

Environmental impact of the conflict in Gaza

Preliminary assessment of
environmental impacts



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Acknowledgement

UNEP is the leading global environmental authority that sets the global environmental agenda. The organisation promotes the coherent implementation of the environmental dimension of sustainable development within the UN system and serves as an authoritative advocate for the global environment. UNEP is keeping the environment under review by providing policy advice, early warning information and promoting international cooperation. It is under this mandate and at the request of the State of Palestine, that UNEP in collaboration with GRID-Arendal has undertaken this preliminary and rapid review of existing information on the current conflict in the Gaza Strip to inform and prepare for conflict-related environmental impact assessments.

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Gaza City from the tallest building in the Gaza Strip
Photo: Unsplash /Mohammed Ibrahim / published August 2022)

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Executive Summary

This Preliminary Assessment was prepared by the United Nations Environment Programme (UNEP). It is an initial response to an official request from the State of Palestine, issued in December 2023, that UNEP conduct an assessment of the environmental impacts of the conflict in Gaza. Conflict was ongoing in Gaza throughout preparation of this report. The security situation and access restrictions prevailing in Gaza influenced the type of analysis UNEP was able to undertake.

The Preliminary Assessment provides a summary of what is known about the environmental impacts of the ongoing conflict in the Gaza Strip. In addition to describing known, and in many cases visible, environmental impacts, this assessment highlights conflict-related environmental issues that are of serious concern, but about which the United Nations has limited information at this stage. Some conflict-related impacts—such as the likely contamination of soil and the Coastal Aquifer by chemicals and heavy metals—can only be fully understood through more detailed sampling and analysis, which is not possible under current conditions.

Gaza is a small, densely populated coastal area, the environment of which has been affected by repeated escalations of the decades-long conflict, unplanned urbanization and population growth. Interventions to protect the environment from pollution, and to restore degraded ecosystems, have been highly constrained by complex governance arrangements prevailing since 2007 – which include de facto control of internal arrangements within Gaza by Hamas-led authorities; Israeli closures; and restrictions on the import of goods. These factors have contributed over the past decades to a severely degraded environment, with consequences that reach beyond the confines of the Gaza Strip. Despite these constraints, major investments had been made during the past five years in environmental management – especially in wastewater treatment and solid waste infrastructure. These investments were helping to control contamination and protect people, terrestrial, freshwater and marine ecosystems from pollution. Palestinian and international partners were also taking steps towards the recovery of the critical Coastal Aquifer, and restoration of an internationally important wetland, Wadi Gaza.

The escalation of conflict since 7 October 2023 has clearly had a profound impact on people and the environment in Gaza. Intensive bombardment by Israel has led to unprecedented intensity of destruction in terms of infrastructure, productive assets and service delivery. Sewage, wastewater and solid waste management systems and facilities have collapsed. The destruction of buildings, roads and other infrastructure has generated over 39 million tons of debris, some of which is contaminated with unexploded ordnance, asbestos and other hazardous substances. Human remains are buried in this vast quantity of building debris.

Another set of urgent but less immediately visible environmental challenges include the contamination of land, water resources and the air by munitions and unexploded ordnance; possible instability of land arising from the prior construction of an extensive system of tunnels; and contamination of soil and water resources arising from the recent destruction and flooding of such tunnels.

Understanding the scale, extent and appropriate remediation measures to address these challenges will require a specialised, science-based assessment. Such an assessment helps to minimize long-term impacts on the environment, and mitigate the harm caused by conflict to the greatest extent possible. Such assessment should be undertaken as soon as possible, and measures put in place to protect people and prevent further contamination of soil, freshwater and the marine environment.

Environmental analysis also needs to be incorporated into plans for humanitarian response and early recovery. The vast quantity of debris must be safely managed and, to the extent possible, recycled to avoid further contamination of land and watercourses and minimize depletion of scarce natural resources. Systems for the management of sewage, wastewater and solid waste must be restored, and contamination from munitions, chemical and fuel spills must be identified and removed. This will require environmental management frameworks, carefully sequenced repair and reconstruction of damaged infrastructure, restoration of movement of people and goods within Gaza, and resumption of the power supply. Further, specialised analysis will be required to understand

and address the complex challenges associated with munitions debris and the tunnels.

Further, joint analytical and planning work will be required during 2024 to support the recovery of Gaza's environment and people. The Preliminary Assessment concludes with a summary of the types of assessment work envisaged during the months ahead. These include incorporation of environmental issues fully into the envisaged multilateral Rapid Damage and Needs Assessment process, and a further, field-based assessment of priority environmental issues, which should be undertaken by qualified specialists whenever conditions permit.



Nuseirat camp, Gaza
© UNRWA 2022

About this Preliminary Assessment

The United Nations Environment Programme

UNEP is the leading global environmental authority that sets the global environmental agenda. The organisation promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations (UN) system and serves as an authoritative advocate for the global environment.

UNEP is keeping the environment under review by providing policy advice, early warning information and promoting international cooperation. It is under this mandate and at the request of the State of Palestine this Preliminary Assessment has been produced.

Request from the State of Palestine to the United Nations Environment Programme

In December 2023, UNEP received an official request from the State of Palestine to conduct an assessment of the environmental impacts of the conflict in Gaza. The type of assessment requested by the State of Palestine is a well-established aspect of UNEP's work, pursuant to United Nations Environment Assembly (UNEA) mandates including Resolutions 2/15, 3/1 and 6/12. The goal of such assessments is to determine the extent of damage and inform a science-based approach to recovery and reconstruction, to be taken forward when conditions allow (Figure 1).

A science-based assessment helps to minimize long-term impacts on the environment and mitigate the harm caused by conflict to the greatest extent possible. UNEP is working with Palestinian and international partners to understand environmental damage incurred since October 2023, and to begin planning for recovery. The current preliminary report may contribute to such planning.

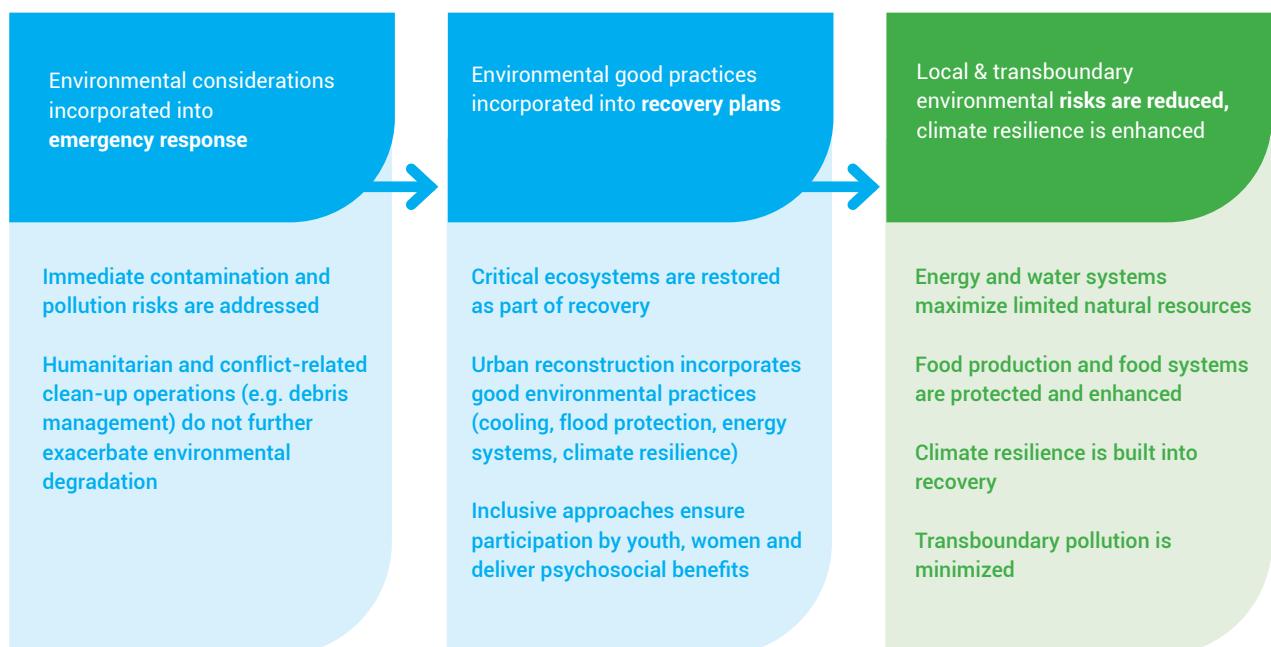


Figure 1: Integration of environmental analysis into emergency response and recovery can deliver numerous benefits

Status and structure of the Preliminary Assessment

This Preliminary Assessment provides a summary of what is known about the environmental impacts of the conflict in Gaza. It also highlights environmental issues of serious concern, but about which the UN has limited information at this stage.

At the time of publication, conflict is ongoing and due to security constraints it has not been possible to undertake field-based assessment work. Following the official request from the State of Palestine, and during preparation of the multilateral Gaza Strip Interim Damage Assessment, UNEP sought access to visit Jerusalem and Ramallah. UNEP's request to the State of Israel for a visa for one senior international staff member was not granted.

The current report draws on several sources, including damage assessments undertaken by the United Nations (UN) and multilateral partners, including the World Bank¹. It includes remote sensing assessments undertaken using established methodologies (e.g. for debris quantification). It draws on knowledge of how past escalations of the conflict in Gaza have affected the environment, combined with an understanding of the significantly larger scale of the current escalation. Scientific literature has also been reviewed relevant to the situation in Gaza, and to environmental damage arising from conflicts and disasters. The report has been enriched by observations, background material and other inputs from UN colleagues working on and in the Gaza Strip. UNEP works continuously with sister UN entities on understanding the extent of damage to the environment, and acknowledges their support.

UNEP contributed to the development of the Gaza Strip Interim Damage Assessment (hence forward referred to as the Interim Damage Assessment) which was issued jointly by the three multilateral institutions on 29 March 2024 (World Bank [WB], European Union [EU] and United Nations [UN] 2024). The Interim Damage Assessment provides important information about the unprecedented

extent of damage – estimated in March 2024 to total US\$18.5 billion – and the authors noted that “the estimated scale of the damages is expected to increase because the conflict is still ongoing.”

In the current report, in an effort to ensure information is as current as possible, UNEP has used some previously unpublished material from UN field-based sources. In some instances, UNEP has also used unverified reports from the media of damage and impacts: for example, in the case of reports about the use of types of munitions as an indication of the potential for environmental contamination.

Other UN entities are covering the political, peace and security, and humanitarian aspects of the conflict. These are not therefore covered in this document, except where data collected by the humanitarian system (for example the increase in waterborne diseases) provide an indicator of environmental degradation.

The Preliminary Assessment is organised as follows:

Section 1 summarises the state of the environment and natural resources in Gaza before the escalation that started on 7 October 2023. This section notes longstanding drivers of environmental degradation that have put pressure on natural resources and critical ecosystems. The impact on people and the environment is also described. These drivers and pressures have contributed over the past decades to a severely degraded environment. Section 1 also describes responses that before October were contributing to limited positive changes relating to environmental management.

Section 2 describes how the conflict has generated environmental hazards and interrupted almost all environmental management systems and services (including ecosystems services).

Section 3 describes a further set of urgent but less immediately visible environmental challenges that have arisen as a result of the conflict, some of which will require specialised assessment and management.

¹ In addition to its staff capabilities, the World Bank has been using a market vendor, Ipsos, to support the assessment of damage arising from the conflict in Gaza. Ipsos has been a regular contractor with the World Bank assisting in crisis data collection for Disaster Damage and Needs Assessment. The contractor is tasked to provide analytical and qualitative updates of the daily situation on the ground. Ipsos assessments are made based on traditional and social media reporting, ground partner information, Synthetic Aperture Radar (SAR), multi-spectral, high resolution optical and infrared satellite imagery and data triangulation from various sources, including publicly available non-governmental organisation and relief organisation information. Source: World Bank Gaza Damage Assessment bi-weekly reports.

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Section 1: The environment and natural resources in Gaza before the current conflict

The whole occupied Palestinian territory (the Gaza Strip and the West Bank, including East Jerusalem) was affected by environmental change and degradation before the escalation of the conflict following 7 October 2023. In a report issued in 2020, UNEP described several powerful drivers of environmental change in the occupied Palestinian territory (UNEP 2020). These drivers include environmental governance constraints relating to the ongoing occupation and complex political and security situation; high population growth accompanied by rapid, poorly planned urbanization; and climate change, which is already contributing to changes in the water cycle and temperatures in the Eastern Mediterranean. The whole Mediterranean region has been identified by the Intergovernmental Panel on Climate Change as a "climate change hotspot" with a large number of vulnerable natural systems and socioeconomic sectors (Ali 2022). In its analysis, which was undertaken from 2019 to 2020, UNEP found and documented substantial evidence of environmental change and degradation, based on a thorough review of data from government sources, reports by international organizations and peer-reviewed scientific papers; consultations with stakeholders; and field visits to over 40 sites by a UNEP delegation.

Key findings of the 2019-20 analysis included:

- i) **A freshwater crisis in Gaza**, linked to over-abstraction from the Coastal Aquifer (linked to a steady increase in demand) and poor water quality caused by use of agricultural pesticides, along with leaching of sewage. Nitrate concentration in the aquifer was six times higher than World Health Organization (WHO) recommendations, with chloride concentrations also high. Contaminants found in the groundwater present particular risks to children and pregnant women;
- ii) **Pollution of the marine environment**, caused by the flow of untreated or partially-treated water and wastewater into the sea, with impacts on marine ecosystems, human health and desalination operations;
- iii) **Contamination of soil caused by the discharge of raw and untreated wastewater** into wadis and agricultural lands, and the widespread disposal of solid waste in informal dumpsites, many of which are located close to urban areas of agricultural land;
- iv) **Contamination of soil, water and air from unregulated industries**, including informal e-waste and vehicle processing. In Gaza, unregulated industries were found to be contributing to high incidences of childhood lead poisoning.

Between publication of this UNEP report (May 2020) and the escalation of conflict in October 2023, the state of the environment in the Gaza Strip continued to be affected by many of the drivers of degradation summarised above – including the environmental impacts of a serious conflict escalation in 2021 (World Bank Group, EU and UN 2021). During the same period some important enhancements in environmental management systems were also achieved in Gaza. The ongoing environmental challenges, and some limited improvements up to October 2023, are summarized below.



