Throwing away our health

The impacts of solid waste on human health – evidence, knowledge gaps and health sector responses

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Abbreviations

COPD	chronic obstructive pulmonary disease
COVID-19	coronavirus disease
EHS	environment health and safety
ESM	environmentally sound management
e-waste	electrical and electronic waste
GHG	greenhouse gas
HCW	health care waste
HHRA	human health risk assessment
HIV	human immunodeficiency virus
MSW	municipal solid waste
MSWI	municipal solid waste incinerator
MSWM	municipal solid waste management
NHL	non-Hodgkin lymphoma
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxin
PCDF	polychlorinated dibenzofuran
PM	particulate matter
POP	persistent organic pollutant
PPE	personal protective equipment
SDG	Sustainable Development Goal
SWM	solid waste management
UNEP	United Nations Environment Programme
UN-Habitat	United Nations Human Settlements Programme
VOC	volatile organic compound
WaCT	Waste Wise Cities Tool
WHO	World Health Organization

Executive summary

This report synthesizes current knowledge of the health risks associated with solid waste and its management, identifies key evidence gaps and highlights the critical role of the health sector in ensuring effective public health protection.

Solid waste management is increasingly recognized as a critical global public health and environmental challenge. Among various waste streams, municipal solid waste (MSW) – generated by households, businesses and institutions – is the most visible form of waste and is rapidly increasing. Its volume is projected to rise significantly, driven by urbanization, population growth and changing consumption patterns.

While high-income countries generate more waste per capita and typically have stronger infrastructure and regulatory systems, low- and middle-income countries – where waste generation is increasing most rapidly – often lack the capacity to manage it safely. MSW, when managed inadequately, can release a wide range of pollutants into the environment, contaminating air, water, soil and vegetation. It also creates breeding grounds for disease vectors such as insects and rodents. Open burning and inefficient incineration emit harmful substances, including dioxins and furans, which contribute to air pollution. Hazardous chemicals from uncontrolled disposal sites can leach into ecosystems and bioaccumulate in the food chain. Populations may be exposed to a wide range of biological, chemical, physical and psychological health risks. Waste workers (particularly those in the informal sector), vulnerable groups such as children and pregnant women, communities underserved by municipal solid waste management (MSWM) services and those living near MSWM facilities are especially at risk.

Evidence on the health impacts of MSWM is largely based on epidemiological studies, most of which focus on populations living near incinerators and landfills in high-income settings. Some studies have identified associations with adverse birth outcomes, congenital anomalies, cardiovascular diseases, respiratory conditions and certain cancers. However, the evidence remains limited due to several methodological and contextual challenges. Assessing health impacts of MSW is complex, given the diversity of exposure pathways (e.g. air, soil, water and direct contact), variability in waste composition, differences and uncertainties about the effectiveness of waste containment and treatment practices, and the wide range and concentration of pollutants involved. Moreover, MSWM facilities are often located in areas already affected by other sources of pollution, making source attribution difficult. Many studies rely on ecological or observational designs, which often lack control for confounding factors and limit causal inference. Additional barriers include significant data gaps on exposure levels and treatment technologies. Data from low- and middle-income settings – where waste is often poorly managed and risks are likely to be highest – are particularly scarce. Strengthening the evidence base in these settings is essential to better understand the full health burden, inform effective policy and protect vulnerable populations.

Living in a clean and safe environment is a fundamental human need and right. Clean environments are critical for protecting physical health and for preserving dignity, promoting mental and social well-being, and supporting healthy resilient communities. The current trajectory of global solid waste generation and mismanagement presents critical challenges. Without urgent intervention, the growing volume of waste will continue to strain infrastructure, pollute ecosystems, contribute to climate change and undermine public health. These consequences will lead to higher health costs and will strain economies, as resources are diverted to address these growing environmental and health burdens. However, when properly managed, solid waste can become a valuable resource, with the potential to generate clean energy, recover reusable materials, create green jobs, and reclaim land for productive and sustainable uses.

