious substances, such as heavy metals. This makes it a particularly problematic soil and water contaminant[70]. Detailed studies and monitoring of air, water and soil should be conducted to determine levels of pollution and to assess the risks to the local population and their environment.

Oil production in Syria has now almost completely stopped, due to damage to facilities, a shortage of specialist staff, ongoing conflict and insecurity and an almost complete breakdown of the extraction and production supply chain[71]. Oil infrastructure has been targeted by armed groups since the beginning of the conflict. It is highly likely that there have been far more incidents than the ones described below, as reliable data is difficult to collect without field access.

Elsewhere, oil pipelines are reported to have been targeted in Homs, where a crude oil pipeline between the neighbourhoods of Baba Amr and Sultaniya was attacked on on 8th December 2011; exploding and creating a thick plume of black smoke for several hours after the blast[72]. The Local Coordination Committee of Syria (LCC) claimed cases of suffocation had been reported in the neighbourhood of Baba Amr as a result of the smoke[73]. The same pipeline was reportedly attacked for a second time on 15th February 2012, and for a third time on 19th June 2012, affecting nearby residential areas for hours[74]. Fighting has also taken place around the Jazal oil field near Homs, which was reportedly recaptured by the SAA in 2015[75]. An analysis of satellite data undertaken for this study indicated that fighting has taken place in and around oil storage sites in Homs, with clear risks of contamination from damage to infrastructure.

IN SYRIA: INDIRECT IMPACT OF DAMAGE TO OIL REFINERIES

In addition to the environmental and public health threats from deliberate or accidental damage to oil facilities, damage to infrastructure has also had knock-on effects. The Syrian Economic Forum claims that the regime lost more than 97.5 percent of its registered volume of oil production between 2010 and 2014[76]. Opponents of the Syrian government have benefited from the situation, in particular IS, which now controls around 60 percent of Syria's oil production[77]. Reports suggest that the makeshift oil refineries used by IS and others have caused significant local environmental damage[78], with locals living near an ad-hoc refinery describing birds "turning black" because of the smoke[79]. Facilities that have fallen under the control of IS or other rebel groups may be more susceptible to accidents and spills due to a lack of management expertise, particularly where they have been damaged during fighting.

Desperate residents in some regions have taken advantage of oil leaks to acquire fuel for heating purposes, only to find out that this fuel has harmful side effects. The uncontrolled burning of crude oil for domestic purposes can release dangerous levels of pollutants. Residents are often unaware of the risks, which has led to an increasing number of skin and respiratory

A man works at a makeshift oil refinery site in al-Mansoura village in Raqqa's countryside May 5, 2013.

diseases in areas were crude oil has been stolen[80]. The products from artisanal refineries may be particularly hazardous and the Free Syrian Army and the Asala wa al-Tanmia Front have both warned against, or even prohibited, the setting up of make-shift refineries[81]. Communities living in proximity to the sites are likely to have been affected, and their impact of health and the environment should be investigated[82].

Damage to industrial areas

HAZARDS RELATED TO INDUSTRIAL AREAS

The true extent of the environmental and health risks created by attacks on, or damage to, industrial sites are hard to assess without field observations, on-site measurements, and long-term health assessment. Documented cases indicate that the impacts can vary greatly, depending on the type of industry targeted, the type and severity of damage and a range of other variables. NATO airstrikes on a petrochemical plant in Pancevo in 1999 released toxic substances, including vinyl chloride monomer (VCM), ethylene dichloride (EDC) and metallic mercury[83]. This led to soil, surface and groundwater, and air pollution and threatened the health of workers at the complex. There have been reports of so-called Pancevo cancer, which is thought to be angiosarcoma of the liver, potentially linked to exposure to high levels of VCM[84].

In Lebanon, UNEP found that attacks on industrial facilities, such as a detergent factory, a textile factory and a food and juice company, often led to localised, measurable soil and water contamination. The environmental and health risk was generally low and remained local, yet it could have caused wider water contamination if left unattended after the hostilities had ended.

Similar concerns where voiced in UNEP's 2005 analysis of "hotspots" in Iraq, after damage to munitions plants, petrochemical sites and a pesticide production facility. Though the 2003 war saw fewer deliberate attacks on industrial sites, some industrial areas were damaged in both the fighting between US and Iraqi troops and through looting[85].

During the ongoing conflict in Ukraine, local NGOs mapped incidents at industrial facilities and mines[86]. A subsequent coordinated analysis by the Ukrainian government, the World Bank, EU and UN concluded that *"While the hostilities have hampered accurate data collection, it is expected that a relatively large but unknown number of industrial installations and mining sites are likely to have been damaged by military operations. This would have created land, water, and soil contamination and difficulties for hazardous waste management. It is expected that 10–20 mines in the region have been flooded, potentially causing massive environmental damage in the region. Other public and industrial hotspots not covered in this phase of the assessment may have incurred similar impacts. Some hazardous industries located in areas that are not under government control may also pose risks to Ukraine-controlled areas*"[87].

Attacks on industrial sites can have serious environmental and economic consequences. The presence of large volumes of chemicals and other hazardous substances creates a risk of uncontrolled releases into the environment as a result of direct targeting, or as a result of inadvertent damage where fighting takes place in proximity to sites.

IN SYRIA: DAMAGE TO INDUSTRIAL AREAS

Damage to industrial infrastructure in Syria, and with it potential "hotspots" of pollution, are likely to have occurred in several regions. For the following section, research has focused on satellite analysis of industrial areas, combining them with maps, social media and news reports. The following areas of concern were identified:

There are four key industrial zones in Syria: Adra, al-Sheikh Najjar, Hasya and Deir Ez-zor. Plans to establish more industrial zones were interrupted by the conflict[88]. Direct damage to industrial sites in Homs, Hama, Damascus and Aleppo has been reported, with buildings destroyed, burned or looted, while some factories have been taken over by armed groups[89].

Industrial production has slowed and many factories have been forced to shut down as a result of damage, risk of violence and shortages of electricity and raw materials[90]. In some cases, the government has allowed industrial companies to move to safe areas, such as Tartous. Some sectors, such as the silk industry, have reportedly almost entirely moved to neighbouring countries[91]. The pharmaceutical sector has been hit particularly hard. Around 90 percent of the pharmaceutical industry's facilities were located in Aleppo, Homs and rural Damascus, which have all seen heavy fighting[92]. It is estimated that 25 pharmaceutical plants have been destroyed, while others have halted production due to high costs and a shortage of raw materials[93].

Rebels and the Syrian Army have fought over Aleppo since the beginning of the conflict. The city's critical infrastructure has all but collapsed, as has law and order[94]. The al-Sheikh Najjar industrial zone is situated 15 kilometres from Aleppo, and was once on its way to becoming the biggest industrial zone in the Middle East. It was intended to host 6,000 companies at its establishment in 2004 and 1,250 were in operation when the conflict started in 2011. The majority of the factories produced textiles, though there were also companies producing plastics,

food, cement and pharmaceutical products[95].

The industrial zone has witnessed heavy fighting during the conflict. It has been heavily defended by rebels, yet also heavily bombed with barrel bombs, before finally being seized by the Syrian Army in July 2014. What was left behind was what journalist Robert Fisk described as the *"biggest and most sophisticated fortress ever built by followers of the late Osama bin Laden, which is now nothing but miles of destroyed factories and burned chemical plants"*[96]. Industrial production is reportedly only at 20 percent of its pre-conflict levels[97]. The government's media channel Sana reported in December 2014 that 300 factories were entirely or partially operating again, after having been provided with electricity and diesel fuel[98]. Reports from journalists noted widespread destruction and looting in Sheik Najjar in August 2015, both by the SAA and rebel groups[99]. Analysis of satellite images indicates severe damage to heavy industry facilities in northern Aleppo but at the time of writing it is not known exactly what type of industry was present at those sites.

The industrial city of Adraa has also seen heavy fighting[100]. Adraa is located 35 kilometres to the northeast of Damascus[101] and hosts a number of heavy industry facilities, including cement factories, chemical plants, oil and gas storage and military production sites, as well as water treatment plants[102]. It was reportedly retaken by government forces in September 2014 after being occupied by rebels for more than a year[103]. During the fighting, military forces occupied several factories and buildings, including a steel plant. According to the director of the industrial area, Ziad Baddour, around 1,100 facilities were still working in July 2014. It remains unclear what state the facilities are in after the fighting in September. Recent news reports in August 2015 also indicated that IS forces had overrun the industrial city of Hisyah, south of Homs. This site hosts a number of light and heavy industrial facilities[104].

Appendix I provides a general overview of industrial sites and the likely presence of types of chemicals at those sites and related health hazards. It is based on UNEP/OCHA's Hazard Identification Tool (HIT)[105]. The methodology of the HIT is based on the Flash Environmental Assessment Tool (FEAT)[106],a scientific assessment methodology to detect the most acute hazards to human health and the environment after natural disasters. Note that this table in Appendix I is indicative and incomplete, but could be used as an initial guidance for assessment what kind of chemicals could be present at these sites.

Damage to critical infrastructure

HAZARDS RELATED TO CRITICAL INFRASTRUCTURE

The destruction of critical infrastructure, such as water, sewage and electricity systems, can have serious repercussions for civilian health and the environment. Pollutants released from damaged facilities can lead to air, soil and water pollution. Where attacks disable critical infrastructure, knock on effects can be severe. A prime example is the destruction of electrical power facilities in the Gulf War in 1991, which shut down water purification and sewage treatment plants. This led to outbreaks of gastroenteritis, cholera, and typhoid, and is thought to have caused an estimated 100,000 civilian deaths and a doubling of the infant mortality rate[107].

Historical cases demonstrate that conflict induced damage to water infrastructure can cause environmental pollution and with it threats to public health. Following the 2006 conflict in Lebanon, UNEP found that water and wastewater networks had been extensively damaged,

threatening a major risk of groundwater contamination and potentially a public health hazard[108]. In an assessment in Sudan in 2007, UNEP found that the deliberate targeting of critical infrastructure, such as water pumps, had been common[109], but due to a lack of quantifiable data on field conditions in the country, UNEP could not quantify the impact of these attacks on the environment and public health.

IN SYRIA: PROBLEMS WITH WATER SUPPLY

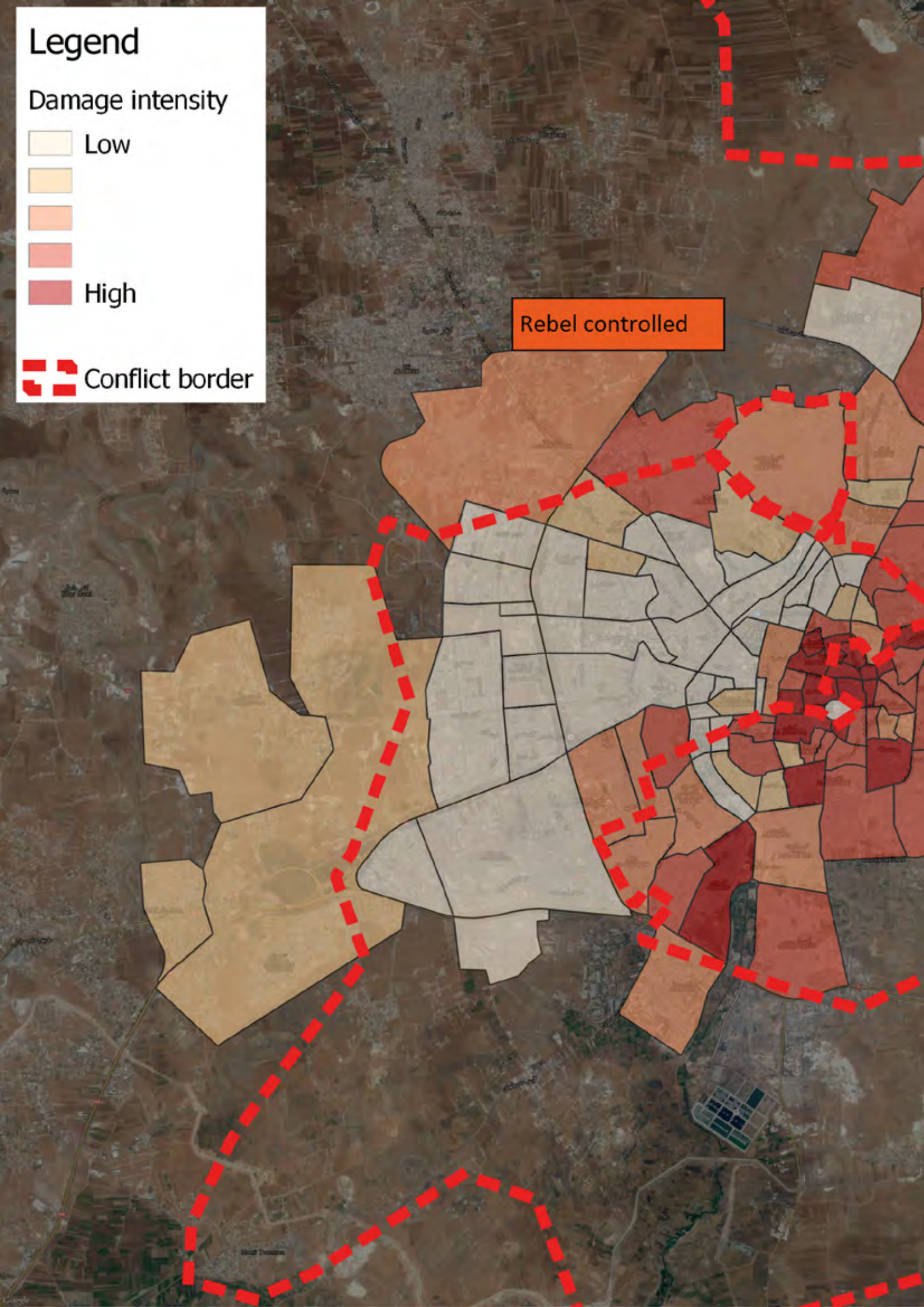
Water supply networks have regularly been targeted in the Syrian conflict. NGOs and media sources claim that water supply systems, including dams, water pipes and waste treatment plants, have been damaged or destroyed due to attacks and counter-attacks, by both regime and rebel forces. For example, Syrian state media reported attacks on drinking water well projects in al-Khaldiyeh village to the north of Sweida, and in Ariqa-Dama in Daraa province[110].

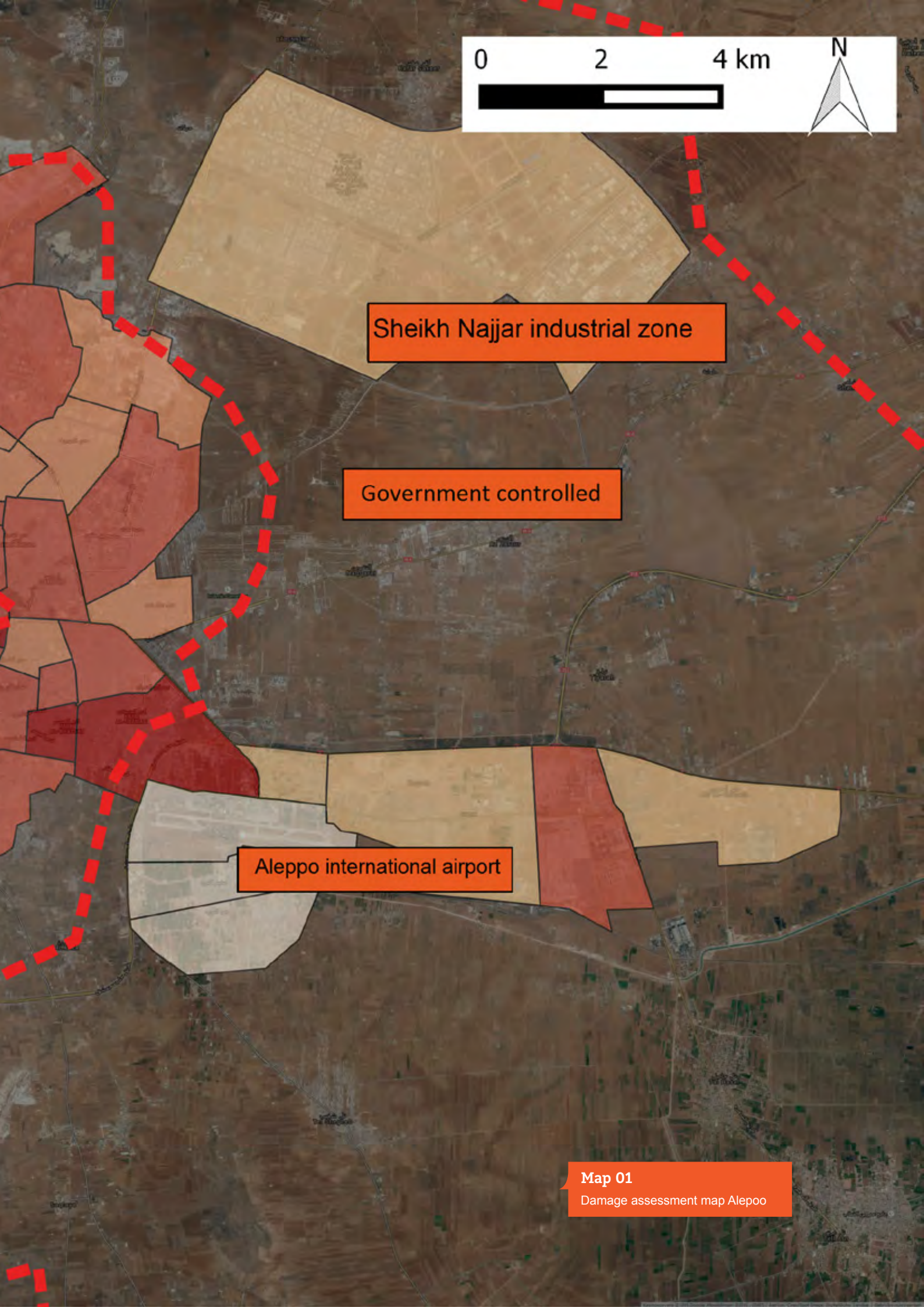
A water pumping station in Al Khafsah in Aleppo stopped working on 10th May 2014 as a result of a military attack[111]. This incident caused panic in the city, after nearly three million people lost access to water. A similar incident was reported in Aleppo, on 9th November 2012, when aerial bombing wrecked a water pipeline[112]. Water shortages as a result of attacks on water treatment plants and water pipelines have also been reported in Hama and Homs. Both cities lost their water supply for several weeks, increasing the risk of waterborne diseases[113]. In Aleppo, damage to the sewage system resulted in the contamination of drinking water[114]. This posed a serious risk to the population's health, as the price of fuel has skyrocketed, limiting the ability to boil water.