Refugee life conditions, Nuseirat camp, Gaza.
© 2022 UNRWA. Photo by Mohammed Hinnawi

Gaza Strip: Geography and demography

Gaza's environmental challenges are particularly severe because of its limited land area, high population density, poverty and major governance constraints – including occupation and conflict.

The Gaza Strip is situated along the eastern coast of the Mediterranean Sea, with a total area of 365 square kilometres (km²) (45 kilometres long, 6–12 kilometres wide). Gaza is in a transitional zone between the arid desert climate of the Sinai Peninsula and the temperate and semi-humid Mediterranean climate along the coast. It includes sand dunes to the west, along the Mediterranean coastline; loessial arid brown soil further inland; and some sandy regosols in the southeast of the Strip. The sand is permeable with good porosity. Sand quarries have transformed the natural habitats for biodiversity (Thawabba et al. 2017). To the north are four ridges (Coastal ridge, Gaza, El-Muntar and the Beit Hanoun ridge) ranging from 20 to 90 metres above sea level.

Gaza has one of the highest population densities in the world, with 6,102 individuals/km² (Palestinian Central Bureau of Statistics [PCBS] 2023). A large share of households are below the poverty line (World Bank 2023a). Before the current escalation and large-scale displacement of people within the Strip, parts of northern Gaza had a population density of over 30,000 per km².² Urbanization in Gaza has occurred rapidly, with inadequate planning. Severe overcrowding has led to unauthorized 'vertical' construction, with associated environmental and disaster risks, severely limiting the effectiveness of municipal planning or zoning in the refugee camps.³ Around 40 per cent of Gaza's population are children under the age of 15, and 60 per cent are refugees (United Nations Office for Humanitarian Affairs [UN-OCHA] 2023). Both urban areas and agricultural intensity in Gaza have increased during the past decade: built-up areas expanded from 69 km² in



Deir El-Balah refugee camp, Gaza – photograph taken before October 2023
© UNRWA)

2013 to up to more than 85 km² in 2020, while agricultural areas increased from 175 km² in 2013 to 220.6 km² in 2020 (Musallam, Zhou and Jewitt 2023).

Environmental challenges

Water: Large-scale discharge of untreated wastewater within and from Gaza has been a serious cause of groundwater and marine pollution for many years. During the 2010s, the amount of untreated or partially treated sewage/wastewater flowing from the Gaza Strip into the Mediterranean Sea increased steadily from 90,000 cubic meters (m³) per day in 2012 to 100,000 m³ per day in 2016 and 110,000 m³ per day in 2018 (UNEP 2020).

Freshwater resources in Gaza were also under immense pressure, with a reduction in rainfall accompanied by limited regulation leading to groundwater being over-extracted at alarming rates – resulting in diminishing output of the aquifer and deteriorating water quality (World Bank 2018). By 2020, the Coastal Aquifer groundwater level had dropped to more than ten metres below mean sea level (UNEP 2020). Seawater intrusion into the aquifer has been described by the World Bank as an "ecological catastrophe and a main climate change vulnerability" (World Bank 2018).

Natural recharge of the aquifer is constrained by expansion of built-up areas in Gaza, which increases in runoff (decreasing infiltration) and evaporation (Musallam, Zhou and Jewitt 2023). Models project that without interventions, there will be further decreases in the level of the aquifer, due to a combination of human activities and climate change (Musallam, Zhou and Jewitt 2023). Timely, sustained action and investment is thus considered necessary to protect the aquifer from irreversible degradation (Musallam, Zhou and Jewitt 2023).

2 By contrast, population density in Manhattan, New York, United States of America is 27,346 per km² (Source: <https://worldpopulationreview.com/boroughs/manhattan-population>). Population density in Hong Kong, China is 7060 per km² (Source: <https://data.worldbank.org/indicator/EN.POP.DNST?locations=HK>).

3 The use of the term "refugee camps" specifies areas in which registered Palestine refugees were living before the current escalation (as opposed to areas into which Palestine refugees and non-refugees have been displaced as a result of the current escalation). According to UNRWA, "Nearly one-third of the registered Palestine refugees, more than 1.5 million individuals, live in 58 recognized Palestine refugee camps in Jordan, Lebanon, the Syrian Arab Republic, the Gaza Strip and the West Bank, including East Jerusalem. A Palestine refugee camp is defined as a plot of land placed at the disposal of UNRWA by the host government to accommodate Palestine refugees and set up facilities to cater to their needs... Socioeconomic conditions in the camps are generally poor, with high population density, cramped living conditions and inadequate basic infrastructure such as roads and sewers." <https://www.unrwa.org/palestine-refugees>



Displaced Palestinian children queue to fill household water containers at Beach Elem school in Gaza
(2021 UNRWA/M. Hinawi)

Additionally, the aquifer's water quality was compromised by pollution from agricultural pesticides and poorly treated sewage, causing nitrate levels to reach six times the WHO recommended limit for safe drinking water (World Bank 2023a). Chloride concentrations during the past decade were also high, posing particular risks to children and pregnant women (UNEP 2020).

Population density and sustained demographic growth translate into gradually increasing domestic water needs, as well as demand for agricultural production to protect food security. According to WHO, between 50 and 100 litres of water per person per day are needed to ensure that most basic needs are met and few health concerns arise (United Nations [UN] n.d.).

Before the current hostilities, people in Gaza had access to four main freshwater sources: the Coastal Aquifer (accessed via approximately 300 groundwater wells), desalinated water supplied by the three short term low volume desalination plants, piped water from the Israeli company Mekorot, and UNRWA and private sources (municipal and private vendors operated small-scale desalination units supplied from groundwater wells, some powered by solar PV, and water tanker trucks). The amounts provided by these sources and the change since the outbreak of conflict are summarized in Section 2, Table 1 below (p.20) The limited water available in Gaza

before the current escalation was largely of poor quality, which translated to only six per cent of the Gaza population having access to safely managed, piped drinking water (WB, EU and UN 2024).

Solid waste management and disposal: Solid waste management challenges contributed to pollution in Gaza. Before October 2023, 1,726 tons of solid waste were generated in Gaza every day, comprising organic matter (more than two-thirds), cardboard, glass, metals, paper and plastics (United Nations Development Programme [UNDP] 2024). Solid waste management in Gaza presented growing challenges before the current escalation: 3.9 million tons of waste were disposed of at the main Johr Edeek landfill in the north, which has been operating beyond capacity. Fires and piles of solid waste were contributing to growing concerns regarding the negative environmental, health and social impacts (UNDP 2024).

Improper management of healthcare waste presented significant environmental and health risks. Research published in 2021 found that infectious medical waste in Gaza was often not adequately segregated from non-infectious normal waste, leading to contamination of land and water sources, and increasing the risk of disease transmission (Abukmeil et al. 2021). Progress had been made during 2020–23 on medical waste management, including the establishment of two main medical waste treatment facilities which were treating 1–1.5 tons of such waste per day (UNDP 2024).

Urban and critical infrastructure: Gaza's urban and critical infrastructure, especially Gaza City, has suffered extensive damage due to recurrent conflicts. The 2008–2009 conflict resulted in significant destruction, including damage to 2,692 buildings and around 600,000 tons of demolition debris. The water and sanitation infrastructure, along with electricity supply, have been repeatedly affected leading to prolonged reconstruction and recovery periods (UNEP 2020).

Land and soil: Just 10 per cent of arable land of the occupied Palestinian territory is located in Gaza, with the majority of such land in the West Bank (World Bank 2023a). Gaza's arable land is used intensively for agriculture, growing crops including citrus, vegetables, almonds, dates, olives, guavas, strawberries and flowers (UNEP 2020). Intensive agricultural activities have led to soil deterioration, including a decline in organic matter and the loss of nutrients (UNEP 2020). Furthermore, ground water contamination from agrochemical runoff adds to water pollution from other sources (inadequately treated urban sewage, leachate from solid waste and saline intrusion from seawater), resulting in poor water quality impacting human health as well as agricultural productivity.

Restrictions on access to services, as well as the shrinking natural resource base, has impacted the Palestinian economy and has disproportionately affected women and low-income households. Disruptions to water supply and other basic services increase the burden of domestic labour, and the challenge of working productively in the informal sector. Restrictions on the use of water and land, and on the import of materials and technologies has affected farming practices. Farmers were using excessive chemical fertilizers and pesticides to increase crop yield as well as the compounding effects of restrictions on scarcity of land and water (UNEP 2020).

Recent investments in environmental management

Major investments in some areas were delivering benefits for people and the environment prior to October 2023. These are described in the section below.

Infrastructure for water desalination and wastewater treatment, plans to recharge the Coastal Aquifer. Major investments have been made in wastewater treatment – including the construction of the Northern Gaza Emergency Sewage Treatment (NGEST) plant in northern Gaza, at a cost of US\$74.4 million; and wastewater treatment plants in Central Gaza and Khan Younis. The latter two plants were both commissioned in 2023. Plans to 'rest' and recharge the Coastal Aquifer were also being developed and implemented by Palestinian Water Authority (PWA), the Coastal Municipalities Water Utility (CMWU) and international partners working in the water sector. The PWA was undertaking continuous assessment of wells, and making efforts to reduce groundwater extraction. The World Bank's Water Security Development Project sought to enhance the PWA capacity and to improve the supply of bulk water, leading to reduction of groundwater abstraction from municipal wells, which would have positive impacts on the aquifer.⁴ This World Bank project was showing "good progress in all its activities" in September 2023 (World Bank 2023b). Three short term low volume

(STLV) desalination plants were constructed to reduce dependence on the aquifer. To enhance groundwater recharge, infiltration basins for three wastewater treatment plants had been constructed so that treated water could be used to charge the aquifer. Stormwater collection lagoons had also been constructed with the same objective. Further plans were being developed to reduce the dependency on the aquifer via increased use of treated wastewater for irrigation (instead of agricultural wells).

The plans described above were designed to avoid the further and potentially irreversible contamination of the Coastal Aquifer, a natural water resource on which people in Gaza have relied for centuries.⁵ PWA water data show that the investments were having a beneficial impact on the negative trend in water quality: contamination of both groundwater and marine water had begun to decrease in 2023 with the implementation of new wastewater treatment plants, although they had not yet reached the target level of improvement.⁶

Interventions including the introduction of resource-efficient hydroponic agricultural techniques also sought to increase agricultural production in the context of restrictions on water and land availability.

Such investments in water and sanitation infrastructure were especially important in light of Gaza's high population density: in addition to protecting ecosystems, they helped to limit people's exposure to pollution, while allowing the agricultural sector to continue food production. The latter is important for food security in Gaza. Before the current hostilities, Gaza was largely self-sufficient in terms of fresh vegetables, eggs, white meat (i.e. poultry).⁷ Water and sanitation improvements were also necessary to allow people to use the sea as a relatively low-risk area for recreation: this was especially beneficial for families with young children. Efforts to protect marine water quality were important for Gaza fisheries, for the safe operation of desalination plants in both Gaza and Israel, and for the marine ecosystems of the Mediterranean Sea.

4 "To address the issue of chronic poor ground water quality in Gaza, [the Palestinian Water Authority] PWA with support from the World Bank other donors designed a comprehensive solution, which includes investments in both infrastructure development and institutional strengthening to address the Gaza water and sanitation crisis. Core elements include building a Gaza Central Desalination Plant (GCDP) along with the required Associated Works network infrastructure; increasing water imports from Israel; constructing a minimum of three Short Term Low Volume (STLV) seawater desalination plants; reducing Non-Revenue Water (NRW); developing waste water treatment and reuse schemes; establishing a National Water Company; and Strengthening the Gaza Coastal Municipalities Water Utility (CMWU) as the sole utility for water and sanitation service delivery in Gaza." World Bank, Water Security Development Program (WSDP) (P168739) Concept Note, 20 December 2018.

5 Recent scientific modelling indicates that despite the challenges facing the aquifer, "groundwater recovery in the Gaza Strip is feasible." A "freshwater intervention" scenario, whereby abstraction using municipal and agricultural wells was reduced by 50 per cent and 25 per cent respectively as a result of increased use of desalinated seawater, would "strengthen the seaward hydraulic gradient as a result of an overall rise in groundwater levels for the entire simulation area, which will cause a considerable seawater retreat as a result of freshwater flushing, especially in the northern, Khanyounis, and the north-western Gaza provinces." (Musallam, Zhou, & Jewitt, 2023).

6 UNEP communication with Palestinian Water Authority, May 2024.

7 Data source: FAO, April 2024.



Palestine refugee women are prioritised for emergency cash-for-work opportunities in Gaza.

© 2023 UNRWA. Photo by Mohammed Hinnawi

The relationship between energy and water supply/treatment in Gaza is a critical issue. The significant energy consumption for water-related activities, such as operating desalination facilities and water-treatment plants, has been compounded in the recent past (before 7 October 2023) by energy shortages, with wastewater treatment plants operating below capacity (UNEP 2020; World Bank 2023a). Such energy issues relating to the water sector were gradually being addressed via the introduction at wastewater treatment plants of either solar power or methane-gas driven generators.

Shift to renewable energy: Before the current escalation, less than 35 per cent of the Gaza Strip's electricity demand was provided through the Gaza Power Plant, which had limited capacity and was supplemented with electricity imports from Israel. A shift to renewables in Gaza's power sector was under way: this contributed to emissions reduction and to stability of the power supply (which is important for environmental management facilities including wastewater treatment). The residential sector is the primary consumer of electricity in Gaza, accounting for 60 per cent of the total consumption. Before October 2023, 20 per cent of households had adopted solar energy, reflecting a growing trend towards renewable sources (UNEP 2020; Pax 2023). This helped to compensate for the intermittent energy supplied by the Gaza Power Plant (capacity of 140 megawatts [MW]) which was affected by fuel supply constraints and operational challenges (Pax 2023; World Bank 2023a). Gaza power shortages were

particularly acute during peak periods in winter and summer (UNEP 2020). In 2023, Gaza had on average 10 hours of electricity per day, in 2022 the average was 12 hours and in 2020–21 it was 13 hours (UN-OCHA 2023).