To address these challenges, this report calls for a coordinated, multisectoral response that integrates public health, environmental protection and sustainable development. It emphasizes the importance of applying the waste hierarchy – prioritizing prevention, reuse and recycling – and adopting integrated sustainable waste management approaches. Key actions include reducing the generation of waste, expanding effective and affordable waste collection services, improving control levels at recovery and disposal facilities, monitoring potential contamination of air and groundwater, eliminating open dumping and burning, and ensuring the safe treatment of hazardous waste, including health care waste and electrical and electronic waste. It also includes protecting workers, neighbours and others potentially exposed to the health risks associated with solid waste.

Achieving these goals demands strong governance, robust policies and raising public awareness to shift consumer behaviour. These require political commitment to make effective waste management a priority. Financial sustainability requires adequate public investment, fair charging systems and implementation of extended producer responsibility policies. Producers should be incentivized to reduce waste along the entire lifecycle of their products and held accountable for the costs of managing waste from their products, rather than shifting the burden to resource-limited municipalities, particularly in low- and middle-income countries. Consumers should also be informed and motived to choose more sustainable products and to reduce, reuse and recycle solid waste by making environmentally responsible options more accessible, convenient and affordable.

The health sector has a clear role to play in this transformation. As a major waste generator, it should take proactive steps to minimize health care waste at source, promote safe segregation and treatment, and invest in environmentally sustainable technologies. This is especially vital during public health emergencies, when waste volumes surge and systems are under pressure. Beyond its own operations, the health sector should advocate for health-protective policies, support occupational safety standards, conduct health risk assessments and raise public awareness. Strengthening the evidence base through research, surveillance and biomonitoring is essential to inform policy and practice. Integrating informal waste workers into formal systems, improving access to health services and addressing the social determinants of health are critical for reducing health inequities and promoting inclusive development.

Solid waste is not only an environmental concern – it is also a public health crisis. The health sector must shift from reactive responses to proactive engagement, working with sectors such as environment, agriculture and urban development. Promoting prevention, supporting safe waste management and enabling community action can help build cleaner, healthier and more resilient societies.

1 Introduction

Solid waste management (SWM) has long been recognized as essential for protecting public health. Since ancient civilizations, rudimentary systems for waste collection and disposal have been used to maintain cleanliness. In the 19th century, outbreaks of cholera and typhoid in rapidly growing cities led to the introduction of formal waste collection systems and regulations – well before disease transmission was fully understood. These early public health efforts laid the foundation for modern waste management systems, emerging in response to uncollected waste and later expanding to address environmental risks from inadequate disposal *(1, 2)*.

Solid waste encompasses a wide range of discarded materials from households, industry, health care, agriculture and other sources. It includes plastics, food waste, electrical and electronic waste (e-waste) and hazardous materials *(3)*. Over time, countries have improved technologies and strengthened regulations to reduce the environmental and health risks of waste *(2)*. Despite these efforts, solid waste remains one of the most pressing global environmental and public health challenges – one that the health sector tends to overlook.

Among the various waste streams, municipal solid waste (MSW) – generated by households, small businesses and institutions – has emerged as a particularly urgent concern. It is projected to increase from 2.1 billion tonnes in 2020 to 3.8 billion tonnes by 2050, driven by rapid urbanization, population growth and rising consumption *(3)*. MSW accounts for about 10% of total waste volumes in regions such as the European Union *(4)*. However, it is the most visible form of waste – found daily in household bins, on city streets and at recycling or disposal sites. MSW presents unique challenges due to its complex and evolving composition, which increasingly includes a wide range of chemicals and synthetic compounds. While most MSW is non-hazardous, in many countries with limited waste management capacity, hazardous materials are often disposed of alongside MSW, compounding health and environmental risks *(3)*.

The disparity in municipal solid waste management (MSWM) between countries is stark. High-income countries produce more MSW per capita, but benefit from higher rates of waste collection and stricter waste management controls. In contrast, low- and middle-income countries generate less waste per capita, but are expected to see significant increases in waste production. However, their waste management systems are often unprepared for such rapid growth. These countries may face the added burden of imported waste from wealthier nations – including waste with potentially harmful compounds – and frequently lack the infrastructure to manage it effectively, leading to harmful practices such as open dumping and burning.