IN SYRIA: PROBLEMS WITH WATER MANAGEMENT

Areas that have seen heavy fighting, such as Aleppo, Damascus, Deir ez-Zor and al-Raqqa are dealing with a breakdown in the supply of electricity and water and waste management services. Many power plants have been damaged, and are also dealing with fuel shortages. Loss of power has had a serious impact on the water distribution and sanitation systems, which were already inadequate prior to the conflict. Many pumping stations have been damaged and are unable to supply communities.

The situation became particularly serious during the first half of 2014, when large areas of the Aleppo and Deir ez-Zor governorates were completely cut off from running water[115]. The combination of these factors seriously elevated the risk of epidemics and led to an increase in water pollution. According to the World Health Organisation (WHO)[116], the availability of safe water in July 2014 was one third that of pre-crisis levels. UNICEF, which is dealing with WASH programmes in Syria, sounded the alarm over the impact of the conflict on water management, particularly the destruction of water systems during the fighting in Aleppo and elsewhere[117].


Legend
Damage intensity
Low
High
Conflict border
Rebel controlled



Map 01
Damage assessment map Alepoo

Case study: Aleppo[1]

Attack on cement factory in Southern Aleppo with Hell Cannon by rebel groups, April 2014. Screengrab from Youtube video.

Aleppo, one of the oldest continuously inhabited cities of the world, and Syria's largest city before the war, has suffered severe damage. Of the three million inhabitants in 2011, 1.8 million have been displaced, both in and outside the city. Since the outbreak of the civil war, more than 52 percent of Aleppo's housing units have suffered partial damage or have been destroyed. Of its 123 neighbourhoods, 21 have been left uninhabitable, while 53 are only partially functioning.

A number of areas containing heavy industry in the northern and southern parts of the city have sustained considerable damage as result of attacks and shelling. A full overview of all the sites and a damage assessment of the destruction of the city can be found in Map 1.

For those still living in, or who are returning to the city, damage to these sites presents some specific environmental hazards. Based on the available data, the following hazards can be identified:

Exposure to toxics from industrial sites/military sites

Heavy fighting in the Ar Ramouseh industrial area in southern Aleppo, and around the industrial sites of Sheikh Najjar and Blleramoon in the north east may have created local environmental hotspots. Analysis of satellite images shows severe damage to the Ar Ramouseh area, which hosts a number of chemical facilities, such as a fertiliser plant, an oil and gas storage site and a cement factory. The cement factory in the north of Aleppo sustained further damage during an attack that occurred in mid-2015.

1 Most of the information below is from UN Habitat's 2014 Aleppo City Profile Multi Sector Assessment

The targeting of military storage facilities during the prolonged military campaigns in and around Aleppo may also have generated localised chemical hazards as well as UXO. An overview of hazards associated with damage to a variety of industrial facilities can be found in Figure X.

Looting

The dispersal of chemical pollution because of the looting of former military and industrial sites is a potential risk in Aleppo, particularly in the area around Aleppo İnternational Airport.

Exposure to conflict rubble

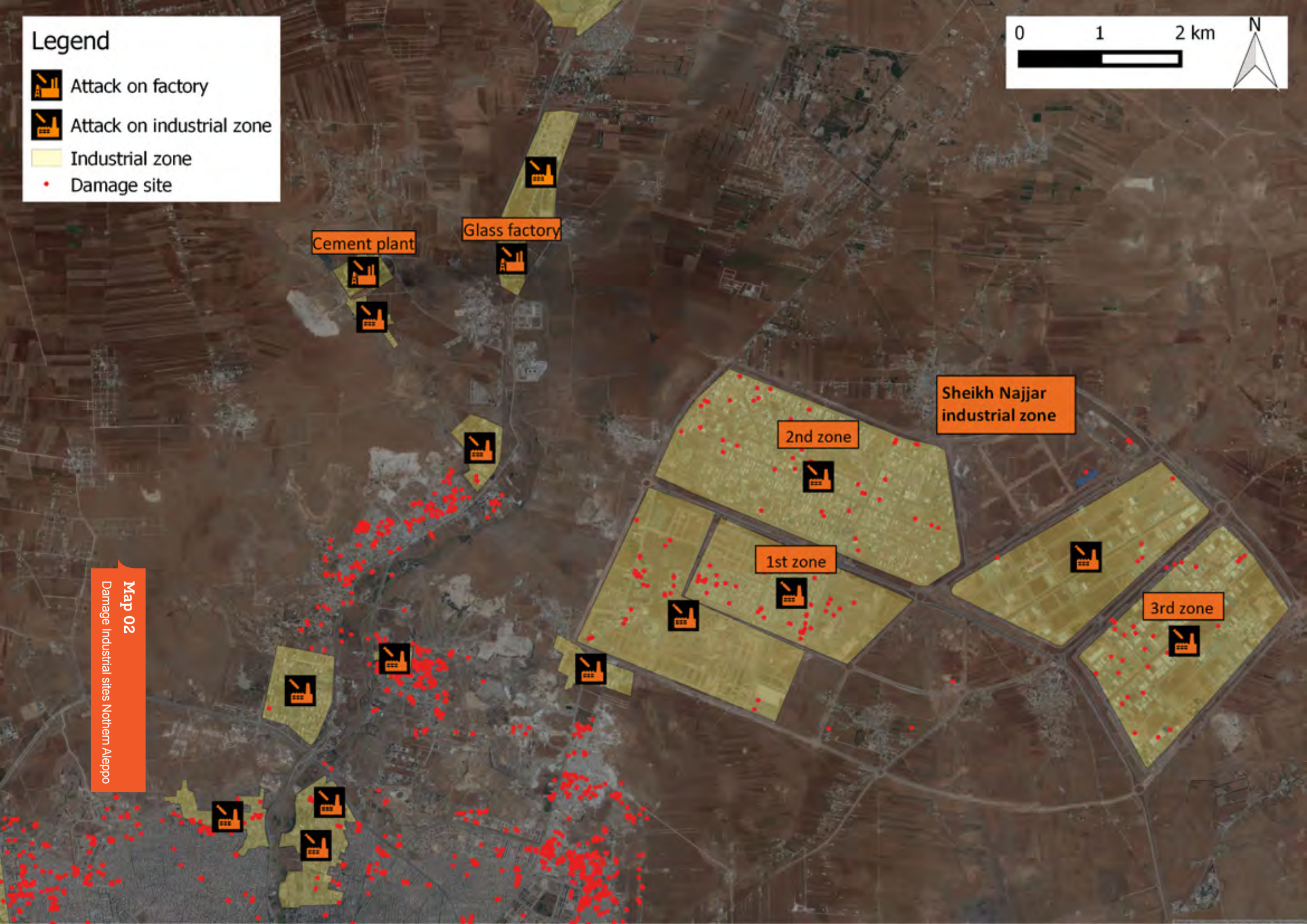
Damage to properties has generated millions of tonnes of rubble, which can contain a number of hazardous materials. Asbestos, cement, heavy metals, domestic chemicals and combustion products may all be present and can have detrimental effects on the environment and public health if not properly managed. Reports note the presence of rubble and debris in many areas of Aleppo.

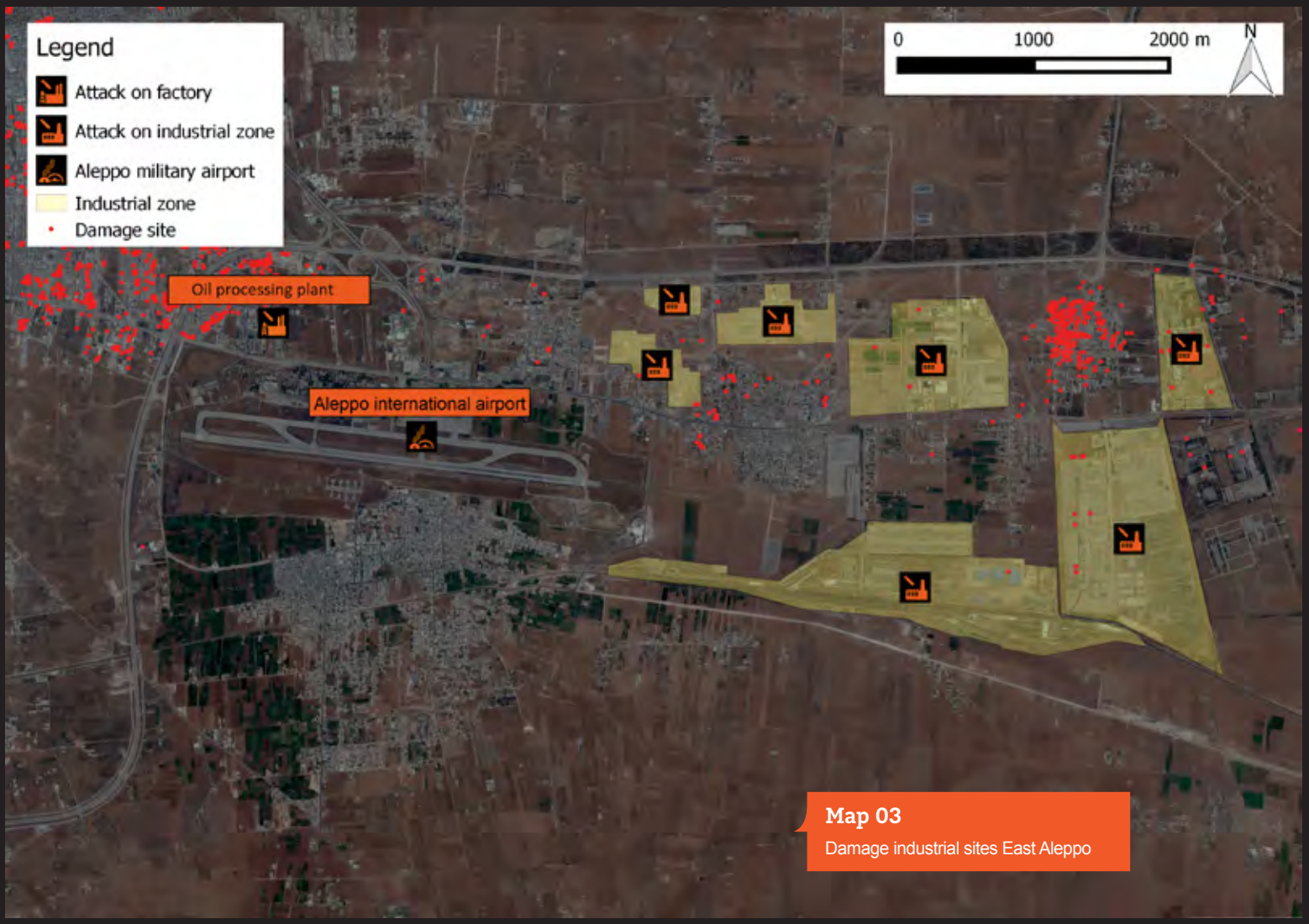
Exposure to toxic munitions constituents

Prolonged heavy fighting has likely resulted in pockets of contamination with heavy metals from munitions and toxic munitions constituents. Civilians remaining in or returning to these areas may be at risk of mixed exposures to munitions residues and pulverised building materials.

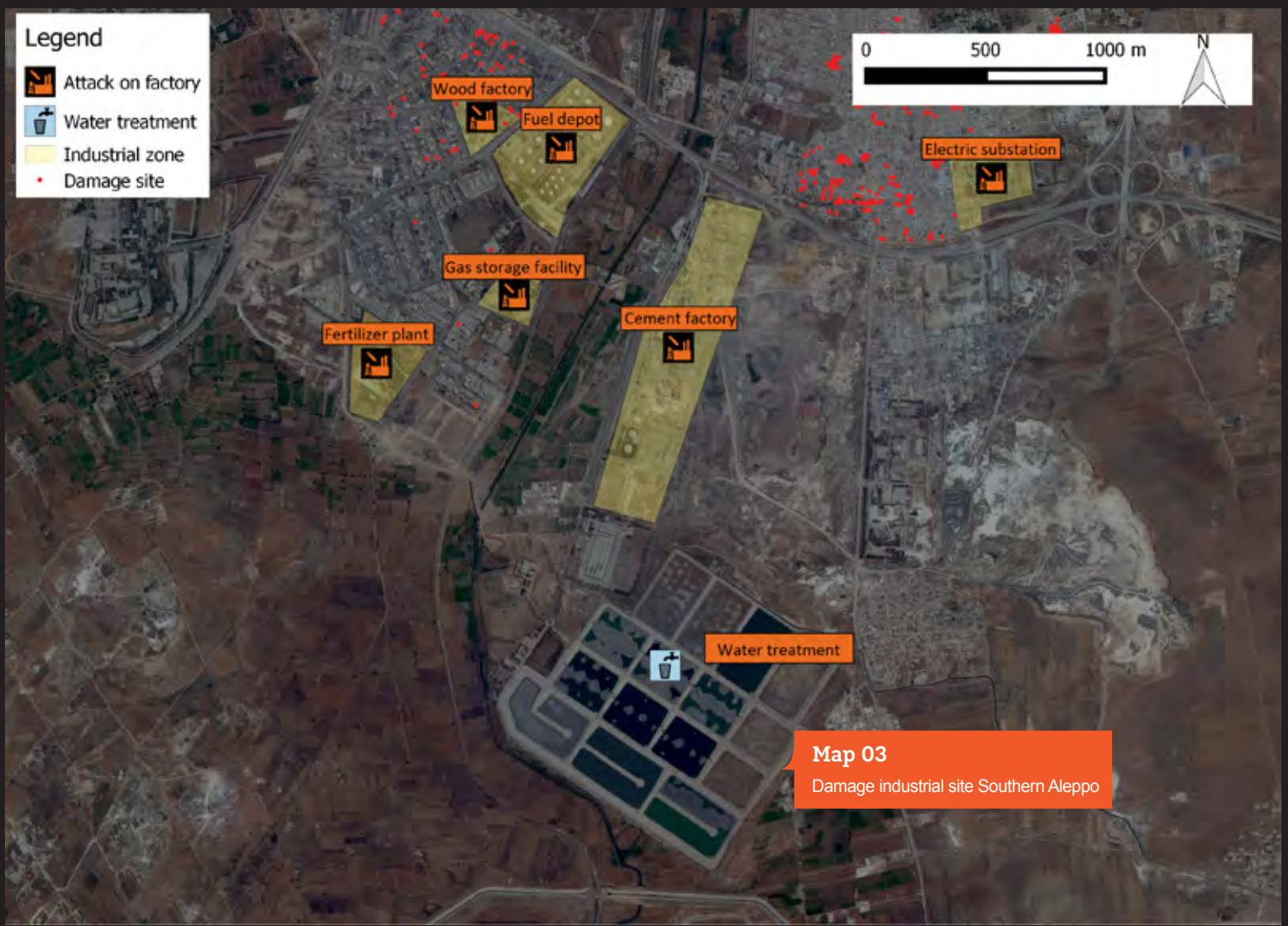
The collapse of waste management

After the outbreak of hostilities, government waste collection collapsed in east and north Aleppo; in other areas, collection resumed in a lower collection cycle with limited capacity. The absence of a fully functioning waste collection system resulted in large scale garbage dumping and the outbreak of diseases. Citizens in some areas resorted to the burning of waste, which prevents the outbreak of decease and can in some cases prevent contamination. However, depending on the chemical composition of waste, open pit burning can generate acrid smoke and allow the dispersal of harmful substances.


Legend
Attack on factory
Attack on industrial zone
Industrial zone
Damage site
0
1
2 km
N
Cement plant
Glass factory
Sheikh Najjar industrial zone
2nd zone
1st zone
3rd zone
Map 02
Damage Industrial sites Nothern Aleppo



Map 03
Damage industrial sites East Aleppo



Map 03
Damage industrial site Southern Aleppo

Rebels groups attack the Zeyzoun power plant, August 2015.

Free Syrian Army rocket attack on the Mhardeh power plant, November 2014.

IN SYRIA: DAMAGES TO THE ELECTRICITY NETWORK

Syria's electricity network has increasingly become a military target during the conflict. By early 2013, Syria's Minister of Electricity claimed that more than 30 power stations were inactive, and at least 40 percent of the country's high voltage power lines had been attacked. Although Syria's electricity grid was already unreliable before the conflict, this has been worsened by the conflict and blackouts are now routine even in government-held areas. Rebel-held areas are particularly badly affected, with bombings, the rebels' failure to manage the electricity network and cuts ordered by the regime all affecting supply[118].

Many instances of the deliberate destruction of electricity generating plants have been reported. In August 2014, a plant in Mhardeh near Hama was targeted by an armed group with shells, mortars and light weapons in an attempt to take control of it. As the most prominent power plant in the central area, it was considered a key target for armed groups. The plant was severely damaged and went offline due to another attack on power lines to the east of the plant[119]. The same plant was attacked again in November 2014 with rockets and shells, causing further damage. One shell hit a diesel oil tank, causing a fire that consumed an estimated 1,350,000 litres of diesel[120]. Other power plants affected by the conflict include a thermal power plant east of Aleppo, the Zeyzoun power plant between Idlib and Homs and the al-Zara plant between Homs and Hama, where the latter two were severely damaged[121].

Facilities within Syria's electricity system, such as power stations, substations and distribution stations potentially still have transformers and other equipment in use or storage that contain Polychlorinated Biphenyls (PCBs). In 2008, the Global Environment Facility (GEF) reported that 91 transformers contained PCBs, and other 225 large transformers were suspected of containing PCBs. In total this amounted to 1,384.3 tons of oil containing PCB compounds in the 91 small transformers and 2,392.3 tons in the 225 large transformers[122]. It is unclear whether these transformers have been taken out of the system, and safely stored or exported. Conflict damage has the potential to cause the release of PCBs into the environment and damaged power stations, substations and distributions stations should be flagged as potential PCB contaminated sites.

In October 2013, the media reported that rebels had attacked a gas pipeline, causing a fire in a key power plant near Damascus airport and causing blackouts around the country[123]. The Arab Gas Pipeline, the only source of natural gas imports, was forced to shut down as a result of being a target of attacks[124]. The US-led coalition has also targeted infrastructure; including an airstrike on the large Kuniko gas plant, which is located south of Deir ez-Zor, after it fell into IS's hands[125]. The Kuniko plant supplied both rebel held areas in Deir ez-Zor, and a regime-controlled power station in Homs, which provided several provinces with electricity and also helped power generators in the oil fields[126].