In the last ten years, there has been a steep increase in solar panel installations in Gaza, from just 12 in 2012 to 8,760 in 2022 (Pax 2023). Investments in energy storage would be crucial to ensure energy security, particularly during crises, and to enhance the resilience of the electricity sector (World Bank 2023a). To support this transition, the United Nations Development Programme (UNDP) had been working on installation of photovoltaic facilities in Gaza hospitals and schools, and the use of solar energy for the treatment of wastewater.⁸ The United Nations Office for Project Services (UNOPS) supported the installation of the solar energy systems (721 kWp) on the rooftop of the European Gaza Hospital (EGH) and photovoltaic (PV) solar systems at five schools in Gaza (Beit Hanoun, Zahrat Al Madain, Al Aishiah, Al Karmel and Khalid Bin Al Waleed) to support the education system. The Office of the Quartet has also been supporting the Palestinian Authority in 2023 by identifying the Gaza grid's capacity to absorb renewable energy, and defining how to incorporate more utility-scale solar PV projects.



UNRWA's Gaza Training Centre provided vocational training to female and male Palestinian refugees on installing, operating, maintaining and programming solar photovoltaic systems. (2021 UNRWA/ M. Hinnawi)

8 UNDP Renewable Energy for All: project documents available here: <https://www.undp.org/papp/projects/renewable-energy-all-photovoltaic-cells-gaza-hospitals>

In addition to the renewables projects described above, the Office of the Quartet has also been working since 2015 on the Gas for Gaza (G4G) project, based on a mandate from the Palestinian Prime Minister. The G4G project aims to provide a natural gas pipeline to Gaza with capacity to provide enough gas to generate up to 1100 MW of electricity. The G4G project had obtained international funding, and was endorsed by the Government of Israel in July 2023 (Office of the Quartet n.d.).

Solid waste management: The Gaza Solid Waste Management Project (GSWMP) sought to address challenges of solid waste management by establishing more efficient, environmentally and socially sound waste management systems, including building new sanitary landfill and transfer stations, intended for serving 46 per cent of Gaza's population (World Bank 2020). The GSWMP started in 2014 but faced significant implementation challenges. Nevertheless, the project had successfully completed key infrastructure investments, including the construction of the al-Fukhary (Sofa) sanitary landfill facility and transfer stations (operational since 2019), and developed closure plans for the Deir al Balah landfill and Al-Fukhari dumpsite (World Bank 2020).

Terrestrial ecosystems: Investments in ecosystem restoration were also being undertaken in Gaza. For example, parts of the internationally important Wadi Gaza wetland were being restored. UNDP initiated short-term activities, which involved the removal of 35,000 tons of accumulated solid waste and the greening of 42,000 m² of land. Additionally, UNDP began designing flood protection solutions and coordinating the design of the Wadi's channel and its protection measures. Work undertaken to date has contributed to reducing pollution, and has laid the groundwork for the long-term restoration of the Wadi's ecosystem.

Planned activities for further restoring Wadi Gaza, scheduled before 7 October 2023, included constructing flood protection solutions throughout the Wadi, establishing core areas that feature a museum dedicated to flora and fauna, and implementing sustainable protection for the Wadi's channel. These plans also encompass the planting of native vegetation, construction of hiking trails and development of recreational facilities such as parks and observation towers for migrating birds.



A cleaned-up section of Wadi Gaza
(© UNDP image bank/ Shareef Sarhan)

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Section 2: Interruption of ecosystems services, environmental management systems and facilities

The conflict in Gaza has interrupted almost all environmental management systems and services (including ecosystems services) while creating new environmental hazards. The collapse of sewage, wastewater and solid waste management systems and facilities has had major impacts on the environment and people. One indicator of the impacts is the increasing rates of communicable disease in Gaza: in the three months following the escalation of conflict, WHO reported 179,000 cases of acute respiratory infection, 136,400 cases of diarrhoea among children under five, 55,400 cases of scabies and lice and 4,600 cases of jaundice. Case numbers of diarrhoea are 25 times those reported before the escalation in the conflict (World Health Organization [WHO] 2023).

The bombardment of Gaza and resulting destruction of buildings, roads and other infrastructure has generated over 39 million tons of debris, some of which is contaminated with unexploded ordnance (UXOs), asbestos and other hazardous substances. Human remains are buried in this vast quantity of building debris.⁹ The environmental challenges posed by these types of conflict-related damage are summarised in the sections below.



October 2023, little boy amid the rubble
© United Nations Photo

⁹ The International Committee of the Red Cross reports that over 7000 people have been reported missing in Gaza. Source: ICRC, Israel and the occupied territories: Key Facts and Figures from 7 October 2023 to 31 March 2024. <https://www.icrc.org/en/document/israel-and-occupied-territories-key-facts-and-figures-october-january-2024>

2.1 Water, wastewater treatment and sewage systems

All sources of water to Palestinians in Gaza—the Coastal Aquifer via wells, desalinated water supplied by the three Gaza desalination plants, piped water from the Israeli company Mekorot, and the small scale water suppliers—have been disrupted, as have wastewater treatment and disposal facilities.

The Interim Damage Assessment (WB, EU and UN 2024) records that 57 per cent of water infrastructure and assets have been destroyed or partially damaged, including the desalination plants in the northern and middle areas, 162 water wells and two of the three connections with Mekorot (Israel's national water company that supplies water to Gaza) resulting in a loss of over US\$503 million. As a result of damage to infrastructure and lack of power, the Water, Sanitation and Hygiene (WASH) system has collapsed, and the water production capacity was in March 2024 estimated at below five per cent of the usual output (WB, EU and UN 2024). In addition, Gaza's wastewater networks—three out of six treatment facilities, and five out of six waste management sites—have been damaged or destroyed (WB, EU and UN 2024).

The pipelines supplying water from Israel have been partially functioning. After an initial shutdown, where the water flowing through the three connections was stopped, the Southern connection was restored mid-October, and Middle connection was restored by the end of October 2023. Supplied water was frequently disrupted due to repeated damages to the bulk water pipelines. The Northern connection in Al Mintar had been destroyed in October 2023, but maintenance to resume water through the connection point took place in April 2024. The Southern connection in Bani Suheila had been partially damaged and resumed water supply end of April 2024, supplying around hour 4800m³/day at a 33 percent capacity; while in April the Bani Saeed connection in the middle area was been operational at a 50 percent capacity (7200m³/day). ¹⁰ The Humanitarian Cluster covering WASH (the WASH Cluster ¹¹) reported an average daily flow of 12,000 m³ per day through these

pipelines during March 2024 – less than a quarter of the daily flow before the escalation.^{12,13}

Displacement and access restrictions prevent people from accessing water facilities, and overload facilities in areas where people are concentrated. Displacement of more than a million people to the south of Gaza has put immense pressure on water and sanitation services there. Rafah's population before 7 October 2023 was under 280,000. Since then, an estimated one million internally-displaced people (IDPs) moved to the south of Gaza (UN-OCHA 2024a). Much of the untreated sewage released into the environment in the Gaza Strip is likely to be concentrated in the south, where the largest number of people have been located for much of the conflict.

The available water supply in April 2024 was estimated to be 2-8 litres per capita per day (l/c/d) compared to 85 l/c/d before October 2023: quantity varies based on the geographic location, availability of water resources, and damage to water infrastructure. Small scale (Short Term Low Volume) private operators have become one of the primary source of water supply following the onset of the conflict, providing an estimated 3,300 cubic meters per day (compared with 11,000 cubic meter of production before the conflict). The cost of water from water tankers to end users has risen dramatically, from 20 NIS before 7 October to 150 NIS in April 2024. Households, humanitarian shelters and IDP centres have reported that they have been forced to resort to rationing water supplies for drinking and cooking, with people forced to forgo personal hygiene and sanitation needs. People have been forced to use alternative water sources for drinking, such as utilizing traditional agricultural wells containing brackish water, often ingesting saline water (with a salt content exceeding 3,000 milligrams per litre), exposing themselves to pesticides and other chemicals usually present in these types of wells.¹⁴

¹⁰ Source: Emergency and Recovery Action Plan for the Water Sector in Gaza, WASH Cluster, April-May 2024

¹¹ The WASH Cluster-State of Palestine is responsible for the overall coordination of the WASH humanitarian planning and response in the West Bank and Gaza. The WASH Cluster includes in its partnership National NGOs, International NGOs, UN agencies, international organizations and educational institutions that are operating in the West Bank and Gaza in cooperation with local authorities. The WASH Cluster partners include 51 organizations.

¹² Source: WASH cluster weekly report, 11-17 March 2024

¹³ Source: WASH cluster data, weeks 13 and 14, 2024.

¹⁴ Source: Emergency and Recovery Action Plan for the Water Sector in Gaza, WASH Cluster, April 2024

Table 1: Status of the available water sources in the Gaza Strip . The «supply» column shows potential supply via each source, not the amounts available during the conflict. The status of water supplies during April-May 2024 is shown in the far right column.

Source	Facilities	Supply (m3/day)	Remarks	Current Status as of April 2024
Groundwater	Over 300 wells across the Strip	Total supply for all purposes 262,000	Mostly unsuitable for human consumption. Highly dependent on fuel availability	Unknown
Desalination (STLVs)	Gaza City (Northern)	10,000	Highly dependent on fuel availability.	Non-operational
	Al Bassa/Deir Al Balah (Middle)	2,000 (production Capacity 5,500)		Partially operational with 1600 m ³ /day of estimated production.
	Southern STLW	20,000 (with the new extension)		Partially operational with 1700 m ³ /day of estimated production.
Mekorot Connections	Al Mintar (north)	52,000	Subject to interruption from Israel	Operational (85% capacity)-850m3/hr
	Bani Saeed (Middle)			Operational (50% capacity)-300m3/hr
	Bani Suhaila (South)			Operational (33% capacity)-200m3/hr
Supply from Egypt	UAE desalination	2,400	Possibility of further expansion will be explored.	Operational (83% of design capacity)
Reuse	NGEST reuse scheme	13,000	Only for Agricultural purposes	Non-operational

Source: Bulk Water Supply Unit, PWA and WASH Cluster Updates – April – May 2024



15 November 2023, displaced people queuing for water
© UNRWA photo by Mohammed Hinnawi

Water supplies have also been contaminated by practices and military actions including the construction, flooding and destruction of the tunnel system. These issues are summarised in Section 3 below.

In response to the crisis, the United Arab Emirates (UAE) has established a new source of potable water for Gaza. Since 31 December 2023, a newly-constructed desalination plant located in Rafah, Egypt was opened. In March 2024, the new UAE-funded desalination plant was supplying 2,400m³ per day.¹⁵

Potential implications for people and the environment

The damage and disruption to wastewater treatment leads to the release of untreated sewage into the environment, contaminating beaches and coastal waters, soils and potentially the groundwater. Untreated sewage contains pathogens, nutrients, particulate organic matter, plastics and hazardous chemicals. The presence of sewage in the environment poses an immediate threat to human health through direct exposure to pathogens. In March 2024, an estimated 60,000 m³ of wastewater and sewage per day were being discharged into the environment – primarily into the Mediterranean Sea. This estimate was based on an assessment that the water available in Gaza during March 2024 was 70,000 m³ per day – far lower than the pre-conflict water availability.¹⁶ The lack of clean water and sanitation disproportionately affects women and girls, impacting their ability to manage menstrual hygiene safely and with dignity (UN Women, 2024)

The cumulative effects of conflict related pollution incidents due to release of untreated sewage, as well as long-term chronic pollution because of lack of capacity in WASH infrastructure have been exacerbated in the current conflict. Schillinger et al. (2020) describe damage to wastewater treatment plants in the Gaza Strip during the Israeli military operations "Cast Lead" in 2008 and "Protective Edge" in 2014, which resulted in leakage of untreated wastewater. UNEP (2009) highlighted that in 2008–2009, more than 100,000 m³ of wastewater and sludge flooded onto farmland and into urban areas from a single damaged sewage treatment plant (Al Zaitoun), leading to a spike in cases of diarrhoea, particularly in



11 January 2024, displaced Palestinians in an UNRWA school-turned-shelter on a rainy day in Deir el Balah
© UNRWA Photo by Ashraf Amra

children, and contamination of groundwater and agricultural land with heavy metals. The same source reported that 12–14 per cent of water samples collected immediately after the hostilities were contaminated with coliform bacteria (UNEP 2009).

The porous nature of much of the soil in the Gaza Strip has been noted as a protective factor for human health after sewage spills because it reduces the amount of open water present in the environment. Porous soil increases the risk of sewage contamination of the groundwater (UNEP 2009). The possible seepage of sewage containing pathogens and chemical pollutants into the aquifer poses a health risk to anyone extracting and using untreated water directly from wells. Further deterioration of the aquifer from sewage infiltration will compound risks to health from poor water quality, depending on how quickly it will be possible to rebuild a reliable supply of safe water (by rebuilding water treatment facilities and/or by supplementing water extracted from the aquifer with fresh water from desalination plants).

Plans to recover the aquifer (summarised above) were linked to efforts to reduce use of wells. Use of brackish and saline wells in Gaza during high-demand periods or emergencies causes the seawater intrusion to expand laterally and vertically into the aquifer (Mushtaha and Walraevens 2023); such use is likely to be occurring during the current emergency. Furthermore, damage and destruction of desalination facilities in Gaza will impact people's access to freshwater, even when power to run such facilities is restored. Damage to desalination facilities will also impede efforts to provide alternative water resources, that could help prevent irreversible damage to the aquifer (Musallam, Zhou and Jewitt 2023).

15 Source: WASH cluster weekly report, 11–17 March 2024

16 Source: UNEP communication with UN officials working in the WASH Cluster, April 2024. Officials note that fully accurate figures are hard to obtain due to the ongoing conflict.

2.2 Solid waste collection and treatment

Disruption in solid waste management has been significant, severely impacting urban infrastructure and public health. The breakdown of solid waste systems was already evident in October 2023, and by November the transfer of waste to landfills was halted (UN-OCHA 2023; UN-OCHA 2024b). This cessation was primarily due to two factors: the scarcity of fuel and security concerns that obstructed access to waste disposal sites.