The mismanagement of waste is linked to widespread contamination of the environment, affecting soil, water and air, and accumulating in food chains. Plastic waste has been widely publicized, with large amounts of plastic particles being found in oceans, rivers, drinking-water and food *(5–7)*. Hazardous chemicals – including those from electronics and other complex waste streams – pose significant long-term threats to ecosystems and public health *(8)*. Accumulation of waste facilitates the spread of pathogens and disease vectors such as mosquitoes and rodents, and increases the risk of outbreaks, particularly in densely populated or impoverished areas *(9)*. Waste workers, underserved populations and nearby communities face high health risks from poorly managed waste. Beyond health, mismanaged waste also drives climate change through pollution and greenhouse gas (GHG) emissions – especially methane – and it affects social and economic stability.

Public concern over solid waste is growing. International negotiations of a treaty on plastic pollution, and the recent decision to establish the Intergovernmental Science-Policy Panel on Chemicals, Waste and Pollution to sit alongside the Intergovernmental Panel on Climate Change and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, have brought the issue of solid waste to the global agenda *(2)*.

Key publications such as the United Nations Environment Programme (UNEP) *Global waste management outlook 2024 – beyond an age of waste: turning rubbish into a resource (3)* have highlighted the urgent need to reduce waste, transition towards a circular economy and underscore the potential cost savings of this shift, including reductions in health-related externalities. The World Health Organization (WHO) has produced key resources (Annex 1) including on health care waste (HCW), e-waste, air pollutants from waste combustion, and chemical and plastic pollutants *(8, 10–14)*. In response to World Health Assembly resolutions (in 2016 and 2023), WHO has been tasked with assessing impacts of solid waste on human health and identifying strategies to strengthen the health sector's role in mitigating related risks.

This report builds on earlier work, including a 2015 consultation, *Waste and human health: evidence and needs (15)*, to incorporate recent epidemiological evidence. It summarizes current knowledge on the health implications of solid waste, particularly MSW, reinforces established good practices in waste management and identifies key evidence gaps. While not exhaustive, the report lays a foundation for future research and reinforces the critical role of the health sector in addressing the global waste crisis.

Chapter 2 provides key definitions of the types of solid waste. Chapter 3 then outlines management processes, mismanagement, and status and trends. Chapter 4 details hazards, exposure pathways and exposed populations, and Chapter 5 reviews the risks and impacts on human health. Chapter 6 proposes multisectoral actions and health sector roles to improve governance and reduce health risks.

2 Solid waste: key definitions

Solid waste refers to any discarded materials, substances, by-products or articles. It can be categorized in many ways, including by origin (e.g. MSW, HCW, industrial waste, agricultural waste, and construction and demolition waste), material (e.g. plastics and food), products (e.g. e-waste) and/or properties (e.g. hazardous and non-hazardous waste) *(3)*. This chapter provides an overview of solid waste and its various types.

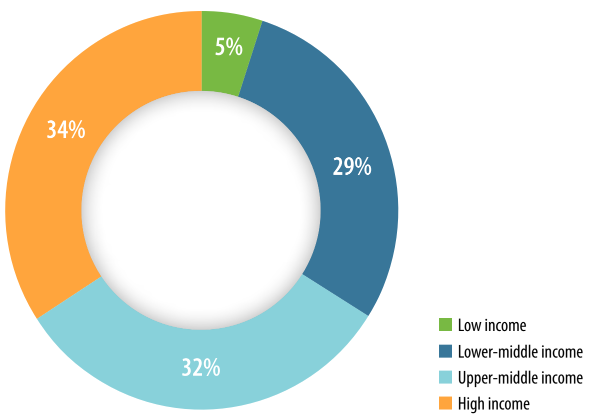
2.1 MSW

MSW consists of a diverse mix of materials, including food and garden waste, glass, plastics, paper, cardboard, metals and textiles. MSW includes recyclable and non-recyclable components, as well as hazardous and non-hazardous materials. Its management is typically the responsibility of local governments, although services may be delivered by private companies paid by households, businesses and institutions, usually under government oversight.