The collapse of waste management

HAZARDS RELATED TO THE COLLAPSE OF WASTE MANAGEMENT

The failure to collect and adequately dispose of waste can lead to serious air, soil and water contamination and health hazards. Uncontrolled waste burning releases smoke, soot and contaminants such as dioxins and furans. Air pollution can also be generated by ash and dust from the landfill surface and gas emissions from the decay of waste, such as methane and carbon dioxide[127]. The smoke from landfill fires, which can be fuelled by materials such as

wood, paper and plastics in the waste, and methane released by breakdown, can also contain high levels of PAHs, phenols, benzene and heavy metals. These forms of air pollution can create serious health hazards, triggering respiratory problems, and on a longer term cause asphyxiation symptoms, chronic diseases and cancer[128]. Young children, pregnant women, and old and ill people may be especially sensitive to exposures.

The creation and mobilisation of landfill leachate, which is generated from the humidity of the waste and from rainwater percolating through it, can cause groundwater pollution. Leachate can contain heavy metals and high levels of organic and inorganic substances, and escape into surrounding drainage structures and open water bodies[129]. It negatively affects water quality by consuming free oxygen in water, which can have serious consequences for ecosystems. Depending on the organic and inorganic substances in the landfill, and whether the landfill has been constructed with an impermeable barrier beneath it, underlaying and surrounding soil can be contaminated, although this is often limited to the surrounding area[130].

IN SYRIA: COLLAPSE OF WASTE MANAGEMENT

Solid waste management was a recognised environmental problem in Syria even before the conflict began. Although domestic waste was generally collected, landfills were generally uncovered, waste was often burned in open pits and hazardous waste was not disposed of separately. The escalation of violence aggravated the situation in several ways.

Due to an almost complete collapse of waste management services, large quantities of municipal waste remain in the streets across the country, most notably in Aleppo, Homs, Hama and in neighbourhoods of Damascus. Elsewhere, many municipalities have resorted to measures such as burning or uncontrolled dumping. This has prompted an ICRC warning over an increased threat from diseases and parasites[131]. The 2014 Syrian Multi Sector Needs Assessment underlined these concerns and noted an increase in communicable diseases from the collapse of waste management systems, with waste attracting vermin and causing respiratory problems and skin diseases[132]. The mixing of municipal waste with medical waste and other hazardous solid waste products is also contributing to increasing hazards for those handling waste. Concerns over these public health issues were already noted in 2013 when the WHO observed that: *"Waste accumulations in streets are breeding sites for pests such as mosquitoes, flies and mice that could transmit many diseases such as Leishmaniasis, causing epidemics and outbreaks, particularly in emergency and conflict situations"*[133]. In areas which have seen continuous fighting such as Aleppo and Hama, the situation is likely to have deteriorated further, although in Homs the government restored limited waste collection services[134].

Pre-existing concerns over the mixing of wastes in landfills may have been exacerbated by the conflict, with an increase expected in healthcare wastes[135]. Overall, municipal waste collection and the maintenance of landfills has been severely impaired during the last four years. Some waste collection initiatives have been started, such as an emergency waste collection project that the ICRC and the Syrian Arab Red Crescent (SARC) established in Aleppo in August 2014. Another project was launched by the UNDP to collect waste in Deir ez-Zor, while in some areas local people had begun their own initiatives to collect garbage[136]. In spite of these local initiatives, the national situation remains problematic.

Finally, it is likely that waste picking and informal recycling have increased as a result of the

Garbage fills a street in Aleppo, February 11th, 2013.

growing poverty and insecurity in the country. People may be searching for emergency construction materials, food, and materials that can be reused or sold. Waste picking can be dangerous due to the presence of sharp or heavy objects, and because of the mixing of wastes, waste pickers may come into direct contact with biohazards and chemical wastes.

Conflict rubble

HAZARDS RELATED TO CONFLICT RUBBLE

When buildings are hit by munitions or damaged through pressure waves resulting from explosions, building materials are pulverised, and they generate large amounts of dust[137]. Pulverised building materials (PBMs) are typically a mixture of materials such as cement, metals, PCBs, silica, asbestos and other synthetic fibres. Exposure to these materials can have a serious impact on health, both during the conflict as well as during their post-conflict management and disposal.

Few studies have been undertaken into the possible health impacts that can result from acute or chronic exposure to PBMs from the use of explosive weapons in populated areas. Nevertheless, the risks posed by asbestos are well known[138]. Populations remaining in bomb-damaged areas may face chronic exposures, as will workers involved in clean-up activities and those working at the waste disposal sites. PBMs also contain concrete, which is generally made up of Portland cement mixed with water and coarse aggregates. The substances and impurities commonly found in Portland cement, which is a mixture of oxides of calcium, aluminium, iron, silicon and magnesium. It may also also contain selenium, thallium and other impurities, depending on the source of the constituents and the manufacturing process involved, all of which can become

environmental contaminants and a hazard to human health[139]. Other than building materials, materials such as PCBs used in insulation in transistors and capacitors, and many materials commonly found in homes, can also pose health and environmental risks.

The few studies that have been undertaken into the composition of rubbles have found that those formed during conflict have a higher proportion of combustion products, such as dioxins and furans, than demolition rubble[140]. Yet far more research is needed on the health and environmental risks from conflict rubble.

UNEP has regularly stressed the need for the removal of conflict rubble and the effective management of PBMs in its post-conflict environmental assessments, for example in Gaza[141], where UNEP found both blue (crocidolite) and white (chrysolite) asbestos in a number of locations. Though both are carcinogenic, blue asbestos is 500 times more carcinogenic than its white form. In Lebanon, Kosovo and Gaza, PCBs were found that had originated in damaged electrical transistors and capacitors[142].

The potential health impact of toxic substances, mainly cement dust and particulate matter, released by demolished buildings is comparable in peace time to times of conflict. However, some experts[143] argue there are increased health hazards resulting from toxic substances in rubble of exploded buildings than from controlled demolished buildings. Some potentially toxic PBMs are generated by high temperatures resulting from explosions, and may thus pose a higher health risk to people than PBMs of demolished buildings. Current scientific research clearly outline the hazards related to PBMs, and warrants more action-oriented approaches towards cleaning up areas where PBMs are present.

Peacetime regulations and guidelines for construction and demolition workers provide some guidance on the potential risks that PBMs pose to health, which include direct effects such as eye, nose, throat and skin irritation, as well as long term illnesses such as pneumoconiosis and chronic obstructive pulmonary diseases.

IN SYRIA: CONFLICT RUBBLE

Four years of fighting has generated vast quantities of rubble and debris from damaged buildings in many districts in Syria's cities – it is believed that 1.2 million houses - or one third of all houses in Syria had been damaged or destroyed by December 2013[144]. Alongside the toxic substances released by conflict rubble, unexploded ordnance presents a huge threat.

Satellite images show massive destruction in Aleppo, Homs, Hama, Idlib, Deir ez-Zor and Damascus[145]. In the old city of Aleppo, a UNESCO World Heritage Site, artillery fighting and the use of barrel bombs[146] has partially or fully destroyed 52 percent of the city's housing stuck[147]. A similar picture has been seen in Homs, where by May 2014 a UN Habitat assessment concluded that 50 percent of neighbourhoods have been heavily damaged, and 28 percent partially damaged[148]. When residents were allowed to return late May they found a "city of death"[149]. Similar analyses have been undertaken on Deir ez-Zor, Da'ara and Idlib, with all indicating large scale destruction of residential areas[150]. Residents remaining or returning to each city will face exposure to potentially hazardous dusts[151].

Looting

HAZARDS RELATED TO LOOTING

Human health risks from access to and contact with hazardous chemicals and wastes on industrial sites can be particularly high during and after conflicts. Following the 2003 Iraq War, UNEP found that extensive damage was done to industrial sites by widespread and indiscriminate looting. Stored chemicals were dumped by looters, leading to direct exposures and localised soil contamination in some cases facilities were burnt down after being looted. At the Al Mishraq Sulphur State Company a large sulphur stockpile fire was caused by looting, which led to regional land contamination and serious damage to human health and crops. Other significant incidents included the looting of a refinery warehouse Al-Doura, which was one of the largest stores of chemicals in Iraq, and the looting of the Al Tuwaitha nuclear site, where civilians reused stolen radioactive barrels for water storage. UNEP estimated that more than 5,000 tonnes of chemicals were spilled, burned or stolen, creating a serious risk to human health and the environment[152].

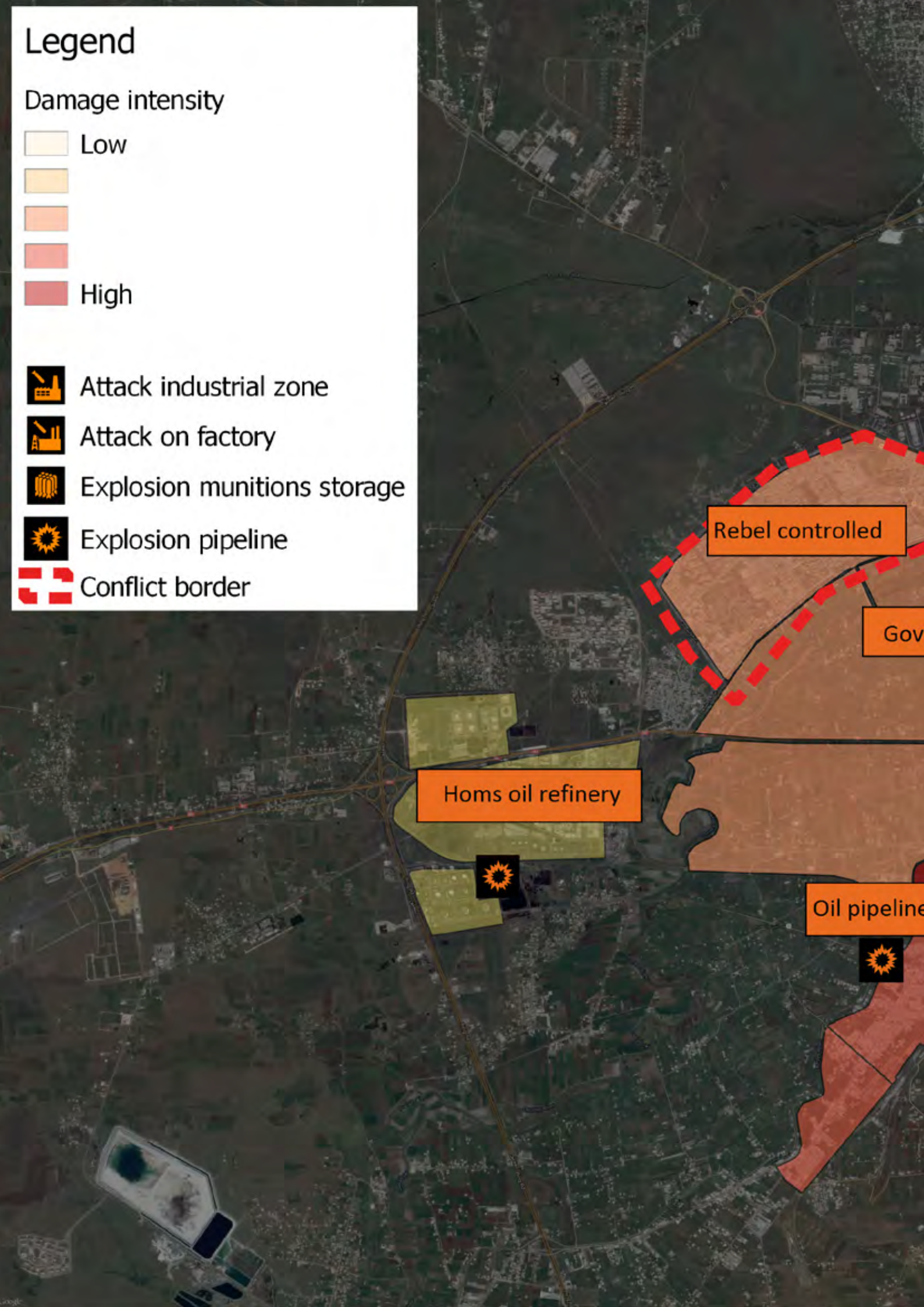
IN SYRIA: LOOTING

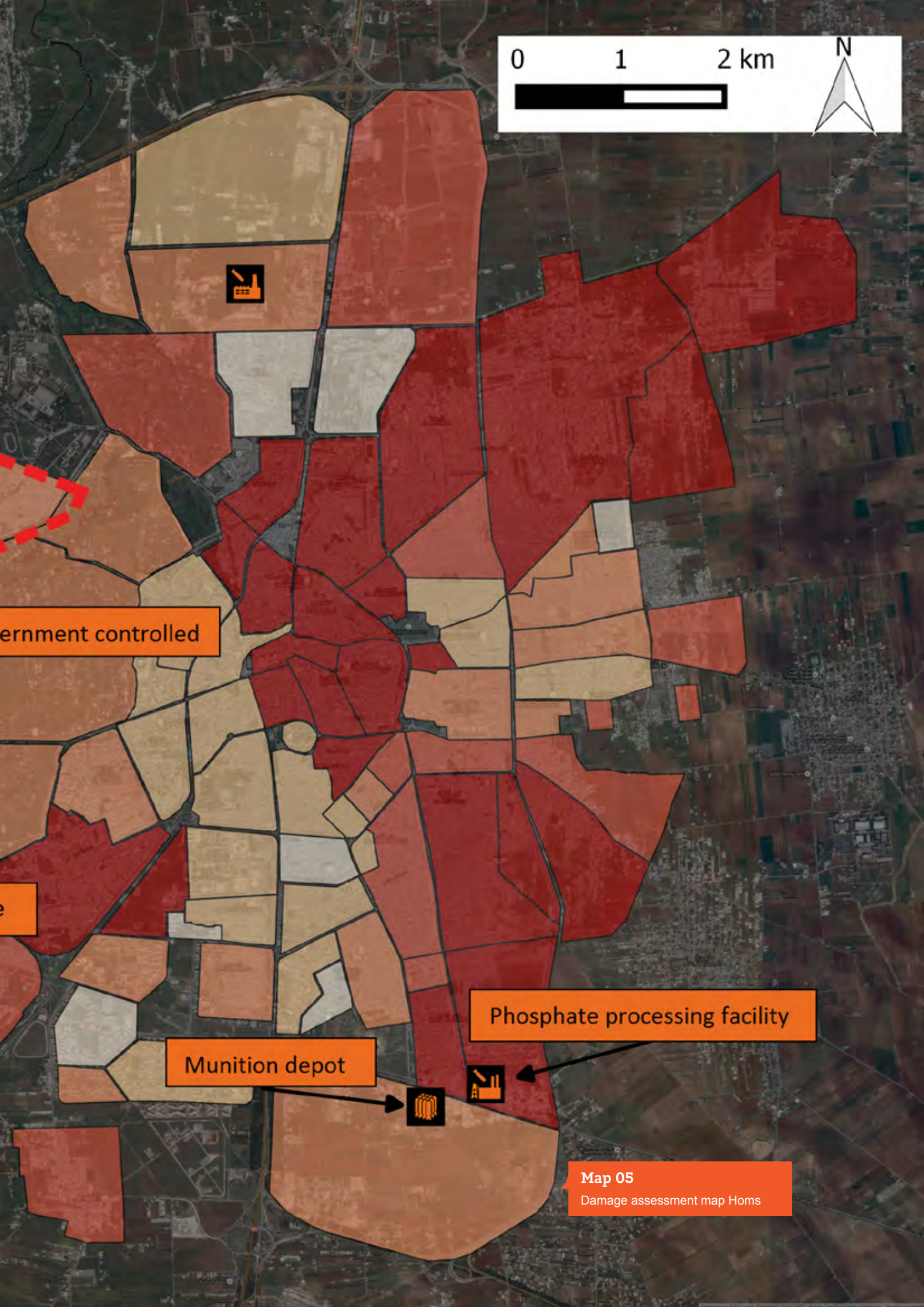
The conflict has so far seen widespread and indiscriminate looting by criminal groups, government forces, and rebels, which extends from opportunistic looting to the plundering of national treasures in historical sites, the seizure of oil fields and the looting of industrial facilities[153]. A Syrian government source stated that in 2013 there are 33,000 industrial and manufacturing facilities located in 44 industrial areas, all but one of which are controlled by rebel forces and many have been damaged, as a result of looting, robbery, demolition and arson[154]. Former industrialist and owner of a textile factory in Sheikh Najjar, Haj Waleed, claimed that factories had been plundered by both rebels and pro-regime militias[155]. Even the Turkish government has been accused of being involved in the looting of factories in Aleppo, stealing industrial equipment and transferring it to Turkey[156].

With some many factories having been looted, damaged or destroyed, it is inevitable that hazardous substances have been released into the environment. With the collapse of state security, many sites containing hazardous materials may have been left accessible. Any future ground assessments should seek data on materials formerly held by facilities, past operations and current status in order to identify hotspots of chemical contamination.

Conclusions

Pollution incidents from previous conflicts and the pattern of fighting and insecurity in Syria indicate that environmental threats from may be widespread. The main acute risks to health and environment are to be expected in areas with heavy industries, such as around Aleppo, Deir ez-Zor and Adra. Soil, air and ground and surface water pollution will have a direct and long-term impact on the environment, while civilians and workers on or near sites face exposure to toxic chemicals and other hazardous materials. Beyond hotspot contamination from damage to industrial sites, acute and chronic exposures to conflict rubble and wastes will be widespread for both civilians and rescue workers.


Legend
Damage intensity
Low
High
Attack industrial zone
Attack on factory
Explosion munitions storage
Explosion pipeline
Conflict border
Rebel controlled
Gov
Homs oil refinery
Oil pipeline



Map 05
Damage assessment map Homs

Case study: Ḥoms[1]

Famous for its Old City, Ḥoms was a tourist hotspot, and well known for its multicultural mix of communities. Before the war, Ḥoms was Syria's third largest city, as of 2011 it had more than 800,000 inhabitants. Ḥeavy fighting erupted in 2011 and continued until government forces reclaimed control of the city in 2014, after a two year siege. Almost half a million inhabitants were displaced and the intense fighting has had an enormous impact on the city. UN Ḥabitat analyses and UNİSAT satellite damage assessments reveal severe destruction in the city's residential areas. More than 54 percent of Ḥoms' housing is uninhabitable, and 26 of its 36 neighbourhoods are completely or partially non-functional.