As the conflict intensified around mid-November, reports indicated that approximately 400 tons of rubbish were accumulating daily in IDP camps and shelters. These were solely produced from the IDP sites located in schools, while additional quantities were generated by the hosting communities, with the overall amount of waste generated between 1,100 and 1,200 tons per day.¹⁷ This increase in waste accumulation, combined with the mounting issue of medical waste within hospital confines, heightened the health threats faced by the population. These conditions created a potential for disease outbreaks, further exacerbating the public health crisis. The inconsistency in waste collection from IDP camps and shelters during this period further highlighted the extent of the disruption to municipal services (UN-OCHA 2023; UN-OCHA 202ba). Informal dumpsites have been developing across Gaza: these have been mapped by UNDP (Figure 2).

From December 2023 to January 2024, there were attempts to mitigate the worsening waste management situation, including an increase in solid waste collection operations, although these efforts were constrained by the ongoing conflict. The shortage of cooking gas during this period, particularly from 5 to 18 December 2023, led to a shift towards less clean energy sources, such as firewood and open-air waste burning. This transition not only posed serious air pollution concerns but also heightened the risk of respiratory diseases among the Gaza population (UN-OCHA 2023; UN-OCHA 2024b). Substantial damage to Gaza's municipal infrastructure has been recorded, including five out of six solid waste management facilities (WB, EU and UN 2024).

Some humanitarian programmes have been established to address the solid waste crisis, including a UNICEF cash-for-work programme, through which around 100 workers have been engaged to provide emergency solid waste and sanitation services (World Bank 2024), and a municipal solid waste transfer programme through which UNDP provides fuel and deploys municipal health workers. In a collaborative effort between UNDP and

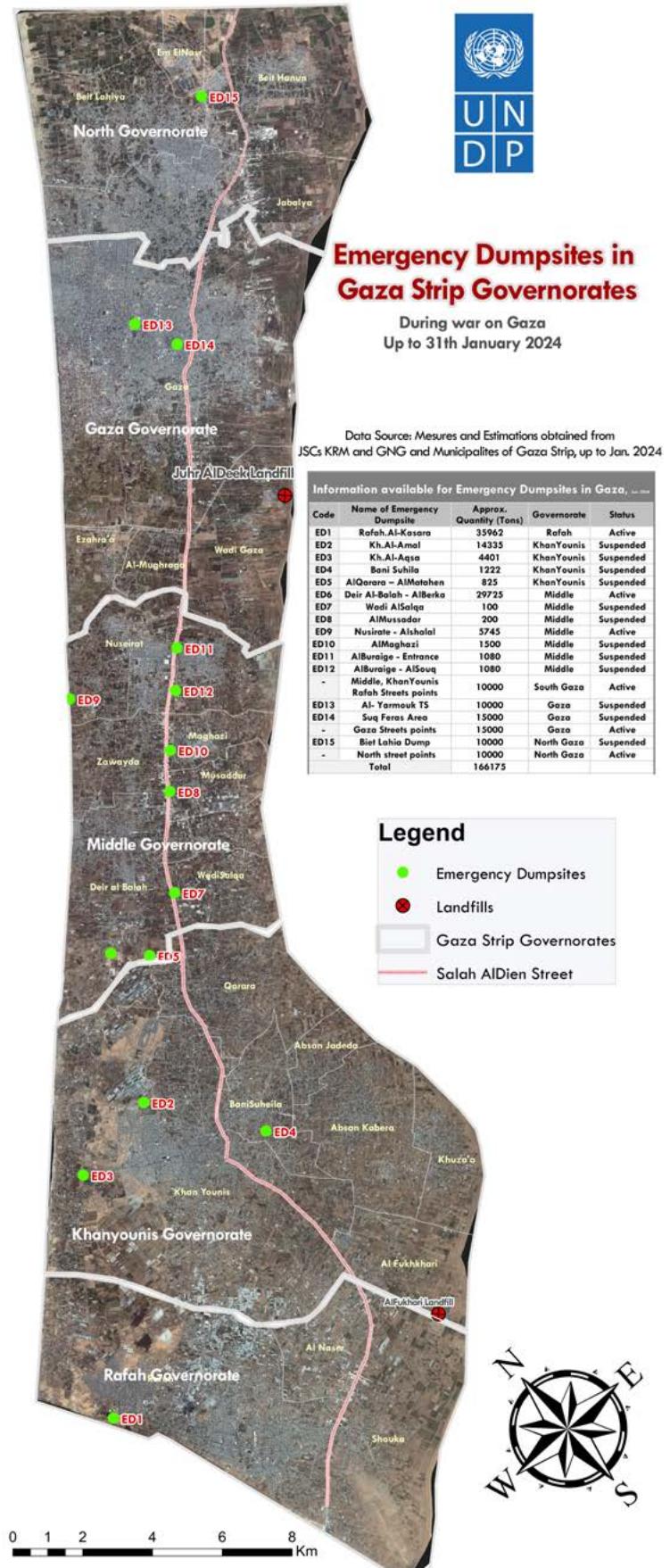


Figure 2: Emergency dumpsites in the Gaza Strip up to 31 January 2024, source: UNDP/PAPP

17 Source: UNDP, Gaza

UNRWA, another initiative has been launched to support the Joint Service Council for solid waste management (JSC-KRM) in the southern governorates of Rafah, Khan Yunis and the Middle Area – where many people have been displaced, putting additional strain on services in those areas. During January to February 2024, approximately 10,000 tons of waste were collected from Rafah and Khan Yunis, helping to mitigate environmental hazards (UNDP 2024).

Potential implications for people and the environment

Improperly managed dumpsites augment the risk of potential leachate, especially during rainfall. This can cause any hazardous substances present in the solid waste to leach into the porous soil, and possibly into the aquifer. An important risk is likely to be posed by hospital waste, which will include a range of hazardous materials including biohazards, pharmaceuticals, disinfectants and others.

Informal waste pickers are exposed to occupational exposure to hazardous compounds in plastic waste and ash from open incineration/partially burnt waste (Velis and Cook 2021). These health impacts may pose a particular risk for women, who have been found to bear a disproportionate share of health risks linked with informal waste picking and domestic waste management in situations where functional solid waste management systems are missing or insufficient (UNEP-IETC and GRID-Arendal 2019).

The environmental and health hazards associated with solid waste (and informal open incineration of solid waste) will be exacerbated by the contamination generated from large quantities of debris, UXO and weaponry used, sewage spills and air pollution. These are covered in Section 3 below. The severity of medium- to long-term environmental impact of the breakdown of waste management systems would be greatly reduced by the prompt recovery of waste management systems, as well as efficient remediation and restoration of uncontrolled waste dumps.

2.3 Destruction of buildings, infrastructure, conflict-related debris

Military operations in dense urban areas generate major quantities of debris, posing risks to human health and the natural environment. Debris arises from damaged buildings and infrastructure and includes building materials such as concrete, bricks, furnishings, personal belongings and other wastes. Conflict debris differs from normal construction and demolition waste in that it contains UXOs and human remains, and it is released in an uncontrolled manner impacting a wider area.

Damage from the use of explosive weapons in populated areas has been unprecedented in scale and intensity in comparison to other conflicts in Gaza. The Interim Damage Assessment notes that as of end of January, more than 60 per cent of the physical infrastructure in all sectors in Gaza, except WASH, had been damaged or destroyed. Approximately 62 per cent of all homes in Gaza have been damaged or destroyed, equivalent to 290,820 housing units. Transport sector damages amount to around US\$358 million, affecting 62 per cent of roads, including 92 per cent of primary roads, and a significant proportion of vehicles (WB, EU and UN 2024).

UNEP has been conducting regular quantification of the debris generated from the Gaza conflict since November 2023. The destruction of buildings and roads has generated an enormous quantity of debris: by May 2024, the amount was estimated at over 39 million tons (see image below). So far, the amount of debris in Gaza is 13 times more than the combined sum of all debris generated by other conflicts in Gaza since 2008. For each square metre in the Gaza Strip, there is now over 107 kg of debris, which may contain UXO, hazardous substances and human remains. The total amount of debris from the current conflict in Gaza is more than five times the quantity of debris generated from the 2017 ISIL conflict in Mosul (7.65 million tons) (UNEP 2018). Text Box 1 describes how UNEP and partners have calculated the quantities of debris in Gaza.

The debris situation in Gaza is unprecedented in several ways including: i) the extent of damage to the housing stock; ii) its geographic spread and spatial density across almost the entire territory of the Gaza Strip; iii) the quantity of debris generated; iv) the rate at which debris is being generated; and v) the expected extremely high levels of UXO contamination coupled with the risk of asbestos from the refugee camps.



3 November 2023, search and rescue operations continue after an Israeli attack on Maghazi Refugee Camp
© UNRWA photo by Ashraf Amra

Table 2: Debris generated in each governorate

Governorate	tonnes of debris
North Gaza	8,134,416 t
Gaza	15,313,427 t
Deir Al-Balah	2,448,472 t
Khan Younis	9,100,037 t
Rafah	604,626 t
Damaged Roads	3,600,000 t
Total	39,200,978 t

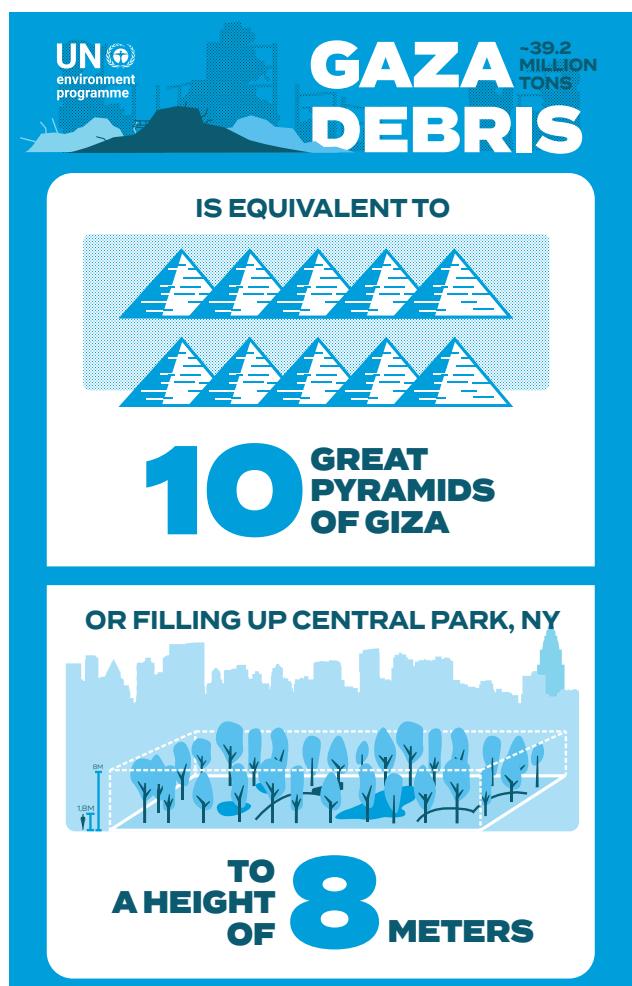
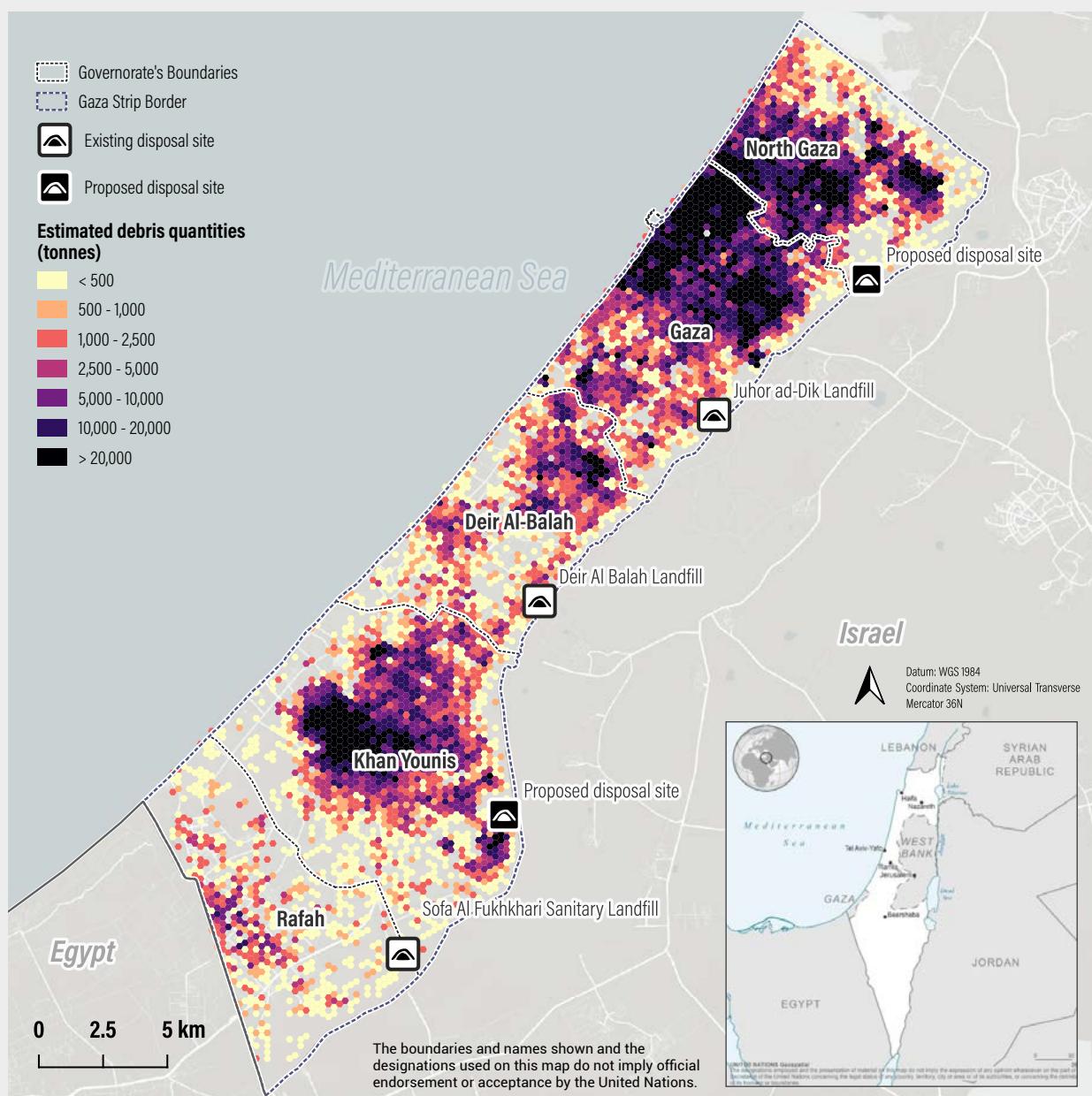


Figure 3: comparison with other well-known monuments and spaces to illustrate the estimated volume of debris in Gaza

Gaza Strip - Preliminary Debris Quantification

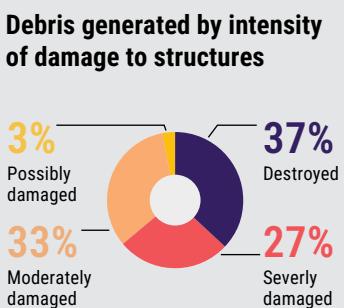


Total debris quantity: (tonnes) **39,200,978**

According to a Comprehensive Damage Assessment from UNOSAT, a total of 137,297 structures were damaged in the Gaza Strip as of 3 May 2024. Of these, 36,591 (26%) were destroyed, 16,513 (12%) severely damaged, 47,368 (34%) moderately damaged and 36,825 (26%) possibly damaged. This corresponds to approximately 55 per cent of the total structures in the Gaza Strip.

So far, debris generated by the current conflict is 13 times more than the combined sum of all debris generated by other conflicts since 2008. For each 1 sqm in the Gaza Strip, there is over 107 kg of debris.

This preliminary analysis has not yet been validated in the field and is appropriate for general planning of debris operational responses and related humanitarian action in the Gaza Strip.



The pie chart above shows the debris generated per number of buildings, categorized by the extent of damage. For example, while the 'destroyed' buildings represent 27% of the affected buildings, they account for 37% of the total debris generated.

Potential implications for people and the environment

The debris itself constitutes a physical barrier in terms of access and a safety risk with major implications on the delivery of humanitarian relief and the return of internally displaced persons. Falling debris and unstable structures liable to collapse may lead to physical injuries, while hazardous materials mixed within the debris create health hazards. Components of the debris can contain harmful substances including asbestos, heavy metals, fire contaminants, UXOs, explosive residue, household chemicals and other hazardous substances specific to certain locations such as hospital laboratories and industrial areas (UNEP 2009).

Dust is another significant concern associated with debris, the inhalation of which over time can cause lung diseases (Hoy 2020). Use of explosive weapons and the demolition of buildings create substantial amounts of dust that poses a hazard to people during the conflict and during clean-up and recovery operations. Inhalation of fine particulate matter can be harmful, notably when the dust, generated during the bombing of structures and infrastructure including industrial sites, is contaminated with organics, heavy metals from munitions, asbestos and other hazardous materials. Due to its lightweight and particulate nature, dust spreads easily. Wind and rain may carry contaminants in the dust into the soil, ground-water and coastal waters, potentially causing impacts to spread beyond the site of original damage or in locations where debris has been disposed.



November 2023, search and rescue operation in the rubble of a collapsed building
© UNRWA photo by Ashraf Amra

Past experiences from conflict escalations in the Gaza Strip demonstrated that physical damage from bombing often co-occurs with fire damage, particularly with certain types of ammunition debris is mixed with asbestos in many areas. UNEP's post-conflict assessment of Gaza in 2009 revealed presence of asbestos in building debris and in landfills (UNEP 2009). Asbestos was found in debris from older buildings, temporary building extensions and sheds, as well as in roofs and walls of livestock facilities. People can be exposed to asbestos through inhalation of asbestos fibres in the air causing lung cancer, mesothelioma, larynx and ovarian cancer and fibrosis of the lungs, also called asbestosis (WHO n.d.). In 2009, UNEP found highly carcinogenic blue asbestos (crocidolite) at some locations.

In Gaza, asbestos is mainly found in the older buildings and structures of its eight refugee camps; especially in the asbestos cement sheets used for roofing. Based on a rapid analysis of the debris generated in refugee camps, it is estimated that around 800,000 tons of debris may be contaminated with asbestos and would need to be handled as hazardous waste. It will therefore be critical that the potentially contaminated debris from refugee camps is kept separate and not mixed with debris sourced from other areas.¹⁸

The Gaza Industrial Estate has been completely destroyed (Figure 4, page 30) (WB, EU and UN 2024). The Gaza Industrial Estate, hospitals and other locations where hazardous chemicals were stored may contain debris with higher concentrations of hazardous materials (UNEP 2009).

Hazards from such sites include chemicals found in several medical products, pharmaceuticals and disinfectants, cleaning products, laboratory chemicals and pesticides.¹⁹ Identifying buildings that could contain hazardous materials is important for assessing contamination risks (WHO 2024). To resolve these environmental challenges, debris must be safely managed, removed or recycled. This will require environmental management frameworks, carefully sequenced and planned to ensure that debris disposal does not generate new environmental problems.

Sustainable debris management

Debris removal and management is crucial for safe and effective humanitarian assistance delivery and for the first phases of the recovery and reconstruction process. It is equally critical that the debris is managed in a sustainable manner to maximize the opportunities for debris recovery to support Gaza's rebuilding including through the creation of much needed livelihood opportunities. Coordination amongst multiple actors including community-based associations, local authorities, mine action actors, international agencies, non-governmental organisations and donors will be essential to ensure that debris management is undertaken in a coherent manner and is well integrated with humanitarian and early recovery plans.

Preliminary scenarios on the cost of managing the estimated 39 million tons of debris range from around US\$647-513 million; depending on whether a disposal or recycling option for the debris is pursued.²⁰ Clearing the debris from key infrastructure services and road networks is estimated to require around five years, and removal and disposal of all the debris may take up to 15 years assuming availability of a reasonable level of heavy equipment.²¹ Furthermore, it is estimated that 490 hectares of land would be needed to dispose of the debris: this would be a major challenge given the shortage of available land in Gaza. Recycling 50 per cent of the debris is estimated to require around 45 years, which would generate a revenue stream of around US\$294 million reducing overall costs by around 23 per cent and reducing the amount of land required for disposal by 50 per cent. It is important to emphasise that these estimates are indicative and are provided to illustrate the level of resource and time requirements for debris operations. The scenarios may be significantly modified depending on the number of trucks, recycling systems and other heavy equipment that could be made available to the Gaza Strip.

Given the spatial constraints to dispose of debris within Gaza's small area and the shortage of quarrying and construction materials, it will be vital that a circularity-based approach to debris management is taken up to the extent possible. Indeed, recycling is likely to be a necessity as quarry reserves in the Gaza Strip—estimated at around 28 million tons—were already overexploited

18 Source: Joint UN rapid debris analysis, 2024

19 WHO states that the most common hazardous chemicals in the health sector include cleaning and disinfecting agents, sterilants, mercury, toxic drugs, pesticides, latex and laboratory chemicals and reagents. See: Exposure to hazardous chemicals (who.int)

20 The cost of recycling is estimated at USD 778 million. However, after deducting the revenue from the recycled aggregates estimated at USD 283 million, the net cost for recycling amounts to USD 495 million.

21 Based on the assumption that 105 trucks (12m³/19 ton capacity) would be available for hauling the debris and operating in 8 hours shifts, 30 days a month.

Box 1: Explanation of debris quantification methods

UNEP has been conducting regular quantification of the debris generated from the Gaza conflict since November 2023. The latest quantification of conflict-generated debris in the Gaza Strip undertaken by UNEP and UN-Habitat is based on UNOSAT Comprehensive Damage Assessment from 3 May 2024. Three variables are used to calculate the amount of debris generated from destroyed and damaged buildings: i) the area covered by the building or its "footprint"; ii) the height of the building to determine the number of floors; and iii) the "living space" which is a function of multiplying the footprint of the building by the number of floors. A ratio of debris tonnes per living space area is then applied to calculate the quantity of debris from the damaged or destroyed building.

For the debris quantification modelling, the building footprint and height data was extracted from the Palestinian Central Bureau of Statistics database, which covers the period up to 2017. For buildings constructed after 2017, the building footprint was determined by digitizing building boundaries from high-resolution satellite imagery from May 2023. The building heights were obtained by approximation from the European Commission's Global Human Settlement Built-H data layer, with the average height per story being established at 3 meters. Each destroyed or damaged built square meter is considered to have generated one tonne of debris, based on an average estimate from previous post-conflict debris management programs in Gaza. For example, for a three-storey destroyed building with a footprint area of 300 square meters, the total living space will be 900 square meters ($300\text{m}^2 \times 3$) generating 900 tonnes of debris ($900\text{m}^2 \times 1 \text{tonne/m}^2$).

The confidence level in this quantification method is estimated at 80-85%. The Palestinian national building database used in undertaking the debris analysis adds to the reliability of the debris estimates. Furthermore, a conservative approach was used in calculating the debris amounts with a view to minimizing the error margin and potential overestimation. Similar methods for calculating debris amounts have previously been applied to quantify debris estimates in other post-conflict and post-earthquake situations, with reliable results. The resulting debris estimates produced have been used by governments, the UN and other partners to help plan debris management interventions and set project targets to support the recovery and reconstruction of the affected areas.

This is a preliminary quantification of the debris situation in Gaza, primarily meant to provide an initial overview of the scale of the debris problem for general planning purposes. More detailed field-based calculations will still need to be carried out at municipal and neighbourhood levels to obtain more accurate calculations needed for implementing operational interventions at the local level.



October 2023, aerial view of collapsed buildings and destruction in the Gaza Strip
© United Nations Photo

and considered likely to deplete within 15 years to meet housing construction needs prior to the conflict (Al-Araby 2021). It will therefore be important to leverage and build on Gaza's previous experience in debris recycling, and which can be further enhanced based on regional and international best practice. Debris recycling will need to be significantly upgraded and scaled up given the exceptional scale of the current debris challenge. Priority applications for the recycled aggregate identified by Gaza municipalities include road construction foundations and shoreline protection, both of which have been carried out in Gaza in the past. Higher end-use applications will also need to be examined (e.g. road pavement layers, concrete and pavement blocks) that are of greater economic interest in terms of cost returns. All recycled material applications will need to be subject to quality assurance controls to ensure compliance with national construction standards.

It will be equally critical that environmental and health safeguards are applied in debris management operations, including provision of training and personal protective equipment. Another key issue is dealing with the loss of housing, land and property documentation records given that debris removal from homes requires owner permission. Provisions for handling of human remains in the debris, and protecting the estimated 290 cultural and archaeological sites in the Gaza Strip, are also key elements that would need to be carefully managed.

2.4 Energy, fuel and associated infrastructure

Energy supplies from the Gaza power plant and energy imports from Israel ceased immediately after the conflict began in October 2023 (WB, EU and UN 2024). Israel's halt of its fuel supply and electrical supply had widespread effects on healthcare, water treatment and domestic life across the Gaza Strip, especially in urban centres like Gaza City and northern Gaza (UN-OCHA 2023).

The conflict has led to severe damage to the electricity grid distribution networks, as well as off-grid distributed rooftop solar photovoltaic systems that are deployed across Gaza in public buildings like schools, hospitals and health facilities, water supply facilities, cultural and residential buildings. An estimated 510 km of the electricity distribution network has been destroyed or damaged (61.5 per cent of the total) (WB, EU and UN 2024). Feeder lines have remained non-functional throughout the conflict (World Bank 2024).

Fuel has been consistently scarce throughout the conflict, as noted earlier. The lack of power has halted water treatment plants, leading to environmental degradation due to untreated sewage and a shortage of clean drinking water. By November 2023, the only operative mill in Gaza remained unable to grind wheat due to electricity and fuel shortages (UN-OCHA 2023).



Figure 4: Solar photovoltaic panels installed at the Gaza Industrial Estate, part of an IFC-funded project on renewable energy in Gaza, which was recognized as an important example of "Financing for climate friendly investment" (Source: World Bank Group)



13 November 2023, Al salam flour plant in difficulty for lack of fuel, Deir el Balah
© UNRWA photo by Ashraf Amra

Nearly 80 per cent of the 49,000 commerce, industry and services sector establishments assessed in the Interim Damage Assessment have been destroyed or damaged (WB, EU and UN 2024). In earlier reports, the World Bank noted damage to 84 petrol stations and 5 petrol wholesale facilities. On 10 January 2024, the Gaza Power Plant was bombed, causing a fire. The extent of the damage to this diesel-fuelled power plant remains unknown due to limited access and low data availability (WB, EU and UN 2024).

Potential implications for people and the environment

Pollution from leaked fuel has caused environmental challenges in past conflicts in Gaza. For example, during a previous round of conflict, around 1,000 litres of diesel, stored for truck operations at a cement factory in Rafah, leaked into the surrounding environment following the destruction of its storage tank. UNEP conducted tests on the site and found that the soil was significantly contaminated with Total Petroleum Hydrocarbons (TPHs) and aliphatic hydrocarbons, levels which surpassed the threshold requiring intervention. Given the proximity of the spill to a groundwater well, the removal and relocation of the contaminated soil was recommended to mitigate the risk to the groundwater supply (UNEP 2009). This incident underscores the potential for even relatively small quantities of fuel to pose significant risks to groundwater quality in conflict zones. Military-related fuel and fuel deposits' presence in Gaza is unknown.

Significant environmental risks correlate with fuel spills into soil, groundwater and the sea, and with fuel fires, which release not only soot, toxic compounds and climate gases, but are also hazardous and challenging to

extinguish. If any fuel deposits are stored underground in tunnels (see Section 3), detecting and managing spills might be extremely problematic. The possible presence of fuels and other hazardous compounds in tunnels beneath Gaza would also contaminate any seawater used for flooding tunnels, and potentially leach to groundwater beneath tunnels.

While the adoption of solar energy in Gaza, driven by energy insecurity, has been a crucial step toward ensuring a more stable and sustainable power supply for its residents (Todman et al. 2023), the destruction and burning of solar panels amidst the current conflict in Gaza have compounded the environmental risks, introducing significant contamination hazards due to the hazardous materials they contain.