A complete overview of the level of destruction and potential environmental "hotspots" can be seen in Map 5.

For those still living in, or who are returning to the city, damage to these sites presents some specific environmental hazards. Based on the available data, the following hazards can be identified:

Exposure to toxics from industrial sites/military sites
Analysis of battle damage reveals potential environmental hotspots around a phosphate processing factory in the south of the city, and damage to industrial zones in the north.

Exposure from looting materials
Reports indicate that the Al Ḥasawia light industrial site, which hosted 6300 small factories and workshops, has suffered looting. Ḷooters took machinery and property, bringing the economy to a standstill in that area. The informal agricultural infrastructure of Al Basateen, south-west of Ḥoms was heavily damaged and looted. Ḷooting of industrial and agricultural chemicals at the two sites may have helped disperse toxic materials.

Exposure caused by the targeting of oil facilities
Ḥoms hosts one of Syria's two oil refineries. Several small attacks were reported in the media in 2013, reportedly causing light damage[2]. Sabotage to one of the oil pipelines adjacent to a residential area in the west of Ḥoms resulted in the oil fires burning for approximately 12 hours[3]. A similar attack occurred before the conflict fully erupted in 2011[4].

1 UN Habitat (2014) Homs city profile. Accessed at: http://unhabitat.org/city-profile-homs-multi-sector-assessment/

2 UPI (2013) Syrian officials say terrorists damaged refinery in Homs. Accessed at: http://www.upi.com/Business_News/Energy-Industry/2013/11/25/Syrian-officials-say-terrorists-damaged-refinery-in-Homs/14091385382742/; Global Times (2013) Rebels attack Syria's key oil facilities amid fierce fights. Accessed at: http://www.globaltimes.cn/content/827130.shtml

3 Associated Press (2012) Oil pipeline attacked in Homs. Accessed at: http://www.independent.co.uk/news/world/middle-east/oil-pipeline-attacked-in-homs-6939014.html

Exposure to conflict rubble

Damage to properties has generated millions of tonnes of rubble, which can contain a number of hazardous materials. Asbestos, cement, heavy metals, domestic chemicals and combustion products may all be present and can have detrimental effects on the environment and public health if not properly managed. Areas with a mixture of residential and industrial properties, such as the centrally located Al Boughtasia neighbourhood, have been severely damaged.

Heavy shelling and the use of barrel bombs and other explosive weapons are likely to have resulted in contamination by UXOs, heavy metals and energetic materials. Civilians remaining in or returning to these areas may be at risk of mixed exposures to munitions residues and pulverised building materials.

Exposure as a result of uncontrolled munition storage area explosions

The targeting of military storage facilities during the prolonged military campaigns in and around Aleppo may also have generated localised chemical hazards as well as Unexploded Ordnance (UXO). An attack on a government munitions depot in August 2013 resulted in a major explosion, killing 40 people. Widespread dispersal of a range of munitions constituents, heavy metals and propellants is likely to present a long-term local environmental and public health concern unless the area is remediated.

A fuel tank burns after a mortar bomb landed at a refinery in Homs city in this handout released by Syria's national news agency SANA on November 23, 2013. A rocket shell fired on Saturday by opposition fighters directly hit one of the petroleum tanks, causing it to erupt on fire, state media said.

4 Associated Press (2011) Syrian oil pipeline hit by explosion. Accessed at: http://www.theguardian.com/world/2011/dec/08/syrian-oil-pipeline-explosion

Smoke rises in the Hanano and Bustan al-Basha districts in the northern city of Aleppo as fighting continued through the night, on December 1, 2012.

Though it remains impossible to quantify the risks without more detailed data from the ground, it is highly likely that civilians have, and will, face direct health consequences as a result of pollution generated or exacerbated by the conflict, both on a personal and a community level. Not accounted for in this overview is the environmental footprint created by refugee camps, that also adds to exhaustion and/or pollution of natural resources such as ground and surface waters, air quality, ecosystems and has created waste management problems. Some of these concerns have already been assessed in Lebanon by the UNDP and the Lebanese Ministry of Environment[157]. Similar situations are most likely presents in other refugee camps in Syria, Turkey and Jordan. ♦

The table below summarises potential exposures and threats:

Table 01.
Summary conflict pollution concerns Syria

	Exposure	Risk group	Scale/area
Conflict rubble	Ingestion, skin contact and inhalation of toxic substances in conflict rubble. Long term pollution around dumping sites.	Civilians living or returning to damaged areas, workers cleaning up and rebuilding damaged areas.	Populated areas all over the country.
İndustrial/oil sites	Water and soil contamination, air pollution, direct exposure to hazardous substances, indirect public health impact via damage to electricity, water supply and treatment.	Communities near affected sites, livestock, workers/ civilians on site, ecological receptors.	Northern and southern industrial sites in Aleppo, industrial sites in and around Homs, Adra, Deir ez-Zor, oil production and processing areas.
Military remnants	Direct inhalational exposure to hazardous munitions residues, water/ soil pollution with heavy metals/energetic materials.	Civilians clearing munitions, aid workers, DIY munitions manufacturers, especially children, scrap metal collectors.	Urban areas of intense conflict, munitions storage site blasts, attacks on military bases.
Waste management	Communicable diseases, air pollution by burning waste.	Civilians in areas lacking waste collection systems.	Aleppo, Homs, Hama, Idlib, Deir ez-Zor, Daariya, Damascus.

5. Weapons-related contamination

This chapter examines concerns over how weapons-related contamination may impact the environment and public health in Syria. The long-term health and environmental impact of munitions and explosives residues and their break-down products remains largely unexplored. But historic examples from both conflict settings and military firing ranges suggest that they could pose a serious and persistent threat to civilian health and the environment. This chapter does not seek to quantify either the use of munitions and explosives or the health and environmental threat their constituents may pose. İnstead it provides a general overview of the range of munitions being used in the Syrian conflict by different parties, their constituents and identifies concerns about the possible exposures faced by civilians.

Toxic munitions constituents – health risks and environmental fate

Munitions, explosives and other military use materials contain a range of potentially hazardous elements and compounds. Common metal constituents in small and light weapons ammunition include lead (Pb), copper (Cu), mercury (Hg), antimony (Sb) and tungsten (W), for example Pb makes up 95 percent - 97 percent of the metallic components of military ammunitions and grenades[158].

Energetic materials recognised as being toxic and which are prevalent in munitions include dinitrotoluene (DNT), trinitrotoluene (TNT), hexahydrotrinitrotriazine (RDX) and octahydrotetranitrotetrazocine (HMX). Other toxic substances often found in weapons include solid or liquid propellants for various types of rockets and missiles, such as hydrazine, while

nitroglycerin (NG), nitroguanidine (NQ), nitrocellulose (NC), 2,4-dinitrotoluene (DNT), and various perchlorate formulations are employed in missile, rocket, and gun propellants[159].

Whether solid, liquid or vaporised, these substances have the potential to lead to environmental contamination and may negatively affect human health depending on dose, duration and route of exposure. Little data is available on the extent of contamination in conflict settings, particularly in areas that may see intensive use of munitions and where populations may come into contact with residues.

METALS

Unlike organic contaminants, metals do not break down in the environment, although they may be able to move through it, depending on local conditions and the metal in question. Metals generally adhere to soil or partially dissolve in water, where they may be transported to deeper layers, and can end up in biota. Hg is the only metal which volatilises in elemental form at room temperature, other metals are not volatilized, unless methylated/alkylated. Because they do not break down in the environment, heavy metal contamination can result in long-term risks for public health and the environment as a whole.

EXPLOSIVE SUBSTANCES

Explosive substances undergo varying types of chemical and biochemical transformation, depending on the compounds involved and environmental and microbial conditions, this makes predicting their environmental fate and subsequent health risks complex. Most explosive compounds are relatively persistent in the environment, particularly NC. TNT may be transformed by sunlight or microbial action into compounds more toxic than itself. The majority of the particulate explosives are not very mobile in the environment, and absorbed materials provide an ongoing source of groundwater contamination[160]. RDX, HMX and perchlorate appear to be common groundwater contaminants; while TNT is generally not. The aqueous solubility of HMX is low and it tends to accumulate on the surface while TNT dissolves. NG is rather mobile in soil, in part due to its high solubility (1,250 to 1,950 mg/L).

TNT, RDX, HMX, NG, 2,4-DNT, and 2,6-DNT do not readily volatilise in the aqueous phase, therefore volatilisation of energetic compounds is negligible[161]. Particulate explosives adsorbed to soil particles may be spread over a wide area as wind-blown dust[162]. The degradation of explosives is affected by many factors, such as the presence of oxygen, light and microorganisms. For nitramines that end up in the environment, such as RDX and HMX, the half-life is generally hundreds of days[163].

As a recognised problem around ranges or manufacturing and disposal facilities, efforts to predict the risk munitions residues may pose have generated a complex debate over dose-effect relationships, human exposure pathways, mixture toxicology and environmental behaviour[164]. Decades of civilian and military research into the health hazards associated with firing, manufacture and disposal have demonstrated that long-term consequences for humans and the environment are feasible.

Many of the heavy metals, energetic compounds, and some of their decomposition products, such as DNTs and amino-DNTs that have been used in the Syrian conflict have been proven to be carcinogenic, genotoxic or mutagenic. Acute or chronic exposure to some has also been associated with respiratory problems, skins problems, or other detrimental effects on

the organs, and scenarios in which civilians could be exposed to a range of toxic munitions residues in Syria are commonplace. Civilians or combatants can be exposed directly or indirectly to these substances, be it through ingestion of contaminated soil, food or water or by inhalation of toxic fumes, dust or particles. Humans can also be dermally exposed to hazardous substances, especially in arid environments.

Intense fighting in urban areas likely involves the use of a variety of small and medium calibre munitions, explosives from mortars, artillery rounds, bombs, RPGs, and surface-to-surface and air-to-surface missiles. Low-order detonations, i.e., not fully detonated bombs, can result in the leaking of explosives such as RDX, DNT and TNT, contaminating soil, surface water and groundwater[165].

Existing literature on the effects of weapon contamination

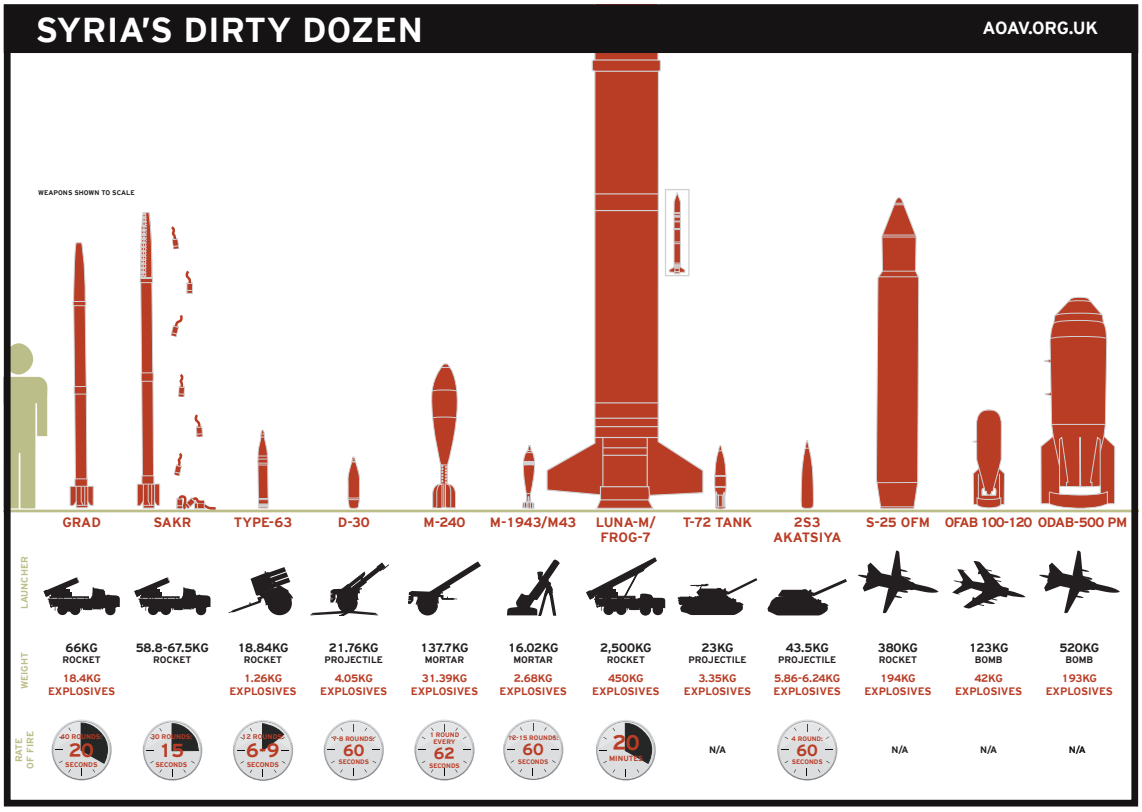
During the last decade, the environmental impact of conflict has been put on the international agenda by UNEP's post-conflict environmental assessments. This has highlighted some of the problems with weapons-related contamination, for example in Lebanon[166], Iraq[167] and Afghanistan[168], and after an ammunition storage explosion in Brazzaville, Congo in 2012[169]. Some limited research has also been undertaken in Croatia, where high levels of heavy metal residues from small arms and light weapons were found in areas of intense conflict[170]. In Iraq, where exposure to higher levels of heavy metals was detected in families living in areas that saw intense fighting during the 1991 and 2003 conflicts, exposure was linked to an increase in congenital birth defects, though the source of exposure remains unclear[171]. The most recent relevant study was published in 2014 on metal exposure of parents and links with birth defects in Gaza, though this study was limited in scope and merely observational[172].

Lessons may also be drawn from studies on domestic military firing ranges, and the environmental regulations that they operate under. Many have faced problematic levels of soil, ground and surface water and air pollution. A growing volume of research that has been undertaken by a variety of defence research institutes in the US, Canada and Europe highlight a number of concerns about the environmental fate and footprint of conventional munitions. In many cases, studies have led to recommendations and sometimes to stricter regulation governing the identification, assessment, clean-up and monitoring of sites, in order to protect public health and the environment[173].

In sum, persistent uncertainties remain over the long-term health effects of exposure to the residues from munitions and explosives. A key factor in this is the lack of environmental data from conflict zones. Nevertheless, the existing body of research on this subject warrants greater scrutiny of the issue in those areas subject to intense fighting. At the very least, broad spectrum sampling undertaken in such areas should seek to identify munitions residues as a first step to determining the likelihood of exposure risks for civilians living in or returning to these areas.

Munitions use Syria

With very limited access to reliable sources reporting on the day to day conduct of the war in Syria, this study is little more than a snapshot of the types of weapons and munitions in



Syria's Dirty Dozen. Infographic provided by Action on Armed Violence.

use. The aim is not to quantify contamination at any specific site in Syria, but instead to map examples of potential "hot spots" of contamination. To this end, we studied news and other reports on specific incidents of munitions use and examples of explosions at munitions storage sites, as well as examples of the manufacturing of IEDs and DIY weapons and munitions.

The intense use of larger calibre and other explosive weapons weapons, and potentially the sustained use of smaller calibre munitions, during the long sieges cut of large population centres such as Aleppo, Damascus and Homs could lead to some forms of contamination with munitions residues, be it from explosives or heavy metals. A range of potential exposure scenarios may be foreseen for civilians who remain in these areas, or for those who return after the hostilities end, for example through direct inhalation of particles in arid environments, or prolonged exposure to persistent remnants such as heavy metals. In some heavily affected areas, consumption of locally produced food can be a concern.

Munitions use by government armed forces

USE OF HEAVY WEAPONS AND EXPLOSIVES

The Syrian Arab Army has deployed a wide variety of weapons, the bulk of which are of Russian or Chinese origin. An analysis of social media reporting from inside the conflict, documented a range of weapons being used. Outlined in the infographic above are the most commonly used types of munitions. A more detailed overview of munitions used and their constituents can be found in Appendix II

IMPROVISED EXPLOSIVE WEAPONS: BARREL BOMBS AND ROCKETS

Aside from conventionally manufactured weapons, the SAA have also used so-called 'barrel bombs', large oil drums, gas cylinders, and water tanks, filled with high explosives such as RDX, TNT and scrap metal for fragmentation effects. Hundreds of attacks have been reported in Aleppo and in several other towns in Syria, such as Daara, Darayya, Idlib and Homs, resulting in the death and injury of thousands of civilians. The use of these weapons has been well documented by independent researcher Eliot Higgins[174] and by Human Rights Watch[175].

Barrel bombs come in different shapes and sizes. As they tend to contain a large amount of explosive material, and due to the difficulty of delivering them accurately to a target, barrel bombs tend to have wide area effects. Like other explosive weapons with wide area effects, such as heavy artillery shells, rockets and aircraft bombs, their use in populated areas is highly problematic. As they are improvised weapons, the effects of any particular barrel bomb are very hard to foresee, making it impossible to adequately assess the risk of harm to civilians and prevent that harm[176]. Apart from the enormous damage and human suffering these barrel bombs cause, these crudely devised weapons often fail to detonate. Unexploded bombs can result in exposure of civilians to the toxic substances used in the device. Reports document a variety of barrel bomb designs with different explosive fills, and weights ranging from a couple of hundred kilogrammes to some weighing more than 1500 kilogrammes. TNT is toxic, a common fill and a potential carcinogen, and the bomb's failure to detonate can distribute it around the area of impact. A number of incidents have been reported by Syrian Civil Defence volunteers, and have been linked to suspected TNT exposure in populated areas[177].