The use of solar technology means that debris from damaged and destroyed panels, along with the by-products of their combustion, now pose new environmental hazards. Preliminary data obtained during preparation of the Interim Damage Assessment suggests that destruction of 67 MW of solar PV systems (industrial, commercial and residential, including the PV cells and batteries), has contributed to the release of hazardous material into the environment, including an estimated 1,675 kg of lead. Figure 3 shows the extensive solar installation on at the Gaza Industrial Estate, which was operational before the escalation of the conflict, and generated and distributed up to 80 per cent of the Gaza Industrial Estate's electricity needs. This solar installation had been funded by the International Finance Corporation (IFC) and was recognised as a globally important example of "finance for climate-friendly investment". Satellite imagery (Figure 4) shows that the Gaza Industrial Estate has been completely destroyed. Smaller-scale solar installations that



Figure 5: A satellite image taken on 16 December 2023 shows the almost complete destruction of the Gaza Industrial Zone. Source: World Bank.

were used by 20 per cent of households in Gaza will also have contributed to widespread pollution from solar panels, which should be addressed as soon as possible to prevent contamination of soil and water resources. Toxic substances such as lead and cadmium, found in the panels, can leach into the soil and water sources when the panels are compromised or burned. Additionally, the burning process releases hazardous chemicals and heavy metals into the environment, contributing to air pollution with potentially toxic fumes from plastics and other synthetic materials used in panel construction. These emissions and contaminations pose immediate health risks to the population through inhalation (Jakhar, Samek and Styszko 2023) and long-term ecological damage by polluting drinking water supplies and agricultural land (Velis and Cook 2021).

2.5 Marine, coastal environments and fisheries

Limited data are available on the impact of the conflict on marine ecosystems, coastal areas and fisheries. While the testing of marine waters off Gaza is not possible at the time of writing, the conflict has almost certainly led to an increase in marine pollution from sources including untreated sewage, solid waste and munitions. The

coastal zone area has experienced significant damages, impacted by the continuous bombardment and land operations. Furthermore, given the intensity of bombardment, it is reasonable to assume the presence of weapons-related debris and UXOs on the beaches, along the shoreline and in nearshore waters, along with physical damage from explosive impacts.

Potential implications for people and the environment

A review of data from past acute marine pollution incidents show high concentrations of chlorophyll and suspended organic matter in coastal waters, visible in satellite images, extending northward with the prevailing currents, reaching Israeli shores around Ashkelon (UNEP 2020). Pathogens associated with sewage-contaminated coastal waters have been documented in the past in Gaza coastal waters, including gastrointestinal parasites that can cause severe illness in humans, those exposed via recreational use of water and via ingestion of contaminated seafood (Hilles et al. 2014). Sewage pollution has also affected desalination plants in Israel, causing shutdowns as well as the use of additives that are in themselves damaging for the marine environment when they are discharged into the sea (UNEP 2020).

Plastic in sewage or sewage-contaminated waters can intensify these health risks by harbouring pathogens and antibiotic resistance genes (Zadjelovic, et al., 2023) This applies to macro plastics in the short term (Metcalf et al. 2022), and microplastics in the longer term (Sharma and Chatterjee 2017). Plastic and additives therein can also directly contaminate seafood (Beaumont et al. 2019).

Bacterial decay of large amounts of organic matter in untreated sewage releases hydrogen sulphide and ammonia, which are toxic to marine organisms. Sewage also contains substantial amounts of suspended organic matter or fine particulate matter, obstructing water column sunlight and potentially smothering seabed organisms when these particles settle. Sewage is also commonly contaminated with heavy metals, endocrine disrupters and pharmaceuticals affecting both wildlife and humans. Some of these contaminants are absorbed by plants and animals, bioaccumulating in marine food webs and causing health risks for humans consuming seafood (Garai 2021). The surge in sewage pollution in Gaza due to the current conflict escalation is exacerbating the pre-existing impacts of chronic, ongoing sewage pollution to marine waters.(Ubeid and Al-Agha 2016; El-Hallaq 2019; UNEP 2020).

Given the severe damage to wastewater infrastructure, the scale of the sewage pollution that is occurring may continue for a sustained period and hence the impact on coastal waters is expected to exceed previous sewage pollution incidents. Re-establishment of a functioning water treatment infrastructure will be needed to reduce such pollution and associated impacts. Recovery of natural flora and fauna from ongoing chronic sewage pollution of coastal waters necessitates a 10–25 years cessation of pollution input (Borja et al. 2010).

Damage to the marine environment and fishing industry will also affect food security in Gaza. Fishing in the Mediterranean was restricted by Israel to 50 per cent of the sea area specified for fishing in the Oslo Accords (UNICEF 2022), even before the current escalation; this restriction has now been tightened to 3km.²² Higher temperatures due to climate change are increasingly driving fish into cooler and deeper waters making fish catches by local fishermen in inshore waters highly sensitive to climate change (UNEP 2020; Pax 2023). Despite these constraints, fishing was an important source of food and provided direct livelihoods to approximately 3,700 people in 2023. This may now be affected by marine pollution as well as by the physical destruction of the Gaza fishing fleet. Marine pollution can impair the nutrition and quality of waters, thus restricting the growth

of fishes and thus impact fish production and catches. Pollution can also impact food safety, as fish in the inshore areas (which are currently the only areas Palestinians can fish) can become contaminated. Given the conflict conditions there are no data currently available on these impacts.

A healthy coastal and marine environment can bring important benefits for mental health and wellbeing. While the mental health impacts of a degraded marine environment may seem negligible under the circumstances, having access to safe, clean beaches may make a difference for a traumatised population in future. Therefore, there may be value in planning for the environmental restoration of beaches and water quality early on during recovery and rebuilding efforts, along with the provision of safe and inclusive access to these spaces.

2.6 Terrestrial environments (terrestrial ecosystems, soil, cultivated lands)

Cultivated and undeveloped terrestrial environments of Gaza have been profoundly affected by the conflict. Analysis of the Food and Agriculture Organization of the United Nations (FAO) data to mid-February indicates that 42.6 per cent (6,694 ha) of all cropland has been damaged. The governorate of Gaza had the largest area of damaged cropland in hectares (1,941 ha; 54.8 per cent of all cropland). Further damage has been caused to 5,027 ha (43.1 per cent) of orchards, 887 ha (41.2 per cent) of irrigated cropland and 780 ha (41.7 per cent) of the rainfed cropland.

The Interim Damage Assessment records substantial destruction in the agricultural sector, estimated at US\$629 million, related to the destruction of trees, agricultural holdings, greenhouses, retail establishments and irrigation infrastructure (WB, EU and UN 2024). Academic analysts have also used remote sensing methods, combined with verification where possible, to assess the loss of trees and greenhouses. Work by Dr He Yin, Kent State University (Yin 2024) finds that as of 3 April 2024, 44–52 per cent of tree crops are likely damaged in Gaza and 42 per cent of greenhouses have damage of more than 10 per cent, while 23 per cent of greenhouses are completely destroyed. Of tree crops damaged, the highest percentages are in North Gaza (55–71 per cent) and Gaza City (58–80 per cent). Dr He Yin's analysis is shown in Figure 6.

22 Source: FAO, 2024.

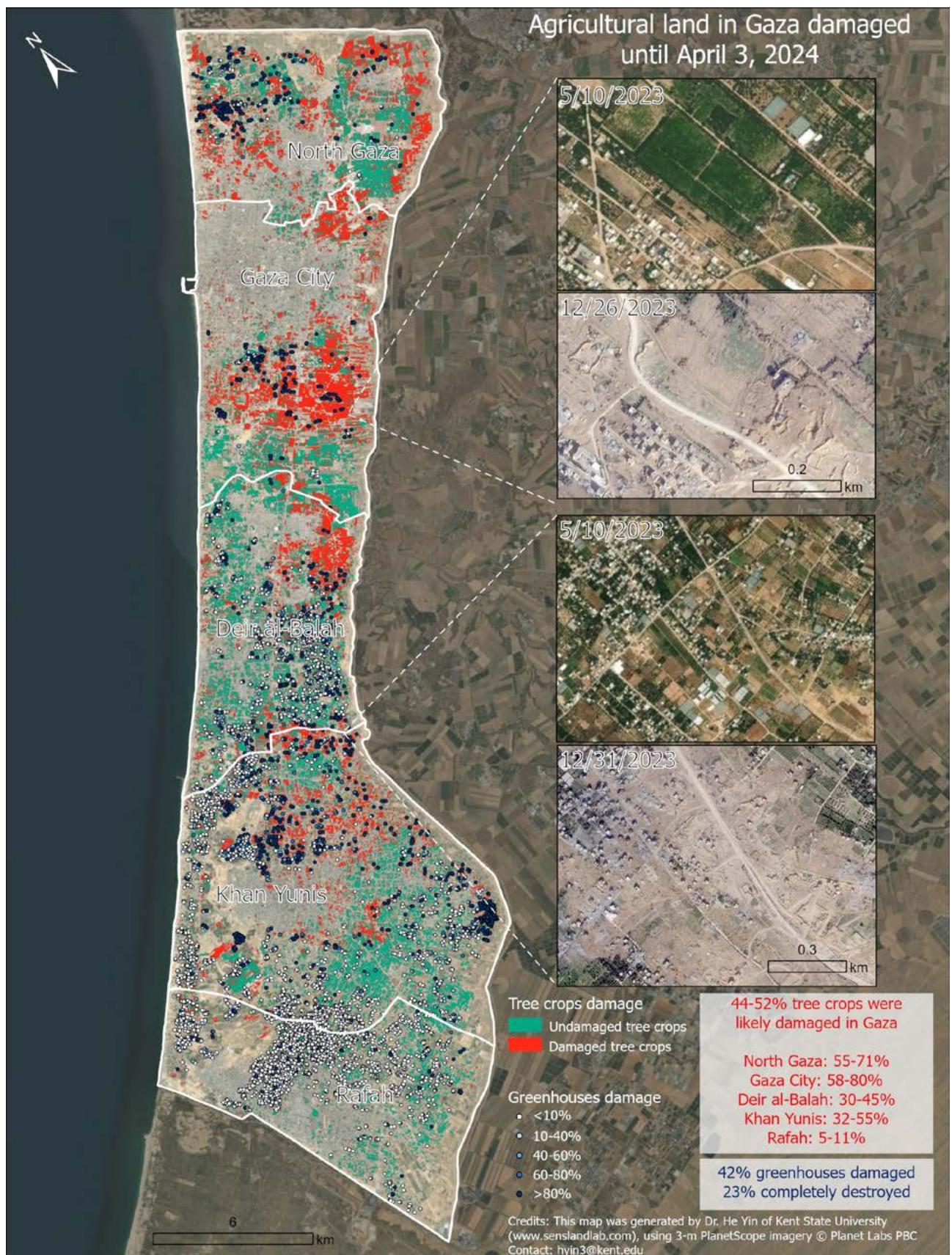


Figure 6: Analysis of damage to tree crops, greenhouses and other agriculture in Gaza (Source: Damage analysis of 3-m PlanetScope imagery © Planet Labs PBC by Dr. He Yin of Kent State University) Note: This map was not produced based on a United Nations map. The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Access to agricultural land has been reduced by the expansion of the exclusion zone around the Armistice Demarcation Line fence from 300m to 1,000m. United Nations Satellite Centre (UNOSAT) analysis of damage to the land within Gaza one kilometre from the Armistice Demarcation Line up to 31 March 2024 "shows an increase on the percentage of damaged agricultural land in October 2023 from 5.36% to 33.13% of damaged land in February 2024" (UNOSAT 2024c). Fodder shortages have placed additional strain on farmers, farmers are prematurely slaughtering their livestock, thus impacting future productivity (UN-OCHA 2023; UN-OCHA 2024b).

According to estimates, between 25 and 50 per cent of Wadi Gaza has been destroyed by the current conflict, and with it the ecosystem services it provides.²³ Satellite images (Figure 7) show the area surrounding Wadi Gaza, on 1 March 2023 and on 29 February 2024.

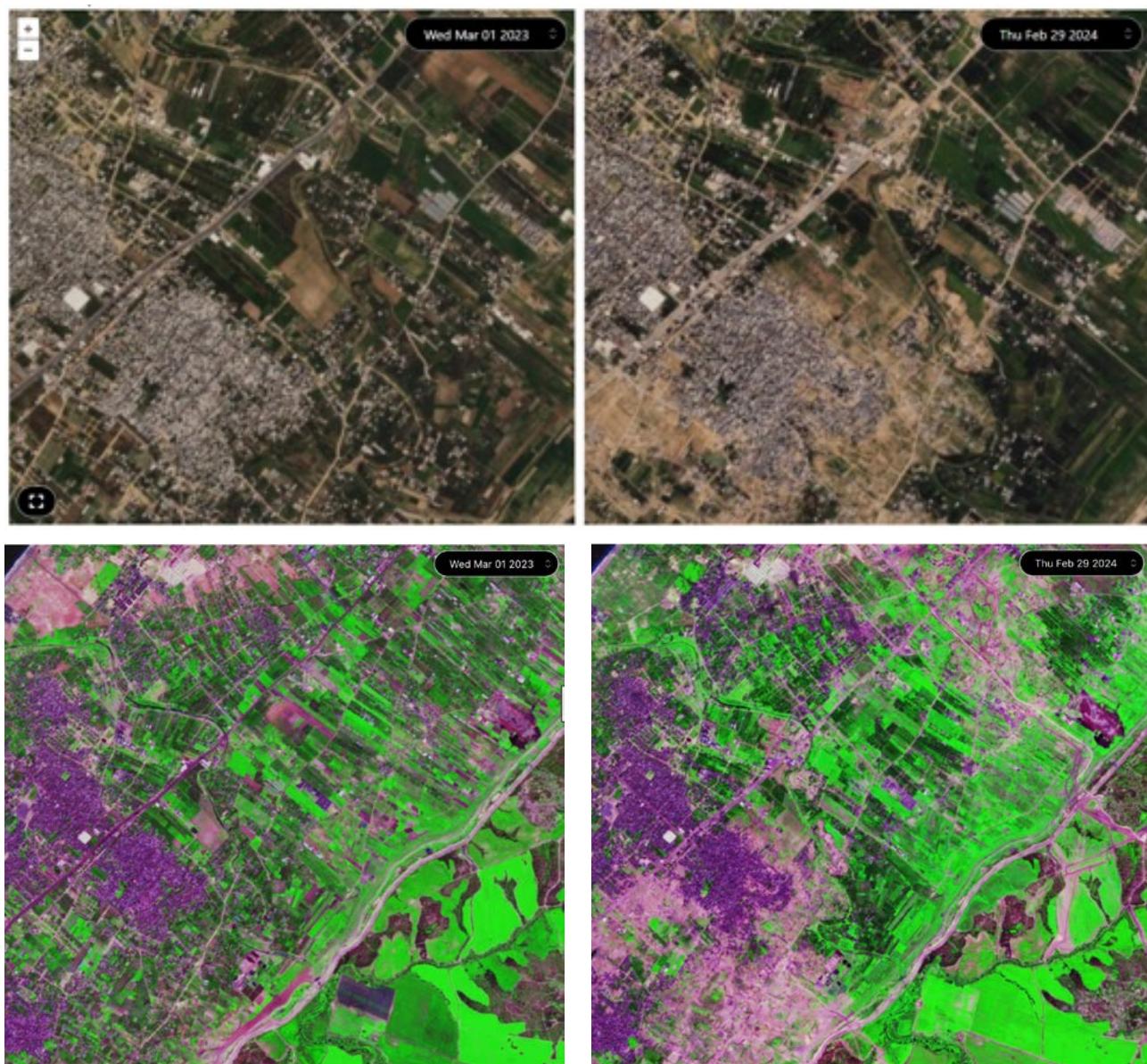


Figure 7: Satellite images of Wadi Gaza and surrounding area, 1 March 2023 and 29 February 2024. Top images are satellite photographs showing natural landscape; second set show vegetation levels (Source: Sentinel 2 [10 m resolution] retrieved by GRID Geneva, March 2024)

23 Estimates: IPSOS (commissioned by the World Bank Group) and Environment Quality Authority Press release: <https://environment.ps/p-2/>.