CHEMICALS

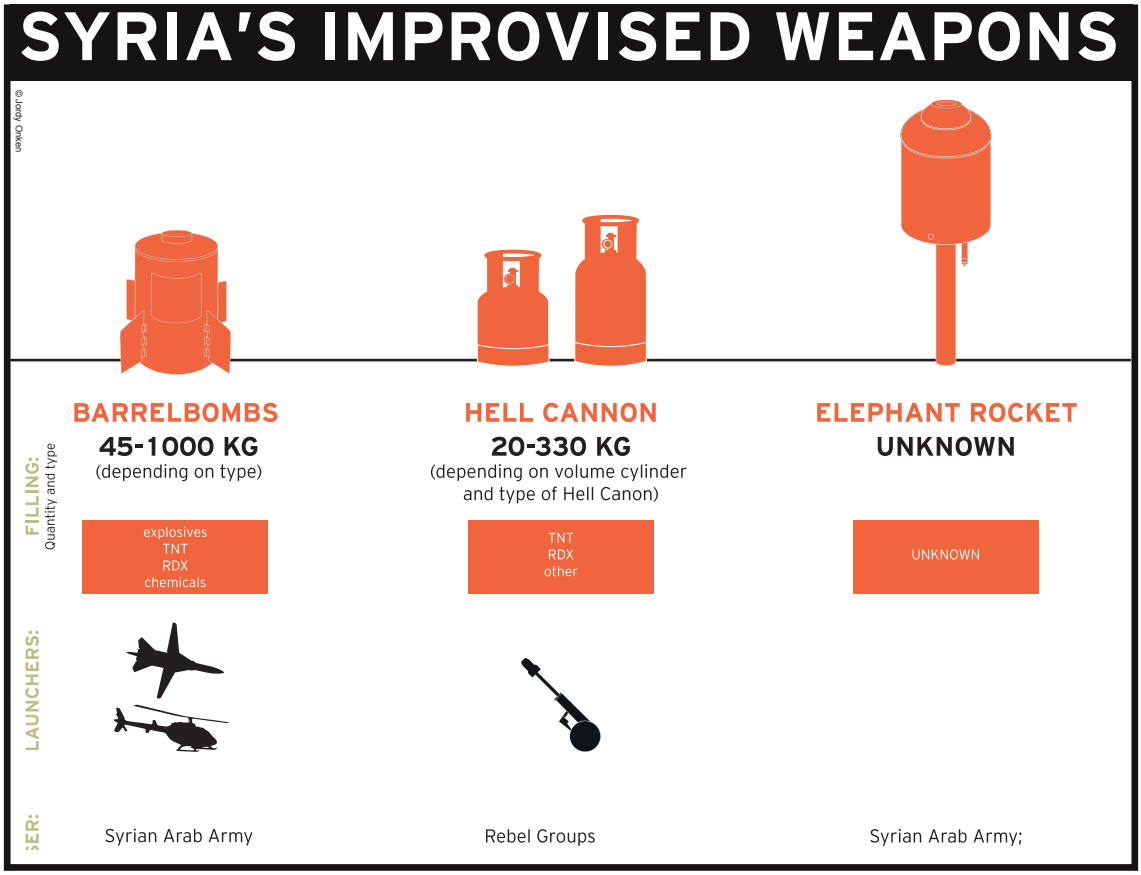
More worryingly, there is increasing evidence that barrel bombs filled with chlorine gas have been used, killing and wounding civilians in several cities and villages[178]. This has been confirmed by the Organisation for the Prohibition of Chemical Weapons (OPCW)[179]. The CWC bans any use of industrial chemicals as a weapon[180].

VULCANO ROCKETS

The use of improvised rockets, also named Vulcano Improvised Rocket Assisted Munitions (VRAM). has been documented since 2012[181]. Larger versions of which are nicknamed 'elephant rockets', because of their size and the noise they make when launched. These rockets are made by attaching rocket motors to large bombs, which are then launched indiscriminately into urban areas. They are short range, destructive and inaccurate[182]. At the time of writing, no information is available on the constituents of the weapons. Likely fills include TNT, RDX and improvised energetic materials. Eyewitnesses have reported their use in Douma,[183] Idlib[184] and Aleppo[185].

Munitions use by armed groups

The different factions fighting in Syria use a wide variety of weapons and ammunition. Initially, most of the weapons used where taken from the SAA by the FSA, or captured during attacks. Later, shipments of heavy weapons were smuggled in from Libya, Sudan, Qatar, Turkey, Croatia and many other places. When faced by shortages of arms and ammunition, rebels have initiated production lines of DIY weapons and ammunition. These have often been of low quality and have lacked precision[186].



A comprehensive assessment of the types and quantities of weapons used is not possible without access to conflict-affected. Yet, based on information collected through social media, it is possible to get an initial, rough idea of the types of ammunition used, the kind of weapons produced and how they are produced. This information will be helpful in identifying hotspots of weapon contamination or areas where additional research is needed.

Home made weapons and ammunitions

Rebel stockpiles of weapons and ammunition were soon expended after the uprising began. Rebels had to start making their own weapons in order to keep fighting. Using expertise from weapons experts and engineers who had defected from the SAA, as well as internet manuals, rebel groups quickly mastered the production of a wide range of weaponry, from napalm-Molotov cocktails, to hand grenades, pipe-bombs, mortars, IEDs and rocket launchers[187]. Most of these weapons were imprecise and were fired indiscriminately into towns and neighbourhoods. Online maps and smart phones were used for range finding and pinpointing enemy locations.

Clearly long-term health or environmental concerns are low on the list of priorities for the rebel fighters involved in the production of makeshift weapons. Processes are undertaken without the necessary safety precautions needed to prevent contamination. Manufacturing bombs and rockets requires a range of hazardous substances and generates hazardous waste streams. Together with the risk of accidental detonation this makes it a tightly regulated process in peacetime. However in Syria, small munitions factories are built in basements and abandoned buildings[188]. Munitions are prepared with a range of relatively easily available materials such as ammonium

Issa, 10 years old, carries a mortar shell in a weapons factory of the Free Syrian Army in Aleppo, September 7th, 2013.

nitrate, aluminium powder, nitrocellulose and TNT for the main charges, and mercury fulminate and lead azide for primary explosives. When possible, unexploded ordnance is collected, dismantled and the explosives (RDX, PBX, TNT), are mixed with ammonium nitrate and used for IEDs or other applications[189].

Children have been employed in these DIY munitions factories, exposing them to a range of toxic substances, to which they are particularly vulnerable, as the 2014 report from Aleppo quoted on pag 61 demonstrates:

Rockets are one of the most widely used DIY weapons in the Syrian opposition's arsenal. These have come in a variety of shapes and sizes, with opposition battalions across Syria coming up with their own designs. Sugar-based rocket fuel has been a popular choice for the rockets, with warheads filled with DIY explosives or explosives harvested from unexploded munitions. The effectiveness of these inaccurate weapons with small explosive payloads is questionable but there's no denying their popularity with the opposition, and they have been used in their thousands throughout the conflict.

Explosions ammunition sites

Over the course of the conflict, numerous explosions at ammunition storage areas have been reported. Historical incidents with unplanned explosions at munitions sites show the potential for water and soil contamination as a result of widespread uncontrolled dispersal of a range of munitions and explosives.

"An older man and two young boys—they can't be more than 12—are at **work without gloves or masks**, their faces and hands as black as coal miners'. With a shovel, they mix **an enormous pile of gray powder**; a fine particulate suspension hangs in the air, illuminated by rays of sun through the glassless windows. **Several additives** are mixed with **ammonium nitrate** to boost the **power of the explosion**. The most common is **diesel fuel**, but Yassin claims to have a nine-part secret recipe that works far better; the one key ingredient he'll reveal is **powdered aluminium**, hence **the silver dust** that constantly coats his hands and arms. ~~H~~e casts an expert eye over the pile. İt hasn't been completely blended yet, and İ can still pick out many of the constituent parts by their color and texture: whitish fertilizer, **chunky grains of TNT**, black ground charcoal, silver aluminium dust[190]."

Explosion of an ammuntion storage site in Homs, August 2013

The limited reporting from Syria has made getting a complete overview of uncontrolled munitions explosions impossible. The most well reported incident took place in Homs in August 2013, when rebels shelled a SAA weapons depot in the southern area of Wadi Al-Dahab (see case stuy Homs). This resulted in a huge explosion of what may have been a missile storage facility but which also contained other types of ammunition. The blast is reported to have killed 40 people and wounded many more. The facility was situated adjacent to a civilian neighbourhood, and may have resulted in wide-spread UXO contamination. A similar explosion occurred in the same area in March 2015, and reportedly involving Grad missiles and other munition types[191].

Less widely reported was an incident that took place in December 2013, at an ammunition storage site near Aleppo International Airport. Rebel missile attacks were also reported on SAA ammunition depots near Latakia[192]. In 2013 in Damascus, the Israeli Air Force bombed a government missile storage site near Damascus that the Israelis claimed was a chemical weapons research plant[193]. Dozens more similar attacks on ammunition storage areas are likely to have taken place during the conflict but without more comprehensive reporting determining their locations and any subsequent health or environmental risks they may pose is impossible.

Military scrap metal

Years of fighting in Syria have left many cities and towns littered with damaged and destroyed military hardware, including tanks and armoured vehicles. When not taken by the rebels or government for spares or repair, these objects may be stripped for valuable metals and equipment, later to be transported to informal scrap metal sites for further processing. The

A'zaz, Syria: Children collect scrap metal by a destroyed tank October 17, 2012.

breaking of military vehicles and hardware can release a range of hazardous materials, ranging from unexploded munitions, to high concentrations of toxic chemicals, such as PCBs, asbestos, lead, lithium and cadmium from batteries, fuel and oils.

In past conflicts, notably in Iraq, concerns have been raised over the exposure of civilians and workers to a range of hazardous chemicals on scrap metal sites[194]. Considering the quantities of military scrap the Syrian conflict has generated, it is likely that such sites may pose risks to civilians and the environment during and after the conflict. In Iraq, children were found to be at particular risk, as they often use destroyed tanks as playgrounds, as were workers on sites. The processing, storage and export of scrap will likely facilitate the dispersal of toxic materials.

Public health and weapons related contamination

Intense fighting in densely populated areas will result in the build-up of metals and energetic materials from weapons. Sources include leaks from UXO, residues from low order detonations, heavy metals from munitions and residues from propellants. These will be mixed with rubble and other debris, presenting dermal, inhalational and ingestion risks for civilians.

From a toxicological perspective, quantifying the health risks that acute or chronic exposures to these complex polluted environments create is challenging. However, what we do know is that a range of weapons and munitions constituents are known to be toxic, that they are dispersed in a bioavailable form and that many can persist in the environment for months or years.

Those that remain in, or return to areas subject to heavy and prolonged fighting, or those involved in the civil defence forces may well face persistent exposures. Efforts should therefore be made to determine concentrations of substances in these environments and the extent to which civilians have been exposed. Without accurate pre-conflict baseline data for metals like Pb that may have a non-military source, identifying the footprint of the conflict will be impossible. However, identifying military-use substances, such as some persistent energetics and metals, could help indicate areas where military contamination was present.

Exposure scenarios that should be borne in mind in any future environmental or public health assessment into the footprint of weapons-based contamination include:

- Exposure to contaminated conflict rubble.
- Exposure to contaminated water sources.
- Exposure for those working in or living in proximity to DIY munition factories.
- Exposures from collecting and processing military scrap metal or for those living in proximity to scrap storage areas.
- Re-use of contaminated land for agriculture or drinking water around damaged ammunition storage areas.

Historically, a lack of field access and the cost of analysis for contaminants have limited our understanding of the health and environmental risks that weapons residues may pose in post-conflict settings. New methodologies are required to remedy this and the range of actors able to record data should be increased. This includes civilians who, by utilising new technologies and smart phones could assist with the identification of hazards and the gathering data on contaminants[195]. ♦

© Freedom House via Flickr (CC BY 2.0)

The very last step of preparing the homemade bomb is putting in a detonator. Here a rebel with hands coated with an aluminum-based ingredient separates the detonators to put them in the gas canisters.

6. Conclusions

While the conflict in Syria is unlikely to end soon, four years of fighting has already resulted in environmental degradation that is further deteriorating the already deplorable situation that civilians are living in. Environmental concerns do not have the highest priority among those organisations assessing the humanitarian consequences and providing direct aid and support to affected communities. Yet this research highlights that there are a number of specific interventions that should get higher priority in post-conflict rebuilding plans. İn other instances, more direct monitoring is required to support adequate response and remediation mechanisms that would be beneficial for communities in affected areas.

The widespread attacks, including the use of explosive weapons, on residential and industrial areas have turned neighbourhoods into rubble, and those unable to leave face the consequences of remaining in hazardous areas with limited assistance and information on the health and environmental risks. Only time will tell which attacks on critical infrastructure such as power plants, and water purification and sewage systems not only resulted in direct environmental problems, but also blocked access to direct basic services for civilians, degrading public health. It is highly likely that with the current absence of governmental structures and capacity, these consequences will not be dealt with any time soon.

This research took a novel approach and assessed the possible toxic footprint of the constituents of conventional munitions and other military materials. This built on research from contamination of military firing ranges and limited research in previous conflicts (Balkan, Iraq). Its aim was to assess how the prolonged and intensive use of a wide range of munitions could create health and environmental risks for civilians. Though cautious, the conclusion would be that further

research is warranted, especially in heavily affected residential areas, where heavy metals and hazardous energetic residues could add to the complex polluted environment that civilians are exposed to.

This desktop analysis has identified four main areas where the environmental impact of the conflict in Syria will have immediate or long-term public health consequences.

1. The targeting and destruction of industrial facilities and critical infrastructure.

“Hotspots” of environmental pollution are likely to occur in and around attacked industrial facilities, critical infrastructure and military bases. Based on publically available information on the types of industry, and if fighting had occurred at these sites, it is possible to identify a range of environmental likely to be present on and near these hotspots. There are particular concerns over environmental threats at industrial sites around Aleppo, in particular at Sheik-Najjar and the heavy industrial facilities nearby, as well as the west around Aleppo airport and the south. Other environmental hotspots are likely at some damaged factories south of Homs, near Homs oil refinery and at heavy industrial facilities in Adra, near Damascus.

The severity of contamination will depend on the quantity and type of chemicals present, the damage sustained by facilities and any mitigation measures attempted by facility staff. Acute health risks may have occurred where looting has taken place, while long-term health and environmental threats will depend on the extent of releases into local waters, soils and air. Contamination caused by the conflict and damage to facilities may be overlain on pre-existing contamination. Artisanal oil production and processing, which has expanded as a result of the bombing of oil facilities in Deir ez-Zor, may be creating a number of intense localised hotspots.

Damage to electrical facilities may have resulted in the release of PCBs into the environment, while attacks on water treatment facilities and sewage systems have created public health risks by restricting access to clean drinking water and reducing the management of human wastes.

2. Heavy damage to residential areas and exposure to hazardous building rubble.

The widespread destruction of residential and light industrial areas in Aleppo, Homs, Hama, Idlib, Deir ez-Zor, Damascus and elsewhere has so far destroyed more than 30 percent of Syria’s housing stock. Huge quantities of pulverised building materials have been generated, containing a mixture of potentially toxic cement dust, house-hold waste, medical waste, asbestos and other hazardous materials.

This is a huge waste stream that not only poses immediate long-term exposure risks for civilians living or returning to these areas but its appropriate management and disposal will present a huge environmental challenge in the longer-term. In the short-term, both emergency responders and workers processing rubble may face repeated exposures to hazards.

3. Contamination from weapon residues.

The ongoing conflict has seen the deployment of a wide range of weapons by all parties. The use of massive quantities of munitions from North Africa, Europe, Russia and Asia, as well as DIY weapons is likely to have left an environmental footprint. Based on historic peacetime and conflict precedents, this research has highlighted a number of concerns over the direct and long-term health effects from the residues of the intensive use of conventional munitions.

The sustained use of munitions in populated areas and attacks on arms storage areas may have led to the dispersion of environmentally significant quantities of metals and energetic materials. Further sources of contamination include military scrap metals and DIY munitions factories, both of which may have created short and long term exposure risks to workers and those living nearby.

4. Collapse of environmental services.

Disruption to an already weak system of waste management provided by the Syrian government has led to an accumulation of municipal waste and to an increase in uncontrolled dumping and burning. Uncontrolled dumping and burning of waste reduces the likelihood that household, medical and industrial wastes will be separated, creating immediate and long-term health and environmental risks. Failure to appropriately manage municipal wastes has led to an increase in communicable diseases.

The most pressing problem with waste collection emerged in Aleppo, and to a lesser extent, in and around populated areas near Damascus, where there was total collapse of waste management. More positively, and with UNDP support, cities such as Homs, have seen some recovery in waste management services.

The purpose of this report has been to identify types of environmental damage in the Syrian conflict that can have a direct impact on civilian health. As a desk study it has not sought to quantify those civilian health risks but instead to demonstrate that the fate of Syria's environment during the conflict is inextricably linked to that of its human population. In doing so it underscores the necessity of further steps to better integrate environmental protection with the protection of civilians. ♦

A Syrian man collects vegetables from a vegetable patch locals grew at the site where a barrel bomb hit a sewage pipe in the Baedeen neighbourhood of the northern Syrian city of Aleppo on September 3rd, 2014.

7. Recommendations

Following the conclusions of this report, a set of general recommendations can be made to states, international organisations and civil society in the broader discussion on conflict and the environment, aiming to improve environmental awareness in humanitarian action during and after conflicts. İn addition to these general recommendations, we provide a set of specific recommendations as a food for thought on a pro-active approach to deal with the environmental impact of the war in Syria.

General recommendations on conflict and the environment

Strengthen discourse and mandate on environment and conflict: The damage to Syria's environment and the immediate and long-term risks that this damage may pose to Syria's civilian population, clearly demonstrate that environmental protection during conflict is a humanitarian issue. Yet environmental damage during conflict suffers from low prioritisation throughout the UN system. This is most clearly reflected in UNEP's currently weak mandate on conflicts, and states should consider how the UN Environmental Assembly (UNEA), UNEP's new universal governing body could be used to strengthen UNEP's mandate in this field.

Increase cooperation between relevant actors: Civil society and a range of other humanitarian and military actors should be encouraged to play a greater and more coordinated role in recording and monitoring wartime environmental damage and the risks it poses to lives and livelihoods. This could be done by

increased mainstreaming of environmental action, exchange of information and by funding research on the environmental impact of conflict.

Develop mechanisms of response and assistance: Complex conflicts involving state and non-state actors make determining strict liability and accountability for environmental damage and its humanitarian consequences challenging. Meanwhile the environment and its inhabitants remain unassisted. States and other actors should consider the example of Syria as part of the developing initiative aimed at strengthening protection of the environment in relation to armed conflict. In doing so, states and civil society should consider how norms could be developed that help minimise damage and how new systems of response and assistance could improve the protection of the civilians and the environmental upon which they depend.

Improve legal measures to protect the environment: States debating how protection for the environment could be strengthened in relation to armed conflicts in the UN Sixth Committee should highlight how the principles and standards established in both International Environmental Law and Human Rights Law could be used to inform progress on the topic.

Specific recommendations for Syria

Bearing these complex scenarios in mind, finding solutions to each of these scenarios would in theory be less complicated. To many of the above described environmental and public health problems, solutions and responses have been devised in peace-time scenarios. A large body of literature on risk assessment tools and fast responses have been devised for chemical incidents[196], hazard identification of toxics[197], disaster waste management[198] and environmental health management in humanitarian operations.[199] Naturally, conflict affected States often lack the necessary capacities, priority or expertise to handle these complex problems, if there is a state structure left at all. Until a response plan is devised and capacity developed, be it by a new state or support is given, either by international expert or aid organisations, the following processes could be started for Syria:

Information collection

- Baseline studies establish a proper understanding of the potential risks in the specific conflict context. A mapping of industries, available ammunitions goes a long way to help assess potential and actually occurring environmental and public health problems throughout a conflict. The usefulness of such baseline studies increases exponentially the more detailed the study is. For example, the assessment of potential risks involved in a particular industrial site increases if the data set includes the sort of potential toxic substances available on a site and their quantity, condition and potential for release into the environment.

- Organisations with access to the field could make use of known geo-spatial data of areas of operation to identify if there are direct public health consequences and/or acute impacts for the communities they work with.

- Collect information from local communities for hazard identification of contamination hotspots such as industrial sites, critical infrastructure, pipelines and other oil related facilities. Map livelihoods, agricultural or livestock areas and water wells in the direct surrounding of the hotspot.

- Involve local communities in the assessment process through citizen science projects that helps collecting data at a central collection point and is assessed by experts. Feedback could be given back directly to affected communities.

- The establishment of an independent repository of such information would provide a big push for the development and mainstreaming of codes of conduct, tools and mitigation programs.

Risk assessment

- Once hotspots are identified, at random sampling could confirm presence of pollutants and contaminants in drinking water wells, surface soil, and food. This process will facilitate a better understanding of the levels of contamination and guide the level of intervention needed to prevent exposure of civilians.

- An environmental monitoring system could be set in place that would record environmental parameters in the most important areas (close to livelihoods, close to water wells, in agricultural areas, in ecological sensitive or important areas).

- Ongoing monitoring using satellite images will provide information on the level of destruction in both residential areas and industrial sites. It could provide information on downstream pollution in cases of severe chemical incidents and monitor changes in the landscape that could help identify environmental impacts.

- A set of indicators could be set in place that would measure environmental progress of the country, e.g. on waste management, access to safe/treated water, access to public health services, identification of polluted sites, air/soil/water quality, etc.

Risk mitigation

- In areas where civilians and workers are working with conflict rubble and dusty environments, basic dust masks and gloves could be provided.

- Conflict rubble, scrap metal, old stockpiles, and remnants of munitions and weapons should be removed as soon as possible, in order to limit the dispersal of contaminants to the environment. Preferably, such hazardous waste should be safely stored into further destruction. As an emergency measure, use of special landfills with a good undercover layer could be used for controlled dumping until further measures are in place.

- Identified pollution hotspots should at least be closed for public access and preferably measures for an “emergency” remediation could be introduced such as a cover layer, prior to more sophisticated clean-up.

- Awareness raising among the general population around pollution hotspots e.g. not to drink from polluted wells or swim/eat fish from contaminated water, wash hands and food to reduce ingestion of polluted particles, don’t let children play with scrap metals.

Recommendations weapons related contamination

To protect civilians in post-conflict setting, the following recommendations could be used to scope priorities for assessment and identification of potential risks of munitions constituents and residues. Bearing in mind that it remains unclear to what extent this would be a direct exposure risk, the findings of this report warrant that specific research on the impact of munitions and their constituents could provide more insight in the environmental footprint of conventional weapons.

- The identification of fighting hotspots would give a first indication were pollution hotspots could be found, containing the largest load of heavy metals and organic constituents of ammunitions and explosives. Similarly, identifications of (DIY) manufacturing sites and munitions stockpiles could reveal potential contaminated sites. Such sites may be identified via warfare documentation (if available), aerial pictures, and information from locals e.g. anecdotal evidence.

- Collecting relevant data on water sources, shelling of specific areas, weapons collection and production points, anecdotal evidence from locals would be useful starting point.

- Around these pollution hotspots (<5 km from the site), the following areas should be mapped: (potential) agricultural fields, (potential) livestock areas, populated areas/livelihoods, water wells, and surface waters in use. If groundwater flows are known, downstream water wells in use should be mapped as well.

- Lead (Pb) could potentially be used as an indicator compound for other metal and organic components, as it is one of the most present components in ammunitions together with mercury(Hg) , cobalt (Co), copper (Cu) and zinc (Zn). Furthermore, Pb is a relevant compound due to its toxic effects at relatively low concentrations. Though lead contamination also occurs through gas emissions from vehicles, it could warrant further research. Whenever field measurements are possible, environmental sampling of surface soil at hotspots and water sampling of the identified wells around hotspots could confirm that certain sites are polluted and actions should be taken to protect public health. ♦

Appendix I

HAZARD IDENTIFICATION TOOL SYRIA

Table 03.
HIT Syria[200]

Location	Actual hazard			Estimated impact type
	Facility	Hazard type	Substances	
Aleppo.	Aerospace manufacture/repair (land-side)	Hydrofluoric acid, cyanide.	Liquid toxic to the environment. Liquid toxic to humans. Liquid toxic after contact with water.	Direct impact on lifesupport functions and nature (direct impact on human health)
Aleppo, Deir ez-Zor, Palmyra, Raqqa (military).	Airports (air-side)	Kerosene.	Liquid toxic to the environment, toxic/ persistent.	Long term impact, direct impact on lifesupport functions and nature.
Accumulation of military and civilian	Scrap yards (collection)	Cleaning agents, solvents.	Liquid toxic to the environment,	Long term impact, direct impact on

scrap metal sites, nationwide.			flammable liquids, toxic/persistent, liquid toxic after contact with water, carcinogenic, mutagenic.	lifesupport functions and nature.
Aleppo, Homs, Hama, Idlib, Raqqa, Damascus.	Defence	Hydrazine, fuel, explosives.	Liquid toxic to the environment, liquid toxic to humans, flammable liquid, toxic/ persistent (explosive).	Long term impact, direct impact on life-support functions and nature, direct impact on human health.
Towns and cities with damaged electricity distribution sites.	Electricity distribution	Ammonia.	Gas toxic to humans, gas toxic to the environment.	Direct impact on human health, direct impact on life-support functions and nature.
Homs, Deir ez-Zor.	Energy production and distribution (steam, propane/ butane, oil and solvents, etc)	Natural gas, propane, butane, ammonia.	Flammable gas, gas toxic to the environment, gas toxic to humans.	Direct impact on human health.
Homs, Deir ez-Zor.	Gas distribution	Natural gas.	Flammable Gas, gas toxic to the environment	Direct impact on human health.
Aleppo.	Glass production	Hydrogen fluoride.	Explosive, solid toxic after contact with water.	Direct impact on human health.
Adra, Aleppo.	Iron and steel foundries	Cleaning agents, solvents.	Liquid toxic to the environment, flammable liquid, toxic/persistent, liquid toxic after contact with water, carcinogenic, mutagenic.	Direct impact on human health, direct impact on life-support functions and nature, long-term impact.
Deir ez-Zor, Palmyra.	Oil and gas mining (onshore, offshore).	Oil and solvents, natural gas.	Liquid toxic to the environment, toxic/ persistent, flammable gas, gas toxic to the environment.	Direct impact on human health.
Adra, Aleppo,	Production accumulators and batteries	Mixed chemicals (fire).	Gas toxic to humans, toxic/persistent (toxic smoke).	Direct impact on human health.

Table 03. (continued)
Reference table[200]

Location	Actual hazard			Estimated impact type
	Facility	Hazard type	Substances	
Adra, Aleppo.	Production (chemicals – other).	Dimethylsulfate, chloride salts.	Liquid toxic to the environment, liquid toxic to humans.	Direct impact on human health, Direct impact on life-support functions and nature.
Homs	Production fertiliser.	Ammonium nitrate, ammonia.	Liquid toxic to the environment, liquid toxic to humans, gas toxic to humans, gas toxic to the environment.	Direct impact on human health.
Aleppo	Production of pharmaceutical base materials.	Methanol, ammonia, iso propanol, pentane, medicine.	Liquid toxic to the environment, carcinogenic, mutagenic, gas toxic to humans, gas toxic to the environment, flammable liquid,	Direct impact on human health.
Aleppo	Production perfumes and cosmetics.	Solvents.	Liquid toxic to the environment, liquid toxic after contact with water, carcinogenic, mutagenic.	Long-term impact.
Aleppo	Production soap and detergents.	Chloride salts.	Liquid toxic to the environment, flammable liquid, toxic/ persistent, liquid toxic after contact with water, carcinogenic, mutagenic.	Long term impact, direct impact on lifesupport functions and nature.
Homs	Production sugar.	Sulphur dioxide.	Gas toxic to humans, gas toxic to the environment.	Direct impact on human health, direct impact on life-support functions and nature.

Aleppo, Homs	Production textiles.	Solvents.	Liquid toxic to the environment, liquid toxic after contact with water, carcinogenic, mutagenic.	Long-term impact.
Aleppo.	Production wood.	Solvents.	Liquid toxic to the environment, liquid toxic after contact with water, carcinogenic, mutagenic.	Long-term impact.
Deir ez-Zor, Homs.	Refinery oil and solvents and gas (incl. storage).	Oil and solvents, natural gas.	Liquid toxic to the environment, toxic/ persistent, flammable gas, gas toxic to the environment.	Direct impact on human health.
Aleppo, Homs.	Textile industry (dyes).	Naphtalene, benzene, bromine, chlorine, alkali, sodium nitrate, sodium sulphide.	Toxic/persistent, solid toxic after contact with water, carcinogenic, mutagenic, liquid toxic to the environment, liquid toxic to humans, gas toxic to the environment, gas toxic to humans.	Direct impact on human health
Aleppo.	Winning, preparing and distribution drinking water (with chemicals).	Chlorine.	Gas toxic to humans, gas toxic to the environment.	Direct impact on human health

Appendix II

REPORTED WEAPONS USE

The following table describes a limited number of explosive weapons used in Syria and could be used as an indicative tool. A full overview of all weapons and constituents would be required to support thorough research on potential weapon contamination.

Table 04.
Reported weapons use

Type of weapons	Name	Description
Cluster munitions	AO-1Sch	Cluster bomb: High explosive fragmentation bomblet with a thick cast iron body.
	AO-2.5RT	Russian high explosive submunition. Fill: TNT & RDX. Explosive weight: 303g.
	PTAB 2.5KO	Russian bomblet/submunition with both an anti-tank and an anti-personnel capability, and a self-destruct after impact mechanism.
	PTAB 2.5m	Improved version of the PTAB 2.5 high explosive anti-tank (HEAT) sub-munition. Contains 454

		grams of RDX/TNT 52/48.
	ShOAB 0.5	Anti-personnel/fragmention submunitions. They weigh approximately 417g each. They are 60mm diameter spheres containing approximately 304 steel balls which act as shrapnel when dispersed by the 70g of TG-30 explosive compound (30% TNT, 70% RDX) contained within the cast steel shell.
	ZP-39	Unknown origin cluster munitions.
	ZAB 2.5	Incendiary submuntions with three different variants, filis: thermite or thermite, PETN and jellied fuel mix.
Rockets	Matra SNEB Rockets	Unguided air-to-ground 68 mm (2.7 in) rocket projectile (RP). Different fills, mainly RDX & TNT.
	S-5 Rockets (multiple versions)	Air-to-ground, or improvised ground-to-ground missile. Solid rocket fuel. Filling: A-IX-2 (73% RDX, 23% aluminium powder, 4% wax).
Unguided bombs	FAB 500	High explosive blast bomb. Explosive weight: 213kg. Fill: RDX & TNT (Torpex).
	FZAB 500	High explosive incendiary version of the FAB500. Thermo-baric fuel-air explosive weapon. 193kg of explosives fill.
	ODAB-500	Contains ethylene oxide and propylene oxide, both highly toxic.
	OFAB 100-120	A thick cased high explosive fragmentation bomb. Explosive weight: 42kg. Fill: TNT/RDX.
	OFAB 250-275	High explosive fragmentation bombs. Fill: 40:60 RDX:TNT mix.
	ZAB 100-105	Incendiary bomb. Explosive weight: 28.5kg. Explosive fill: Incendiary composite.
	ZAB-500	Air delivered incendiary weapon. Fill: 216-343 kg incendiary gel.
Larger rockets and missiles	BM-27	Multiple launch rocket system, 16 launch tubes, firing 220mm rockets. Warhead weight: 90-100kg.

Table 04. (continued)
Reported weapons use

Type of weapons	Name	Description
		Variants: HE-FRAG, chemical, incendiary, fuel-air explosive, cluster rockets with scatterable anti-tank or anti-personnel mines.
	BM-30	Multiple launch rocket system, 12 launch tubes, firing 300mm rockets. Warhead weight: 243kg. Main load: 9M55 or 9M528 rockets (HE, HEAT, thermobaric or cluster munitions).
	Luna-M	Short range artillery rocket, loaded with 9M21 missile. Explosive weight: 500kg, high explosives (unknown composition) or chemical weapon. Solid rocket propellant.
	SCUD	Different versions, explosive weight: 600-985kg high explosive or chemical weapons. Single-stage liquid-fuel propellant.
Multiple Rocket Launch Systems.	BM-14	Multiple launch rocket system, firing 16 140mm rockets. Warhead weight: 18.8kg. Explosives: High explosives or chemical weapons. Solid rocket propellant.
	BM-21	Multiple launch rocket system, firing 40 122mm rockets. Warhead weight: 19.4kg. Explosives: High explosive, fragmentation, smoke, chemical warhead. Solid Rocket propellant.
	RAK-11	Multiple launch rocket system, multiple variants, capable of firing 32 128mm rockets. Warhead weight: 7.55 kg TNT. Solid rocket propellant.

Endnotes

1 Reuters (2015) Syria death toll now exceeds 210,000: rights group. Accessed at http://www.reuters.com/article/2015/02/07/us-mideast-crisis-toll-idUSKBN0LB0DY20150207

2 Amnesty International (2015) Syria's refugee crisis in numbers. Accessed at https://www.amnesty.org/en/latest/news/2015/09/syrias-refugee-crisis-in-numbers/ UNHCR(2015) Syria Regional Refugee Response. Internagency Informaiton Sharing Portal. Accessed at http://data.unhcr.org/syrianrefugees/regional.php

3 For more information on the specific impact of explosive weapons in populated areas, or the International Network on Explosive Weapons (INEW) of which PAX is a founding member see: www.inew.org.

4 AOAV(2015) Four year of harm: Explosive weapons monitor 2011-2015. Accessed at https://aoav.org.uk/2015/four-years-of-harm-impact-of-explosive-weapons-2011-2014/

5 INEW (2015) A commitment to act: Protecting civilians from the use of explosive weapons in populated areas. Accessed at: http://www.inew.org/site/wp-content/uploads/2015/09/INEW-commitment-to-act-Sep-15.pdf

6 The Guardian (2015) Syrian doctors to show the US evidence of Assad's use of chemical weapons. Accessed at: http://www.theguardian.com/world/2015/jun/16/syria-assad-regime-is-weaponising-chlorine-us-congress-to-hear

7 Wall Street Journal (2015) Islamic state accused of new chemical weapons attack in Syria. Accesesd at: http://www.wsj.com/articles/islamic-state-accused-of-using-chemical-weapons-in-syria-1440353562

8 See http://legal.un.org/ilc/guide/8_7.shtml for more info

9 ICRC (2011) 31st Conference of the Red Cross and Red Crescent. Pledge P1290. Accessed at: https://www.icrc.org/appweb/p31e.nsf/pledge.xsp?action=openDocument&documentId=16A50358B3ED1677C1257958003CC786

10 TRWP (2013) Statements on toxic remnants of war at UN First Committee 2013. Accessed at: http://www.toxicremnantsofwar.info/statements-on-toxic-remnants-of-war-at-un-first-committee-2013

11 TRWP (2015) Which states are progressive on conflict and the environment? Accessed at: http://www.toxicremnantsofwar.info/which-states-are-progressive-on-conflict-and-the-environment

12 For more information see http://www.npaid.org/Our-Work/Humanitarian-Disarmament/The-Threats/Toxic-remnants-of-war

13 For more information see http://www.gichd.org/fileadmin/GICHD-resources/info-documents/guide-to-mine-action-2014/GICHD-guide-to-mine-action-2014-chapter-3-Laws-and-standards-in-mine-action.pdf

14 For more information see http://www.gcint.org/environmental-security-and-sustainability/pollution-reduction-toxic-waste-cleanup

15 The Toxic Remnants of War Project (TRWP) http://www.toxicremnantsofwar.info

16 Kelly, A. (2014) Pollution Politics: Power, Accountabilty and Toxic Remnants of War. Toxic Remnants of War Project. Accessed at http://www.toxicremnantsofwar.info/wp-content/uploads/2014/06/TRW_Pollution_Politics_Report.pdf

17 TRWP (2014) Conflict rubble: a ubiquitous and under-studied toxic remnant of war. Accessed at: http://www.toxicremnantsofwar.info/conflict-rubble-a-ubiquitous-toxic-remnant-of-war

18 Eliot Higgins is a well-known investigative journalist who has been collecting open-source data from social media on the Syrian conflict. More information can be found on his website https://www.bellingcat.com

19 All damage assessments on Syria can be downloaded from http://www.unitar.org/unosat/maps/SYR

20 Central Intelligence Agency (2014) The World Fact Book: Syria. Accessed at: https://www.cia.gov/library/publications/the-world-factbook/geos/sy.html

21 World Bank (2014) Data by country: Syrian Arabic Republic. Accessed at: http://databank.worldbank.org/data/views/reports/tableview.aspx

22 Central Intelligence Agency (2014) The World Fact Book: Syria. Accessed at: https://www.cia.gov/library/publications/the-world-factbook/geos/sy.html

23 Worldbank (2014) Data on country and lending groups. Accessed at: http://data.worldbank.org/about/country-and-lending-groups#Lower_middle_income

24 Syria Needs Analysis Project (2014) The impact of the conflict on Syrian economy and livelihoods. Accessed at: http://www.mapaction.org/component/mapcat/download/2960.html?fmt=pdf; Mahamid (2013) Syria's frail economy, before and after the revolution. Al Arabiya Institute for Studies. Accessed at: http://english.alarabiya.net/en/perspective/alarabiya-studies/2013/04/01/Syria-s-frail-economy-before-and-after-the-revolution.html