Potential implications for people and the environment

Physical destruction, degradation and contamination can have detrimental effects on both physical and mental health. Damage to the agricultural land, soil, livestock and trees (including culturally significant assets such as olive trees) will impact food production and security. Considering the intensity of the bombardment, it is highly likely agricultural soils in Gaza are contaminated with heavy metals and other chemicals associated with military equipment and munitions. This type of impact has been recorded in previous conflicts.²⁴

Damage to agricultural land and natural areas arising from the conflict may reduce the fertility of soil, and increase Gaza's vulnerability to desertification. In its assessment following the 2009 conflict in Gaza, UNEP noted several types of damage:

"First, the mechanical ripping and removal of trees, shrubs and crops has moved, mixed and thinned the topsoil cover over large areas. This degradation of the top productive layer will impact future cultivation of the land. Second, the passage of heavy tracked vehicles has compacted the soil into a dense crust, which will need to be tilled with heavy ploughing machinery to make it suitable for agriculture again. Such machinery is not currently available in the Gaza Strip. Third, the destruction of the vegetation cover will make the land vulnerable to desertification. Destruction of tree cover will also accelerate soil erosion during rainfall."

Changes similar to those observed after the 2008–09 conflict are very likely to have occurred during the current conflict. Conflicts in other contexts have had detrimental effects on agricultural production, due to intensive bombing and heavy military vehicles driving over crops (Edeko 2011). Many long-standing consequences can result from these cumulative harms (physical destruction, pollution and presence of explosives). Damage to agricultural soils from World Wars One and Two still negatively affects the environment today (Broomandi et al. 2020). Analyses of the impacts of warfare on the

desert environment, soil, native vegetation and other natural resources of Kuwait found that conflict impacts persisted even after 18 years, and in some cases their hazard potential has increased (Omar & N. R. Bhat, 2009).

The Interim Damage Assessment notes that those in Gaza who previously depended on the agri-food value chain for their livelihoods can no longer rely on this, fuelling a cycle of unemployment, poverty and food insecurity (WB, EU and UN 2024).

The eradication of a sector responsible for food production, in a population struggling with food insecurity for many years, coincided with the loss of livelihoods and the loss of cultural identity and connection to the land, such as that associated with slow-growing olive trees, sources of both nutrition and cultural significance. There are also obvious economic impacts arising from the loss of this productive sector. In 2021, agriculture accounted for more than 10.5 per cent of the Gaza gross-domestic product (GDP). If only tradable sectors are considered, agriculture accounted for two thirds of the (tradable) GDP. The agricultural sector was the main source of exports for Gaza, with more than 45 per cent of the total export flows.

²⁵

There is also a significant likelihood of unexploded ordnance posing a hazard in Gaza's farmland. Farm workers, those involved in recovery and rehabilitation efforts in farmland, and people handling and consuming potentially contaminated food face health risks due to UXO and heavy metal exposure. In the aftermath of other conflicts, even with comprehensive demining and munitions disposal, future use of combat-ravaged lands necessitates "reclamation and re-cultivation of the topsoil" (Organization for Security and Co-operation in Europe [OSCE] 2017, p. 13).

2.7 Air pollution

There are currently no open-source air quality data available for Gaza. A large number of fires have been observed burning in Gaza since the start of the current conflict in October 2023. Major fires burning in Gaza are visible from Sentinel satellite images, such as the one below taken on 16 November 2024 (Figure 8).

24 For example, a study by Vidosavljević et al. (2013) found higher mean values of heavy metals including Copper, Zinc, Nickel, Lead, Mercury, Phosphorus and Barium in agricultural soil samples from high combat activity areas in Croatia compared to those with low combat activity.

25 Source: FAO calculations, April 2024, based on PCBS data.



Figure 8: Fires burning in Gaza, 16 November 2023
 (Source: Sentinel 2 [10 m resolution] retrieved by GRID Geneva, March 2024)

The extent of fires in Gaza during 2023–24 in comparison with previous years can be seen in Figure 9, which shows the number of fires recorded in Gaza per year since 2012.

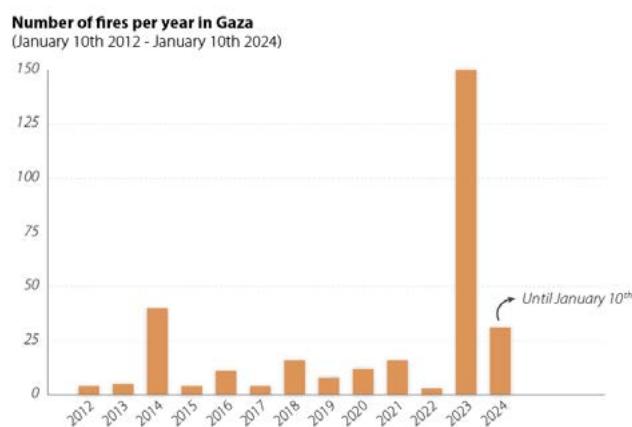


Figure 9: Number of fires recorded in Gaza from 2012 to January 2024 (Source: NASA-FIRMS 2024)

These data are from NASA's open-source Fire Information for Resource Management System (NASA-FIRMS 2024). According to the same source, 165 fires in Gaza in the period 7 October 2023 to 12 January 2024 were recorded (NASA-FIRMS 2024). This may be an underestimation as the data is collected twice a day and may not pick up smaller fires extinguished relatively quickly. Fires obscured by vegetation or buildings and cloud cover would also be excluded. Residential buildings, schools,

businesses and industrial facilities have been burning with 19 fire alerts from the Gaza Industrial Estate between 7 October 2023 and 12 January 2024. Fires pose a particularly high risk of hazardous chemical emissions when occurring at known sites of chemical storage (Griffiths et al. 2022). People in Gaza are also burning materials for cooking and warmth (UN-OCHA 2024b).

There are air-quality monitoring stations in Erez, Karmia and Sderot, located in Israel, roughly 1–3 km north/northeast of the Israel-Gaza strip border and approximately 12–15 km from central Gaza city. These stations are under the responsibility of the Israel Ministry of Environmental Protection (SVIVA 2024). The mean PM2.5 concentration value over 24-hour period for the period 10 October 2023 to 12 January 2024 was higher at all three stations, in comparison with the same period in 2022–23, however the increase could be due to factors unrelated to the conflict.²⁶ Data collected closer to airstrike or fire locations, as well as the dates and magnitude of airstrikes could improve the understanding of air pollution caused by the conflict.

²⁶ These results do not consider the distance between the monitoring station and the actual bombings, weather conditions known to influence air quality, or other local conditions that could impact air quality (for instance traffic or industry).

Potential implications for people and the environment

Air pollution due to waste incineration, and burning materials for cooking and warmth, pose concerns and heightens the risk of respiratory and cardiovascular effects among the Gaza population (UN-OCHA 2023; UN-OCHA 2024b). Open burning of waste plastic creates hazardous substances such as dioxins and polycyclic aromatic hydrocarbons, which can have serious medium to long term impacts (Masiol et al. 2016; Baca et al. 2023). There is a direct risk of sickness from exposure to pathogens and biohazards, and a risk of immediate and long-term effects from toxic materials mixed in the solid waste (e.g. batteries). Airborne particulate pollution laden with hazardous compounds as dust/air pollution is directly inhaled and enters the soil and water, and leaches into groundwater; it can also be absorbed by crops, contaminating food supplies (Pathak et al. 2023).

In temporary shelters with high concentrations of IDPs, air pollution increases the risk of respiratory and cardiovascular distress, and medium to long-term risks of respiratory, cardiovascular disease and cancer (Velis and Cook 2021). Children are particularly vulnerable to air pollution exposure (Buka, Koranteng, & Osornio-Vargas, 2006) (UNEP-IETC and GRID-Arendal 2019).

As noted above, the use of explosive munitions creates substantial amounts of dust which pose a hazard during conflicts, and during clean-up and recovery operations. Inhalation of fine particulate matter can be harmful from dust generated during the bombing of structures and infrastructure, due to contamination from asbestos, organics, heavy metals from munitions and other hazardous substances.



7 January 2024, smoke and flames rise from different parts of Salah al Din road following Israeli bombardments in Deir el Balah
© UNRWA Photo by Ashraf Amra

03

Section 3: Contamination and other conflict-related environmental impacts

This section describes a set of less visible environmental challenges that have arisen as a result of the conflict, which require specialised assessment and management. These challenges include the contamination of land, water resources and the air by munitions debris and unexploded ordnance; possible instability of land arising from the construction and destruction of an extensive system of tunnels; and possible contamination of soil and water resources arising from the destruction and flooding of such tunnels.

3.1 Chemicals and waste associated with armed conflicts

At the time of writing, intensive conflict had been under way in Gaza for eight months. The conflict was characterised by aerial bombardment of buildings, accompanied by bombardment from the sea and land. Heavily impacted locations of shelling from the sea include Gaza City, Rafah City, Beit Hanoun, Beit Lahiya, Khan Younis and the Gaza Strip's northern regions (UN-OCHA 2023; UN-OCHA 2024b).

The specific quantities and types of weapons used in Gaza are not known to UNEP. However, it is clear from statements by Israel (and from evidence of damage, including unprecedented quantities of debris) that an exceptionally large quantity of munitions has been deployed in a densely populated area. In a press statement issued on 10 December 2023, the Israel Defense Forces confirmed to have hit 22,000 targets in Gaza, more than 300 hits or bombings per day (Israel Defense Forces [IDF] 2023). The Mines Advisory Group (MAG), a partner of the UN Mine Action Service, estimated in February 2024 that more than 25,000 tons of explosives have been used on the Gaza Strip since 7 October 2023, "equivalent to two nuclear bombs" (MAG 2024). There have been reports of the use of specific types of weapons in Gaza, including white phosphorus (Sharp and Detsch 2023). UNEP has noted in previous reports that it is difficult to identify or distinguish between white phosphorus and the legal thermite-based ammunition using only photo/video material (UNEP 2022).



October 2023, bombardment in the Gaza Strip
© UNRWA Photo by Ashraf Amra

The Interim Damage Assessment issued on 29 March 2024 compares damage incurred in various sectors during the 2023-24 escalation of conflicts with damage incurred during previous escalations in 2014 and 2021 (see Table 3). The total cost of damages as of end of January 2024, was approximately US\$18.5 billion compared to the US\$338 million in damages caused in 2021 and US\$1.38 billion in the 2014 conflict. Housing sector damages, at US\$13.29 billion, have been particularly high so far compared to previous escalations (WB, EU and UN 2024).

Table 3: Summary table depicting comparison of per sector damage in monetary terms in 2014, 2021 and 2024 (Source: Gaza Strip Interim Damage Assessment, March 2024) (WB, EU and UN 2024)

SUMMARY			
Sector	Damages (US\$)		
	2014	2021	2024
Social Sectors			
Housing	\$780,000,000	\$144,874,400	\$13,298,711,000
Health	\$24,000,000	\$12,869,276	\$553,666,000
Education	\$35,000,000	\$3,063,111	\$341,240,000
Cultural Heritage	\$1,200,000	\$-	\$319,397,000
Social Sectors Total	\$840,200,000	\$160,806,787	\$14,513,014,000
Infrastructure Sectors			
Municipal Services	\$-	\$24,972,143	\$19,647,000
Transport	\$42,000,000	\$19,549,400	\$357,972,000
Water and Sanitation	\$33,000,000	\$13,540,400	\$502,711,000
Energy	\$58,000,000	\$15,145,000	\$278,522,000
ICT	\$-	\$3,550,181	\$90,225,000
Infrastructure Sectors Total	\$133,000,000	\$76,757,124	\$1,249,077,000
Productive Sectors			
Finance	\$-	\$450,904	\$8,174,000
Commerce, Industry, and Services	\$144,000,000	\$40,000,000	\$1,655,486,000
Agriculture	\$266,000,000	\$42,500,000	\$628,780,000
Productive Sectors Total	\$410,000,000	\$82,950,904	\$2,292,440,000
Cross-Cutting Sector			
Environment	\$-	\$17,500,000	\$411,300,000
Cross-Cutting Sector Total	\$-	\$17,500,000	\$411,300,000
Grand Total	\$1,383,200,000	\$338,014,814	\$18,465,831,000



Sama 10-year-old walks through the rubble of her destroyed neighborhood in Khan Younis, southern the Gaza Strip.
© UNICEF/2024/Eyad al Baba

Potential implications for people and the environment

Modern armed conflicts use large quantities of munitions containing heavy metals and explosive chemicals, all toxic even in modest quantities (Chatterjee et al. 2017). TNT, DNT and RDX are the most common explosives and, other types of explosives are often composed of these substances. Relevant examples are triton (TNT and aluminum powder), H-6 (RDX, TNT, aluminum and calcium chloride) and Minol-2 (TNT, ammonium nitrate, aluminum powder). Heavy metal contamination has been recorded as a result of intensive bombings. Failure rates vary, but after the war in 2014, the United Nations Mine Action Service (UNMAS) indicated a failure rate of 10 per cent (UN-OCHA 2014).