25 Syria Needs Analysis Project (2014) The impact of the conflict on Syrian economy and livelihoods. Accessed at: http://www.mapaction.org/component/mapcat/download/2960.html?fmt=pdf

26 World Food Programme (2014) Countries: Syria. Accessed at: http://www.wfp.org/countries/syria

27 Syria Needs Analysis Project (2014) The impact of the conflict on Syrian economy and livelihoods. Accessed at http://www.mapaction.org/component/mapcat/download/2960.html?fmt=pdf

28 Lund, A. (2014) Cold winter coming: Syria's fuel crisis. Carnegie Endowment for International Peace. Accessed at: http://carnegieendowment.org/syriaincrisis/?fa=56917&reloadFlag=1

29 Syria Needs Analysis Project (2014) The impact of the conflict on Syrian economy and livelihoods. Accessed at: http://www.mapaction.org/component/mapcat/download/2960.html?fmt=pdf

30 NTI (2014) Country Profiles Syria: Biological. Accessed at: http://www.nti.org/country-profiles/syria/biological/

31 Kutaini, D. (2010). Pharmaceutical industry in Syria. Journal of Medicine and Life. 3(3). pp. 348-350. Retrieved from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3018990/

32 European Commission: Delegation Damascus (2009). Country Environmental Profile for the Syrian Arab Republic. Max Kasparek & Marwan Dimashki. Agreco consortium. Final Report. Brussels. Accessed at: http://eeas.europa.eu/delegations/syria/documents/content/eu_syria/cep_syria_en.pdf

33 Central Intelligence Agency (2014) The World Fact Book: Syria. Accessed at: https://www.cia.gov/library/publications/the-world-factbook/geos/sy.html

34 European Commission: Delegation Damascus (2009). Country Environmental Profile for the Syrian Arab Republic. Max Kasparek & Marwan Dimashki. Agreco consortium. Final Report. Brussels. Accessed at: http://eeas.europa.eu/delegations/syria/documents/content/eu_syria/cep_syria_en.pdf

35 Gesellschaft für Technische Zusammenarbeit (GTZ) (2010) Managing water for sustainable development: Modernisation of the Syrian Water Sector. Accessed at: http://www.miraproject.eu

36 World Food Program. (2010) Emergency Operation (EMOP) Syria No. 200042: Emergency response to the drought in the North-East of Syria. Accessed at: http://one.wfp.org/operations/current_operations/project_docs/200042.pdf

37 State Planning Commission (2010) Syrian Arabic Republic: Third national MDGs progress report. Accessed at: http://planipolis.iiep.unesco.org/upload/Syrian%20Arab%20Republic/Syria_MDG_2010.pdf

38 European Commission: Delegation Damascus (2009). Country Environmental Profile for the Syrian Arab Republic. Max Kasparek & Marwan Dimashki. Agreco consortium. Final Report. Brussels. Accessed at: http://eeas.europa.eu/delegations/syria/documents/content/eu_syria/cep_syria_en.pdf

39 Ibid.

40 IRIN (2009) Syria: Cleansing the olive oil business. Accessed at: http://www.irinnews.org/report/85878/syria-cleansing-the-olive-oil-business

41 European Commission: Delegation Damascus (2009). Country Environmental Profile for the Syrian Arab Republic. Max Kasparek & Marwan Dimashki. Agreco consortium. Final Report. Brussels. Accessed at: http://eeas.europa.eu/delegations/syria/documents/content/eu_syria/cep_syria_en.pdf

42 Ibid

43 Sweep-net (2010) Country report on the solid waste management in Syria. Accessed at: http://www.sweep-net.org/ckfinder/userfiles/files/country-profiles/CountryreportSyria-En-mai2011.pdf

44 European Commission: Delegation Damascus (2009). Country Environmental Profile for the Syrian Arab Republic. Max Kasparek & Marwan Dimashki. Agreco consortium. Final Report. Brussels. Accessed at: http://eeas.europa.eu/delegations/syria/documents/content/eu_syria/cep_syria_en.pdf

45 Sweep-net (2010) Country report on the solid waste management in Syria. Accessed at: http://www.sweep-net.org/ckfinder/userfiles/files/country-profiles/CountryreportSyria-En-mai2011.pdf

46 Ibid

47 Ibid

48 Taib, M. (2013) The Mineral Industry of Syria. In: US Geological Survey 2011 Minerals Yearbook. Accessed at: http://minerals.usgs.gov/minerals/pubs/country/2011/myb3-2011-sy.pdf

49 Newton, M. (2009) Syria: Dust-up in the North. Global Arab Network. Accessed at: http://www.english.globalarabnetwork.com/200910063040/Economics/syria-dust-up-in-the-north.html

50 ELARD (2009) Environmental and Social Impact Assessment of Construction and Operation of Syria Cement Plant and Associated Quarrying Activities Syria. Prepared by Earthlink and Advanced Resources Development. Accessed at: http://www.eib.org/attachments/pipeline/20090033_eis1_en.pdf

51 European Commission: Delegation Damascus (2009). Country Environmental Profile for the Syrian Arab Republic. Max Kasparek & Marwan Dimashki. Agreco consortium. Final Report. Brussels. Accessed at: http://eeas.europa.eu/delegations/syria/documents/content/eu_syria/cep_syria_en.pdf

52 Draxler, R, McQueen, J.& Stunder, B. (1994) An Evaluation of Air Pollutant Exposures due to the 1991 Kuwait Oil Fires using a Lagrangian Model. In: Atmospheric Environment, Vol 28, No. 14. pp.2197-2201, 1994.; Browning et al (1991) Environmental effects from burning oil wells in Kuwait, Nature 351, 363 - 367 (30 May 1991); doi:10.1038/351363a0

53 Gopal & Deller (2002) Precision bombing, widespread harm: Two case studies of the bombings of industrial facilities at Pancevo and Kragujevac during operation Allied Force,Yugoslavia 1999. Institute for Energy and Environmental Research. p. 46.

54 Gopal & Deller (2002) Precision bombing, widespread harm: Two case studies of the bombings of industrial facilities at Pancevo and Kragujevac during operation Allied Force,Yugoslavia 1999. Institute for Energy and Environmental Research. p. 46; ATSDR (1999) Toxicoloy profile for Total Petroleum Hydrocarbons. Accessed at: http://www.atsdr.cdc.gov/toxprofiles/tp123.pdf

55 Ibid

56 United Nations Environmental Programme (UNEP) & United Nations Centre for Human Settlement (Habitat) (1999) The Kosovo conflict: Consequences for the environment and human settlements. Accessed at: http://www.unep.org/disastersandconflicts/CountryOperations/UNEPsPastActivities/Kosovo/tabid/54623/Default.aspx

57 Gopal & Deller (2002) Precision bombing, widespread harm: Two case studies of the bombings of industrial facilities at Pancevo and Kragujevac during operation Allied Force,Yugoslavia 1999. Institute for Energy and Environmental Research. p. 65.

58 Ibid

59 Ibid

60 TRWP (2014) The environmental consequences of targeting Syria's oil refineries. Accessed at: http://www.toxicremnantsofwar.info/targeting-syrias-oil-refineries

61 Al Jazeera (2012) 'Besieged' Homs endures tank assault. Accessed at: http://www.aljazeera.com/news/middleeast/2012/02/20122854220167748.html

62 Oweis, K. Y. (2012) WRAPUP 2 Simultaneous bombs hit army compounds in Aleppo. Reuters. Retrieved from: http://www.reuters.com/article/2012/09/09/syria-idUSL5E8K92PX20120909

63 Daily Star Lebanon (2013) Syria rebel shellings sparks oil refinery. Accessed at: http://www.dailystar.com.lb/News/Middle-East/2013/Oct-09/234131-syria-rebel-shelling-sparks-oil-refinery-fire.ashx#sthash.LU9HrsbX.dpuf

64 Breaking News (2013) Mortar attack sparks fire in Homs refinery as Syrian Arab Army repels gunmen in Aleppo. Accessed at: http://breakingnews.sy/en/article/29573.html; CNN (2013) Syria says terrorist attack causes country-wide blackout. Accessed at: http://edition.cnn.com/2013/10/23/world/meast/syria-civil-war/

65 Lund, A. (2014) Cold winter coming: Syria's fuel crisis. Carnegie Endowment for International Peace. Accessed at: http://carnegieendowment.org/syriain crisis/?fa=56917&reloadFlag=1; Today's Zaman (2014) US airstrikes hit ISIL oil refinery in Syria near Turkish border. Accessed at: http://www.todayszaman.com/_us-airstrikes-hit-isil-oil-refinery-in-syria-near-turkish-border360088.html

66 Johnson, K. (2014, Sep 24) U.S. strikes ISIS oil installations. Foreign Policy. Accessed at: http://www.defense.gov/transcripts/transcript.aspx?transcriptid=5506

67 Ibid

68 U.S. Department of Defense (2014) Department of Defense press briefing by Rear Adm. Kirby in the Pentagon briefing room. Retrieved from: http://www.defense.gov/transcripts/transcript.aspx?transcriptid=5506

69 Sayigh, Y. (2015) The War Over Syria's Gas Fields. Accessed at http://carnegieendowment.org/syriaincrisis/?fa=60316

70 TRWP (2014) The environmental consequences of targeting Syria's oil refineries. Accessed at: http://www.toxicremnantsofwar.info/targeting-syrias-oil-refineries/

71 Syria Needs Analysis Project (2014) The impact of the conflict on Syrian economy and livelihoods. Accessed at: http://www.mapaction.org/component/mapcat/download/2960.html?fmt=pdf

72 BBC (2012) Explosion damages pipeline in Syrian city of Homs. Accessed at: http://www.bbc.com/news/world-middle-east-17038164

73 CNN (2012) Syria constitution vote called 'window dressing'. Accessed at: http://edition.cnn.com/2012/02/15/world/meast/syria-unrest/

74 Tomlinson (2012) Oil pipeline blown up in rebel city of Homs on 13th day of bombardment as Syrian forces storm central district of Damascus. Daily Mail. Accessed at: http://www.dailymail.co.uk/news/article-2101427/Syria-Oil-pipeline-blown-rebel-city-Homs-forces-government-forces-storm-Damascus-district.html

75 Reuters (2015) Syrian army secures oil field perimeter, kills militants: TV. Accessed at: http://www.reuters.com/article/2015/06/24/us-mideast-crisis-syria-oil-idUSKBN0P40T220150624

76 Syrian Economic Forum (2015) The Islamic State benefits from the regime's loss of 97.5% of Syria's oil production. Accessed at: http://www.syrianef.org/En/?p=4179

77 Ibid

78 Johnson, K. (2014, Sep 24) U.S. strikes ISIS oil installations. Foreign Policy. Accessed at: http://www.defense.gov/transcripts/transcript.aspx?transcriptid=5506

79 Daily Star Lebanon (2014, July 26). ISIS grabs oil and gas fields in Syria and Iraq, but challenges remain. Accessed at http://www.dailystar.com.lb/News/Middle-East/2014/Jul-26/265188-isis-grabs-oil-and-gas-fields-in-syria-and-iraq-but-challenges-remain.ashx

80 Al Monitor (2013). Syria's oil sector suffers major losses. Accessed at: http://www.al-monitor.com/pulse/culture/2013/03/syrian-oil-losses.html##ixzz3PYqPVlnR

81 Daily Star Lebanon (2014, July 26). ISIS grabs oil and gas fields in Syria and Iraq, but challenges remain. Accessed at: http://www.dailystar.com.lb/News/Middle-East/2014/Jul-26/265188-isis-grabs-oil-and-gas-fields-in-syria-and-iraq-but-challenges-remain.ashx

82 VICE (2014) Black-Gold Blues: The hazards and horrors of the makeshift oil industry in rebel-held Syria. Accessed at http://www.vice.com/video/syria-syrian-oil

83 United Nations Environment Programme (UNEP) & United Nations Centre for Human Settlement (Habitat) (1999) The Kosovo conflict: Consequences for the environment and human settlements. Accessed at: http://www.unep.org/disastersandconflicts/CountryOperations/UNEPsPastActivities/Kosovo/tabid/54623/Default.aspx

84 Ibid

85 UNEP (2005) Environmental hotspots in Iraq. Accessed at: http://www.unep.org/disastersandconflicts/portals/155/disastersandconflicts/docs/iraq/Iraq_ESA_hotspots_2003.pdf

86 ZoI (2015) The Ukraine conflict's legacy of environmental damage and pollutants. Sustainable Security. Accessed at: http://sustainablesecurity.org/2015/04/21/the-ukraine-conflicts-legacy-of-environmental-damage-and-pollutants-2/

87 GoU, EU, UN, Worldbank (2015) Ukraine Recovery and Peacebuilding Assessment. Analysis of Crisis Impacts and Needs in Eastern Ukraine. Accessed at: http://www.un.org.ua/images/stories/RPA_V2_Eng_4Web_lowres.pdf

88 Syrian Investment Agency (2010) Industrial cities in the Syrian Arab Republic. Accessed at: http://sia.gov.sy/invmapsite/index.php?page=show&ex=2&dir=docs&lang=2&ser=1&cat=58&ref=home

89 Hamada (2014) The Syrian crisis: Repercussions of the pharmaceutical industry. Syrian Economic Forum. Accessed at: http://www.syrianef.org/En/wpcontent/uploads/2014/02/Pharmaceutical-Industry-en.pdf; Daily Mail (2014) War-ravaged Syrian industrial zone hopes for new life. Accessed at: http://www.dailymail.co.uk/wires/afp/article-2842436/War-ravaged-Syrian-industrial-zone-hopes-new-life.html

90 Hamada (2014) The Syrian crisis: Repercussions of the pharmaceutical industry. Syrian Economic Forum. Accessed at: http://www.syrianef.org/En/wpcontent/uploads/2014/02/Pharmaceutical-Industry-en.pdf; Syria Needs Analysis Project (2014) The impact of the conflict on Syrian economy and livelihoods. Accessed at: http://www.mapaction.org/component/mapcat/download/2960.html?fmt=pdf

91 Syria Needs Analysis Project (2014) The impact of the conflict on Syrian economy and livelihoods. Accessed at: http://www.mapaction.org/component/mapcat/download/2960.html?fmt=pdf

92 Syrian Economic Forum (2014) The Syrian crisis: Repercussions of the pharmaceutical industry. Accessed at: http://www.syrianef.org/En/wpcontent/uploads/2014/02/Pharmaceutical-Industry-en.pdf

93 Daily Star Lebanon (2013) Syria war wrecks havoc on drug industry. Accessed at: http://www.dailystar.com.lb/Business/Middle-East/2013/Jul-01/222083-syria-war-wreaks-havoc-on-drug-industry.ashx

94 Al Monitor (2014) 'Conflict freeze' desperately needed in Aleppo. Accessed at: http://www.al-monitor.com/pulse/originals/2014/11/aleppo-syria-conflict-freeze.html

95 Daily Mail (2014) War-ravaged Syrian industrial zone hopes for new life. Accessed at: http://www.dailymail.co.uk/wires/afp/article-2842436/War-ravaged-

Syrian-industrial-zone-hopes-new-life.html

96 The Independent (2014) Aleppo's Sheikh Najjar: The death of a once-rich city. Accessed at: http://www.independent.co.uk/news/world/middle-east/aleppos-sheikh-najjar-the-death-of-a-oncerich-city-9503699.html

97 Syria Needs Analysis Project (2014) The impact of the conflict on Syrian economy and livelihoods. Accessed at: http://www.mapaction.org/component/mapcat/download/2960.html?fmt=pdf

98 SANA (2014) 300 factories re-operating in Aleppo industrial city. Accessed at: http://www.sana.sy/en/?p=22013

99 Al Monitor (2015) Aleppo's businessmen blame Turks for damaged factories, looted equipment. Accessed at: http://www.al-monitor.com/pulse/originals/2015/08/turkey-syria-sued-for-looting-aleppo-industry.html

100 New York Times (2013) Across Syria, violent day of attacks and ambush. Accessed at: http://www.nytimes.com/2013/07/23/world/middleeast/syria.html?_r=0

101 Syrian Investment Agency (2010) Industrial cities in the Syrian Arab Republic. Accessed at: http://sia.gov.sy/invmapsite/index.php?page=show&ex=2&dir=docs&lang=2&ser=1&cat=58&ref=home

102 Syrian Economic Forum (2014) New regulations by Ministry of Economy to revive industrial Adraa. Accessed at: http://www.syrianef.org/En/?p=3653

103 Los Angeles Times (2014) Syrian government says it's retaken key city near Damascus. Accessed at: http://www.latimes.com/world/middleeast/la-fg-syria-adra-20140925-story.html

104 Information accessed on the Syrian Investment Map through Internet Archive: https://web.archive.org/web/20140313054213/http://syriainvestmentmap.org/index.php?page=show&ex=2&dir=docs&lang=2&ser=1&cat=57&ref=home

105 UNEP/OCHA n.d. User's Guide Hazard Identification Tool. Accessed at: http://www.eecentre.org/Modules/EssentialTools/UploadFile/Attachment/Hazard_Identification_Tool_Users_Guide.pdf

106 For more information on FEAT, see Posthuma, L. et al (2014) The Flash Environmental Assessment Tool: Worldwide first aid for chemical accidents response, pro action, prevention and prepardness. Environment International. Accessed at http://dx.doi.org/10.1016/j.envint.2014.04.18/

107 Rizer, K. R. (2001) Bombing dual-use targets: Legal, ethical, and doctrinal perspectives. Air and Space Power Chronicles. Retrieved from: http://www.airpower.maxwell.af.mil/airchronicles/cc/Rizer.html

108 UNEP (2007) Lebanon: Post-conflict environmental assessment. Accessed at: http://postconflict.unep.ch/publications/UNEP_Lebanon.pdf

109 UNEP (2007) Sudan: Post-conflict environmental assessment. Accessed at: http://postconflict.unep.ch/publications/UNEP_Sudan.pdf

110 SANA (2014) Terrorists attack drinking water wells in Sweida. Accessed at: http://www.sana.sy/en/?p=9610

111 Shamout, N. (2014) Syria faces an imminent food and water crisis. Chatham House. Accessed at: http://www.chathamhouse.org/expert/comment/14959

112 Reuters (2012) WRAPUP 2-Simultaneous bombs hit army compounds in Aleppo. Accessed at: http://www.reuters.com/article/2012/09/09/syria-idUSL5E8K92PX20120909