In general terms, hazardous materials contained in munitions cause direct and immediate toxicity to flora and fauna (causing mortality, reduced growth, stress, disease and damage to organisms) and/or bioaccumulation through food webs, leading to concentrated amounts of these substances in some organisms when they enter the environment. Some types of hazardous materials persist for a long time in the environment (in soil, groundwater, seawater and marine sediments), causing impacts that can last for decades. The way in which they move through the environment depends on their chemical properties but are likely to be present in debris and hence when being removed or treated could represent direct exposure risks. More details are provided in (UNEP 2022).

Many explosives have known negative effects on human health. TNT is for instance a possible carcinogen and

long-term exposure can lead to liver and kidney damage (United States Environmental Protection Agency [EPA] 2021). It is found in soils where munitions have been used or are buried. Drinking RDX-contaminated water affects the nervous system and can lead to seizures, convulsions, nausea and vomiting (Lima et al. 2011).

Heavy metals are highly toxic, some of which (especially arsenic, cadmium, chromium, lead and mercury) can cause multiple organ damage even at low levels of exposure, and they are carcinogenic (Järup 2003). Chronic exposure to low levels of lead can lead to developmental delays and long-term impacts on the brain, as well as on general health (WHO 2023b). Heavy metals bioaccumulate in some species, including fish consumed by humans, and contaminated agricultural soils can lead to contaminated crops, especially vegetables (Tchounwou et al. 2012; Velis and Cook 2021). Experience from past conflicts have shown that heavy metal contamination has persisted for many decades (Appleton and Cave 2018). A study focused on soil samples taken in bomb craters on agricultural land in Gaza found elevated levels of nickel, chromium, copper, manganese and lead, with copper, manganese and lead being the most widespread (Al-Najar et al. 2015).

Phosphorus bombs are munitions that consist of white phosphorus or its mixture with other substances, as well as a mechanism for igniting them (Voie et al. 2010). They can explode both in the air and on impact with the ground. White phosphorus looks like wax, is colourless or has a yellow tint, glows in the dark and has a pungent smell of garlic (Weapons Law Encyclopaedia 2022). A blast wave can scatter matter over an area of several hundred square meters. The combustion temperature exceeds 800 degrees



A building collapsed into the street in Gaza.

© UNRWA/Mohammed Hinawi

Celsius. Burning is accompanied by thick and acrid white smoke and continues until the phosphorus is completely burned out or until the supply of oxygen stops. The substance causes severe burns in humans and can lead to a painful death (Atiyeh et al. 2007).

Previous escalations can provide some indication of the type of clean-up required, although the current conflict has been under way for a longer period and has been substantially more intense than previous escalations. UNMAS, which has been involved in the clearing of explosive remnants of war²⁷ in Gaza since 2009, anticipates that the clearance of munitions from Gaza will take many years, and will be "an unprecedented operation" (UN News 2024).

Clearance of munitions, especially of deep-buried bombs dropped by aircraft, is time-consuming and dangerous. Based on past practice in Gaza, UNMAS can clear about one deep-buried aircraft bomb per month. A total of 21 deep-buried aircraft bombs were reported to UNMAS since the 2021 war, and the clearance of these munitions had almost been completed by the start of the current conflict in October 2023. UNMAS estimate that the scale of the contamination sustained during the ongoing 2023–24 conflict will be such that the search for deep buried ordnance will not be undertaken for some time because the focus will necessarily be on surface level ordnance (UN News 2024).



26 November 2023, collapsed buildings and scenes of destruction in Khan Yunis

© UNRWA Photo by Ashraf Amra

27 Explosive remnants of war include unexploded ordnance (UXO) and abandoned explosive ordnance (AXO).

3.2 Construction, destruction and flooding of tunnels in Gaza

The Gaza tunnel system

Hamas has reportedly constructed approximately five hundred kilometres of tunnels under the Gaza Strip (Reuters 2023). According to media reports, the tunnels are widespread and are constructed from concrete, with electricity, ventilation, sewage and communication networks. It is assumed that the tunnels were not built according to the engineering and safety standards that are often required for other types of underground infrastructure, such as mines and metropolitan train systems. The construction of a network of tunnels by Hamas, and Israel's efforts to destroy or render unusable these tunnels, may further contribute to environmental damage.

The IDF announced on 30 January 2024 that they had

"implemented new capabilities during the war, with the aim of neutralizing underground terrorist infrastructure, including by channelling large volumes of water into them. This method was developed in cooperation with the @Israel_MOD, and is only utilized in locations where it is suitable. The IDF takes into consideration the soil and water systems in the area, matching the method of operation to each specific case."²⁸

The UN Environment Programme does not know the extent to which Israel is pumping water into the tunnels, nor the extent or volume of the tunnel system, how it is built and whether tunnels are inter-connected.

Potential implications for people and the environment

If large quantities of seawater were pumped into an extensive network of tunnels, two effects might be expected which could be of concern: contamination of groundwater below the tunnels and potential instability of the area above the tunnels. These two effects are potentially serious and should therefore be investigated as soon as possible.

Possible contamination of groundwater below the tunnels:

The addition of more salt water into the tunnel system would likely increase the leaching of highly saline water into the aquifer, further decreasing potability. In addition, electrical equipment, fuel, building materials and munitions in the tunnels could also leach into soil and groundwater. Flooding of tunnels could increase the migration of contamination, further impacting the quality of groundwater (Gonçalves, Albuquerque, Almeida, Gomes, & Cavaleiro, 2024) (Dudek et al. 2020). This is an immediate issue, due to people's reliance on groundwater, and will add an additional characteristic of contamination to be remediated in the longer term. Saline water is also a threat for industry, agriculture and horticulture. For example, high salinity levels can lead to poor crop yields, including salt tolerant varieties of grains.

Potential instability of the land above the tunnels:

Flooding or conflict-related structural changes could affect integrity of the tunnels, leading to collapse and hence surface collapse of buildings and structures. The quality of the tunnels and their supporting infrastructure is unknown, hence the uncertainty regarding the nature of impacts. However, there may be lessons from mining experience applicable to the situation in Gaza. In most mining situations where tunnels are flooded, the water levels need to be maintained to support integrity of the tunnels and maintenance of water quality (Van Zyl, 2016). The situation in Gaza is different, but could also reflect what happens in shallow aquifers where tunnels are flooded. It has also been observed that the flooding of mines can lead to movements in surrounding rocks and earth and hence "land surface as a result of pressure changes in the flooded zones" i.e. result in subsidence (Dudek et al. 2020).

28 The quote is from the official account of the Israel Defense Forces on the social media platform X (@IDF). The quote was posted at 7PM local time (EET) on 30 January 2024. Retrieved from: https://x.com/idf/status/1752376187563704721?s=46&t=_6e9_qqgoQ2KESKaZiy7yg

Conclusion

This Preliminary Assessment has described an unprecedented intensity of conflict-related damage in comparison to previous conflicts in the Gaza Strip, and provided an initial analysis of its likely implications for people and their environment. The assessment also summarized long-running environmental challenges, and recent Palestinian and international efforts to protect people and ecosystems through enhancing facilities and capacities for integrated water management and solid waste. Progress recorded in some areas had been hard-won and costly, due in part to the political and security constraints prevailing in Gaza. Limited progress has been reversed and overwhelmed by the current conflict.

The UN Secretary-General (UNSG) has made repeated calls for an immediate humanitarian ceasefire in Gaza: this is essential to halt and begin to reverse the “entirely manmade disaster” that is unfolding. At the time of writing, the UN system and its partners are focused on saving civilian lives and averting famine in Gaza, in what has become—in the Secretary-General’s words—a “humanitarian hellscape” (UNSG 2024).

At the same time, UN entities and international partners, including the World Bank Group and European Union, have recognized in their joint Interim Damage Assessment (WB, EU and UN 2024) that “While recovery and reconstruction will require substantial, years-long effort, early recovery actions should begin as soon as the situation allows and complement scaled up humanitarian assistance.” Halting the destruction will allow the hard, work of restoring services such as wastewater treatment and solid waste collection to begin. Restoration of such services will be costly: damage already sustained in the water, sanitation and hygiene sector alone is assessed at over US\$500 million (WB, EU and UN 2024).

Restoring safe living conditions for a densely-populated, water-scarce and contaminated strip of land will also require exceptionally careful planning. Incorporating environmental dimensions into such planning will be necessary from the very start. Planning to rebuild hospitals, schools and homes should incorporate analysis of potential contaminants, so that high-risk areas can be avoided; and be sensitive to possible land instability arising from destroyed tunnels. Clearance of debris also requires an understanding of the contaminants such debris contains, to ensure the clearance and disposal does not spread and further contaminate soil or water, and thus create new risks to Gaza’s inhabitants. Understanding the extent and type of pollution affecting the Coastal Aquifer will also be critically important, to

ensure that people are not further exposed to dangerous chemicals and heavy metals in their water or food.

Future environmental assessment work

Joint work on environmental issues will be important during the months ahead. By incorporating environmental analysis and recommendations into national and international responses and recovery plans and operations, and by working closely with multilateral partners, UNEP can maximise prospects for addressing immediate risks (such as conflict-related pollution and contamination); guide immediate recovery efforts (for example, by providing frameworks to manage hazardous waste and promote safe disposal); support debris management planning and coordination including technical advisory support on maximizing recycling opportunities; and help to ensure that environmental and climate considerations are incorporated into recovery and development plans. This brings benefits for affected populations and for those impacted by transboundary environmental consequences of the conflict.

Two types of assessment work are envisaged: first, incorporation of environmental issues fully into the envisaged multilateral Rapid Damage and Needs Assessment (RDNA) process; and second, field-based assessment of priority environmental issues to be undertaken by qualified specialists, whenever conditions permit. These two expected assessment processes are briefly summarised below.

Rapid Damage and Needs Assessment

The UN, World Bank and European Union are planning to undertake a RDNA in Gaza, based on a globally established methodology and building on information, data and analysis from such entities and other reliable sources of information.

A ceasefire, as called for by the UN Secretary-General, would allow international entities to conduct a full RDNA. An interim assessment for Gaza may be initiated in the absence of a cessation of hostilities. UNEP has been asked to lead the environmental assessment aspect of the RDNA, a task it will undertake in close co-operation and partnership with other UN entities – including the UN partners which maintain a field presence in the Gaza Strip.

The RDNA process is designed to provide an early, rapid assessment of damages and needs, to inform early planning for recovery. The 2021 Gaza RDNA, which was conducted by the World Bank Group in partnership with the

European Union and the United Nations, specifies that to "mitigate the limitations in data collection, the team relied on the use of remote data tools such as high-resolution satellite imagery and social media monitoring as well as the information and guidance provided by UN and humanitarian agencies on the ground in Gaza. This is a 'live' document and will be updated as new information becomes available. The assessment ... is not a replacement of in-depth sector-specific assessments." (World Bank 2021)

The same provisions are likely to apply to the forthcoming joint RDNA, which will be undertaken at speed and will provide an important basis for further, more granular sector-specific assessment work. At present, UNEP anticipates undertaking a full environmental assessment after the completion of the RDNA and building on its findings.

Planning for a field-based environmental assessment

Whenever security conditions allow and access is granted, UNEP will seek to undertake a field-based process that would enable more accurate assessment of the extent and type of environmental degradation, and permit identification of remediation options in consultation with relevant stakeholders, including the scientific research community, public and private sector professionals, civil society, women and youth. Such a field-based assessment would allow UNEP and partners to understand the full extent of environmental damage arising from the conflict, including land, water and air pollution; damage to the aquifer; and contamination from munitions (and the immediate and long-term impacts of such contamination). Such an assessment would also provide the basis for science-based recommendations about how to clean-up, restore and protect Gaza's environment and its people as early recovery from the conflict begins, over the short, medium and long term.

Some aspects of environmental degradation arising from the conflict in Gaza will require specialized analysis and action. Understanding the type, locations and extent of contamination from munitions will be necessary, as a first step towards protecting people (and the food and water systems on which they depend) from such contamination. Understanding whether the construction, flooding and destruction of tunnels has caused severe damage to the environment, including the aquifer and possible instability of soil, will also be important and should be undertaken alongside planning for reconstruction.

As noted above, UNEP is mandated by Member States to serve as an authoritative advocate for the global environment, to monitor environmental status and risks, and to

"lead efforts to formulate United Nations system-wide strategies on the environment." At the sixth United Nations Environment Assembly, which took place as the conflict in Gaza was ongoing, Member States asked the UNEP Executive Director to report on "new and emerging practices, on the collection of data on environmental damage associated with armed conflicts" and to "strengthen the United Nations Environment Programme's collaboration with other UN Agencies and relevant stakeholders to provide, upon requests of Member States of the United Nations or members of UN specialised agencies, environmental assistance and recovery in areas affected by armed conflicts."²⁹

Given high uncertainty relating to the governance and security arrangements in Gaza, and noting the importance of early identification and remediation of environmental risks (including contamination), it may be necessary to use innovative methods—"new and emerging practices"—to investigate such environmental risks. Work with UN partners in the field will continue to be critically important: UNEP will continue to support the UN Country Team's efforts on environment, and to engage in inter-agency efforts to coordinate a system-wide approach and promote a science-informed response to address the environmental impacts of the conflict.

Finally, it is relevant to note that Gaza hosts important higher education institutions, laboratories and civil societies institutions, which hold important knowledge about Gaza's environment. Drawing on such knowledge will be important as steps begin towards recovery of Gaza's natural resources and ecosystems.

²⁹ UNEA Resolution 6/12, entitled "Environmental assistance and recovery in areas affected by armed conflict" is available at: <https://documents.un.org/doc/undoc/gen/k24/008/55/pdf/k2400855.pdf?token=OsSc8Gfmxiu5XXNMZv&fe=true>

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Palestinians line up in a queue to get water in Khan Yunis on May 02, 2024. © AFP

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