113 The Telegraph (2014) Sherlock, R. (2014, May 9) Hundreds of Syrians return to Homs to find a city of death. Accessed at: http://www.telegraph.co.uk/news/worldnews/middleeast/syria/10821189/Hundreds-of-Syrians-return-to-Homs-to-find-a-city-of-death.html

114 Ibid

115 World Health Organisation (2014) Syria: Situation report 4. Accessed at: http://www.emro.who.int/images/stories/syria/SituationReport_20140615.pdf

116 Ibid

117 Kamp Jensen, M. (2015) Water cuts for war-weary civilians in Syria's largest city of Aleppo. Accessed at: http://childrenofsyria.info/2015/07/23/voices-from-the-front-line-water-cuts-for-war-weary-civilians-in-syrias-largest-city-of-aleppo

118 Lund, A. (2014) Cold winter coming: Syria's fuel crisis. Carnegie Endowment for International Peace. Accessed at: http://carnegieendowment.org/syriaincrisis/?fa=56917&reloadFlag=1

119 SANA (2014) Terrorists attack power plant in Mhardeh, Hama countryside. Accessed at: http://www.sana.sy/en/?p=11099

120 Stahlgewitter Syrien. (2014, November 13). 2014-11-12 FSA rocket attack on the Mhardeh power plant. [Video file]. Accessed at: https://www.youtube.com/watch?v=-nOy9qwlMqM

121 The Economist (2013) The struggle over electricity. Accesed at: http://country.eiu.com/article.aspx?articleid=1342349918&Country=Syria&topic=Economy_1

122 GEF (2009) GEF Country Portfolio Evaluation: Syria (1994–2008) Evaluation Report No. 52. Global Environment Facility Office. Accessed at: https://www.thegef.org/gef/sites/thegef.org/files/documents/CPE_Report-Syria_0.pdf

123 New Straits Times (2013) Syria disarmament on track as rebel attack cuts power. Accessed at: http://www2.nst.com.my/top-news/syria-disarmament-on-track-as-rebel-attack-cuts-power-1.384215#ixzz3Kw7hqFJY

124 U.S. Energy Information Administration (2014) Syria. Accessed at: http://www.eia.gov/countries/analysisbriefs/Syria/syria.pdf

125 The Economist Group (2014) Syria: The struggle over electricity. Accessed at: http://country.eiu.com/article.aspx?articleid=1342349918&Country=Syria&to

pic=Economy

126 Reuters (2014) U.S-led raids hit grain silos in Syria, kill workers: monitor. Accessed at: http://www.reuters.com/article/2014/09/29/us-mideast-crisis-syria-idUSKCN0HO0EV20140929

127 UNEP (2009) Environmental assessment of the Gaza Strip. Accessed at: http://www.unep.org/disastersandconflicts/Introduction/PostCrisisEnvironmentalAssessment/UNEPsEnvironmentalAssessments/tabid/54635/Default.aspx

128 Ibid

129 Ibid

130 Ibid

131 New Zealand Red Cross (2015) Breakdown of services increases suffering in Syria. Accessed at: https://www.redcross.org.nz/what-we-do/around-the-world/stories/breakdown-of-services-increases-suffering-in-syria

132 Humanitarian Liaison Group (2014) Syria Multi Sector Needs Assessment. Accessed at: http://www.reachresourcecentre.info/system/files/resource-documents/syr_report_syriamultisectorneedsassessment_october2014.pdf

133 IRIN (2013) Clearing Rubbish. Accessed at: http://www.irinnews.org/report/98334/clearing-rubbish-in-syria-a-life-saving-and-life-threatening-job

134 UN Habitat (2014) Homs city profile. Accessed at: http://unhabitat.org/city-profile-homs-multi-sector-assessment/

135 UNEP (2009) Environmental assessment of the Gaza Strip. Accessed at: http://www.unep.org/disastersandconflicts/Introduction/PostCrisisEnvironmentalAssessment/UNEPsEnvironmentalAssessments/tabid/54635/Default.aspx

136 New Zealand Red Cross (2015) Breakdown of services increases suffering in Syria. Accessed at https://www.redcross.org.nz/what-we-do/around-the-world/stories/breakdown-of-services-increases-suffering-in-syria; UNDP (2015) The youth of Deir Ezzor make a change: Volunteers work together for a cleaner city. Accessed at: ttp://www.sy.undp.org/content/syria/en/home/ourwork/povertyreduction/successstories/the-youth-of-deir-ezzor-collect-garbage-.html; IRIN (2013) Clearing Rubbish. Accessed at: http://www.irinnews.org/report/98334/clearing-rubbish-in-syria-a-life-saving-and-life-threatening-job

137 TRWP (2014) Conflict rubble: A ubiquitous and under-studied toxic remnant of war. Accessed at: http://www.toxicremnantsofwar.info/conflict-rubble-a-ubiquitous-toxic-remnant-of-war

138 Ibid

139 Ibid

140 Ibid

141 UNEP (2009) Environmental assessment of the Gaza Strip. Accessed at: http://www.unep.org/disastersandconflicts/Introduction/PostCrisisEnvironmentalAssessment/UNEPsEnvironmentalAssessments/tabid/54635/Default.aspx

142 TRWP (2014) Conflict rubble: A ubiquitous and under-studied toxic remnant of war. Accessed at http://www.toxicremnantsofwar.info/conflict-rubble-a-ubiquitous-toxic-remnant-of-war

143 Ibid

144 Action on Armed Violence (2014) Syria's shockwaves: The consequences of explosive violence. Accessed at: https://aoav.org.uk/2014/syrias-shockwaves-consequences-of-explosive-violence-for-refugees

145 TIME (2013) The destruction of a nation: Syria's war revealed in satellite imagery. Accessed at: http://world.time.com/2013/03/15/the-destruction-of-a-nation-syrias-war-revealed-in-satellite-imagery/

146 Human Rights Watch (2014) Syria barrage of barrel bombs. Accessed at: http://www.hrw.org/news/2014/07/30/syria-barrage-barrel-bombs

147 UN Habitat (2014) City Profile Aleppo. Multi Sector Assessment. Accessed at: http://unhabitat.org/city-profile-aleppo-multi-sector-assessment/

148 Al Arabiya (2013) Two thirds of Syria's Homs destroyed, NGO group says. Accessed at: http://www.telegraph.co.uk/news/worldnews/middleeast/syria/10821189/Hundreds-of-Syrians-return-to-Homs-to-find-a-city-of-death.html

149 The Telegraph (2014) Hundreds of Syrians return to Homs to find a city of death. Accessed at: http://www.telegraph.co.uk/news/worldnews/middleeast/syria/10821189/Hundreds-of-Syrians-return-to-Homs-to-find-a-city-of-death.html

150 A full overview of all the damage assessments can be found here: http://www.unitar.org/unosat/maps/SYR

151 UNICEF (2014) Severe destruction and starvation overwhelm formerly besieged Syrian city. Accessed at: http://childrenofsyria.info/2014/05/26/severe-destruction-and-starvation-overwhelm-formerly-besieged-syrian-city

152 UNEP (2005) Environmental hotspots in Iraq. Accessed at: http://www.unep.org/disastersandconflicts/portals/155/disastersandconflicts/docs/iraq/Iraq_ESA_hotspots_2003.pdf

153 Al Monitor (2014) War profiteers plunder Syria. Accessed at: http://www.al-monitor.com/pulse/originals/2014/05/syria-aleppo-war-profit-theft-loot-rebels-regime.html##ixzz3LV0G9kLk; Herbert, M. (2014) Partisans, profiteers and criminals: Syria's illicit economy. The Fletcher Forum of World Affairs. 38(1), pp. 69-86.

154 Syrian Economic Forum (2013) 50 billion dollars losses of industrial facilities in Aleppo. Accessed at http://www.syrianef.org/En/?p=1090

155 Al Monitor (2014) War profiteers plunder Syria. Accessed at http://www.al-monitor.com/pulse/originals/2014/05/syria-aleppo-war-profit-theft-loot-rebels-regime.html##ixzz3LV0G9kLk

156 NTI. (n.d.). Syria facilities: Nuclear Map. Accessed at http://www.nti.org/gmap/nuclear_syria.html?/; Syrian Economic Forum (2013) 50 billion dollars losses of industrial facilities in Aleppo. Accessed at http://www.syrianef.org/En/?p=1090

157 MOE/UNDP/EU (2014) Lebanon Environmental Assessment of the Syrian Conflict & Priority Intervention. Accessed at: http://www.undp.org/content/dam/lebanon/docs/Energy%20and%20Environment/Publications/EASC-WEB.pdf

158 Lima et al (2011) Impact of ammunition and military explosives on human health and the environment. Reviews on Environmental Health 26(2): 101-10 January 2011. Accessed at: http://www.ncbi.nlm.nih.gov/pubmed/21905453

159 Pichtel, J. (2012) Distribution and Fate of Military Explosives and Propellants in Soil: A Review. In: Applied and Environmental Soil Science, vol. 2012, Article ID 617236, 33 pages. Accessed at: http://dx.doi.org/10.1155/2012/617236

160 Ibid

161 Ibid

162 UK Environment Agency (1995) DOE Industry profile. Chemical works: Explosives, Propellants and Pyrotechnics Manufacturing Works. Accessed at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290807/scho0195bjkb-e-e.pdf

163 US EPA (2006) Contaminated Site Clean-up Information: Explosives. Accessed at: https://clu-in.org/characterization/technologies/exp.cfm#26]

164 Lima et al (2011) Impact of ammunition and military explosives on human health and the environment. Reviews on Environmental Health 26(2): 101-10 January 2011. Accessed at: http://www.ncbi.nlm.nih.gov/pubmed/21905453

165 Pichtel, J.(2012) Distribution and Fate of Military Explosives and Propellants in Soil: A Review. In: Applied and Environmental Soil Science, vol. 2012, Article ID 617236, 33 pages. Accessed at: http://dx.doi.org/10.1155/2012/617236

166 UNEP (2007) Lebanon Post Conflict Environmental Assessment. Accessed at: http://postconflict.unep.ch/publications/UNEP_Lebanon.pdf

167 A full overview on UNEP's environmental assessments can be found here: http://www.unep.org/disastersandconflicts/Publications/IraqPublications/tabid/54725/Default.aspx

168 UNEP (2006) Ground Contamination Assessment Report Military Waste Storage Site, Astana, Afghanistan. Accessed at: http://postconflict.unep.ch/publications/afghanistan_cont.pdf

169 UNDAC (2012) Environmental Emergency Assessment Ammunitions Depot Explosions Brazzaville. Accessed at: https://ochanet.unocha.org/p/Documents/Congo_UNDAC_Environment_Emerg_Assmt%20Final.pdf

170 Vidosavljevi, D. et al (2013) Soil contamination as a possible long-term consequence of war in Croatia, ActaAgriculturae Scandinavica, Section B - Soil & Plant Science, 63:4, 322-329; Jergović, M. et al. (2010) Cross-sectional Biomonitoring of Metals in Adult Populations in Post-war Eastern Croatia: Differences Between Areas of Moderate and Heavy Combat. In: Croatia Medical Journal. 2010 Oct; 51(5): 451–460.

171 Al-Sabbak, M. et all (2012) Metal Contamination and the Epidemic of Congenital Birth Defects in Iraqi Cities. In: Bullitin of Environmental Contamination Toxicology. 2012 Nov; 89(5): 937–944.

172 Manduca, P., Naim, A., Signoriello, S. (2014) Specific Association of Teratogen and Toxicant Metals in Hair of Newborns with Congenital Birth Defects or Developmentally Premature Birth in a Cohort of Couples with Documented Parental Exposure to Military Attacks: Observational Study at Al Shifa Hospital, Gaza, Palestine. In: International Journal of Environmental Research and Public Health. 2014 May; 11(5): 5208–5223.

173 For example, see: FFI (2008) International Workshop on Munitions and Environment. Accessed at: http://rapporter.ffi.no/rapporter/2008/01568.pdf; NATO (2010) Environmental Impact of Munitions and Propellant Disposal. RT0-15 Technical report. Accessed at: http://ftp.rta.nato.int/public//PubFullText/RTO/TR/RTO-TR-AVT-115///$$TR-AVT-115-ALL.pdf; Ministry of Defense Finland (2013) European Conference on Defense and the Environment. Conference proceedings can be accessed here: http://www.defmin.fi/files/2609/Conference_proceedings_printq_2013.pdf

174 Higgins, E. (2013) Syria's Barrel Bombs Technology. Accessed at: http://brown-moses.blogspot.nl/2013/12/syrias-barrel-bomb-technology-relative.html

175 Human Rights Watch (2014) Syria barrage of barrel bombs. Accessed at: http://www.hrw.org/news/2014/07/30/syria-barrage-barrel-bombs

176 INEW (2015) INEW Policy on barrel bombs. Accessed at : http://www.inew.org/site/wp-content/uploads/2015/09/INEW-policy-on-barrel-bombs-FINAL.pdf

177 TRWP (2015) The civilian health risks from TNT in Syria's barrel bombs. Accessed at: http://www.toxicremnantsofwar.info/the-civilian-health-risks-from-tnt-in-syrias-barrel-bombs/

178 The Guardian (2015) Syrian doctors to show the US evidence of Assad's use of chemical weapons. Accessed at: http://www.theguardian.com/world/2015/jun/16/syria-assad-regime-is-weaponising-chlorine-us-congress-to-hear

179 The Guardian (2015) Investigators confident that chlorine gas was used as weapon in Syria. Accessed at: http://www.theguardian.com/world/2015/jan/07/syria-chlorine-chemical-weapons-attacks-opcw

180 OPCW: Chemical Weapons Convention articles. Accessed: at http://www.opcw.org/chemical-weapons-convention/articles/

181 Higgins, E. (2014) Volcanoes in Damascus. Accessed at: https://www.bellingcat.com/resources/case-studies/2014/07/15/volcanoes-in-damascus; Higgins, E. (2014) New Heavy Short Range Rockets Deployed By Pro-Syrian Government Forces. Accessed at: https://www.bellingcat.com/news/mena/2014/07/16/new-heavy-short-range-rockets-deployed-by-pro-syrian-government-forces

182 Al Jazeera (2015) 'Elephant rockets' kill dozens in Damascus suburb. Accessed at: http://www.aljazeera.com/news/2015/06/syria-douma-elephant-rockets-150617011324100.html

183 Ibid

184 Adams, J. (2015) A new type of Volcano rocket spotted in Idlib. Syria Direct. Accessed at: http://syriadirect.org/news/a-new-type-of-volcano-rocket-spotted-in-idlib/

185 Yalla Souriya (2015) Eyewitness reporting on Syrian news blog (unconfirmed). Accessed at: https://yallasouriya.wordpress.com/2015/07/05/syria-aleppo-very-intense-elephant-rocket-attacks-being

186 Higgins, E. (2013) DIY Weapons In Syria - The Syrian Opposition Deploys Their Latest And Largest DIY Munition. Accessed at: http://brown-moses.blogspot.nl/2013/08/diy-weapons-in-syria-syrian-opposition.html

187 Higgins, E. (2014) The DIY Weapons Of The Syrian Rebels. Accessed at: https://www.bellingcat.com/news/mena/2014/07/13/the-diy-weapons-of-the-syrian-rebels/

188 Taylor, A. (2013) DIY Weapons of the Syrian Rebels. Accessed at: http://www.theatlantic.com/photo/2013/02/diy-weapons-of-the-syrian-rebels/100461/

189 VICE (2013) Inside the DIY Weapons Workshops of the Free Syrian Army. Accessed at: http://motherboard.vice.com/blog/the-diy-weapons-workshops-of-the-free-syrian-army

190 Alkin, M. (2013) How War in Syria Turned These Ordinary Engineers Into Deadly Weapons Inventors. WIRED. Accessed at: http://www.wired.com/2013/07/diy-arms-syria/

191 Syria Mubasher (2013) Explosion in Ammunition dump in Homs (translated) Accessed at: http://slnnews.co/?p=20690

192 Al Arabiya (2013) Explosions rock ammunition depots in Syria, NGO says. Accessed at: http://english.alarabiya.net/en/News/middle-east/2013/07/05/Explosions-rock-ammunition-depots-in-Syria-NGO-says.html

193 New York Times (2013) Video Shows Huge Explosion as Israel Strikes Damascus. Accessed: at http://projects.nytimes.com/watching-syrias-war/video-israeli-strike-damascus

194 UNEP (2005) Assessment of Environmental "Hot Spots" in Iraq. Accessed at: http://postconflict.unep.ch/publications/Iraq_ESA.pdf; Christian Science Monitor (2010) As Iraq war winds down US military cleans up hazardous waste. Accessed at: http://www.csmonitor.com/World/Europe/2010/0722/As-Iraq-war-winds-down-US-military-cleans-up-hazardous-waste

195 TRWP (2015) Conflict in Yemen: lessons for citizen environmental monitoring. Accessed at: http://www.toxicremnantsofwar.info/conflict-in-yemen-lessons-for-citizen-environmental-monitoring

196 WHO (2009) Manual for the Public Health Management of Chemical Incidents. Accessed at: http://whqlibdoc.who.int/publications/2009/9789241598149_eng.pdf?ua=1; WHO (2010) WHO Human Health Risk Assessment Toolkit: Chemical Hazards. Accessed at http://www.who.int/entity/ipcs/publications/methods/harmonization/toolkit.pdf?ua=1

197 UNEP/OCHA User Guide Hazard Idenfitication Tool. Accesed at: http://www.eecentre.org/Modules/EssentialTools/UploadFile/Attachment/Hazard_Identification_Tool_Users_Guide.pdf & UN's Environmental Assessment Tool (FEAT). Accessed at: https://docs.unocha.org/sites/dms/Documents/FEAT_Version_1.1.pdf

198 UNOCHA (2013) Disaster Waste Management Guidelines. Accessed at: https://docs.unocha.org/sites/dms/Documents/DWMG.pdf

199 WHO (2002) Environmental Health in Emergencies and Disasters. A Practical Guide. Accessed at: http://apps.who.int/iris/bitstream/10665/42561/1/9241545410_eng.pdf?ua=1

200 The colours in the column 'Estimated Impact Type' indicates the priority to be given to this specific hazard. (Red = Priority #1, Orange = Priority #2, Green = Priority #3)

Godebaldkwartier 74
3511 DZ Utrecht
The Netherlands

www.paxforpeace.nl
info@paxforpeace.nl
+31 (0)30 233 33 46

P.O. Box 19318
3501 DH Utrecht
The Netherlands