High-income countries tend to produce the most MSW per person: an estimated 1.60 kg per day on average in 2016 compared with 0.91 kg in upper-middle-income countries, 0.47 kg in lower-middle-income countries and 0.41 kg in low-income countries *(16)*. Fig. 1 shows the share of waste generated globally by income level.

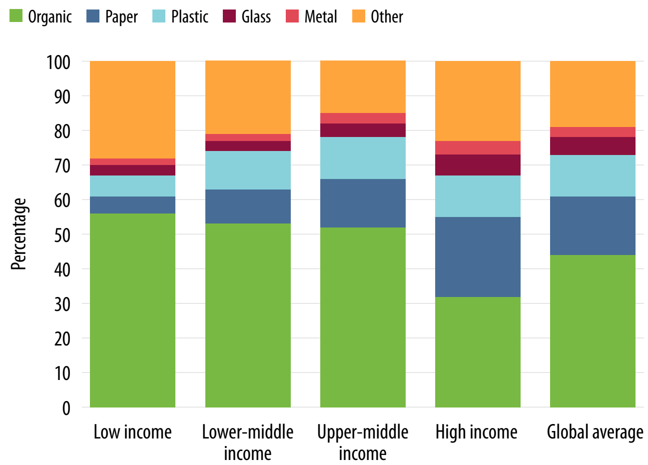
The composition of MSW is highly heterogeneous and varies by locality, including by region, as well as between and within countries. Low- and middle-income countries have a higher proportion of organic waste relative to the total amount of MSW they generate. As income levels rise, waste packaging (especially plastics, see Box 1) becomes more prevalent. In 2016, it was reported that plastics constituted approximately 12% of all MSW globally (Fig. 2).

Fig. 1 **Share of waste generated, by income level, 2016**



Source: adapted from Kaza et al. *(16)*. This is an adaptation of an original work by The World Bank. Views and opinions expressed in the adaptation are the sole responsibility of the author or authors of the adaptation and are not endorsed by The World Bank.

Fig. 2 **MSW composition globally and by income level, 2016**



Source: adapted from Kaza et al. *(16)*. This is an adaptation of an original work by The World Bank. Views and opinions expressed in the adaptation are the sole responsibility of the author or authors of the adaptation and are not endorsed by The World Bank.

Box 1

Plastic waste, environmental pollution and human health

Plastic production and waste

Plastics have become deeply embedded in modern life due to their durability, versatility and low cost. They are used across a wide range of sectors, including in packaging, household appliances, medical equipment, transport and construction. While plastics play essential functions – such as preserving food or enabling drug delivery – their widespread use has led to a dramatic increase in plastic production, which has doubled over the past 20 years. Approximately 460 million tonnes of plastics are produced annually. Despite this massive output, only 9% of plastic waste was recycled in 2019. The majority – around 50% – was landfilled, 19% was incinerated and 22% was mismanaged, often leaking into the environment, with substantial amounts entering oceans and other water bodies *(17)*.

In 2019, nearly two thirds of plastic waste originated from short-lived, single-use products: 40% from packaging, 12% from consumer goods and 11% from clothing and textiles. In 2022, the Organisation for Economic Co-operation and Development reported that plastics were responsible for 3.4% of global GHG emissions, underscoring the environmental impact across their entire lifecycle *(17)*. The mis-management of plastic waste has led to its presence in nearly every part of the environment. Plastics have been detected in water, air, soil and even within food and beverages, thus raising growing concerns about their impact on the environment and human health *(7)*.

Plastics as a public health concern

The impacts of plastic pollution on human health is increasingly documented at every stage of their lifecycle, from production and use through to disposal, as highlighted in recent comprehensive reviews *(18, 19)*.

More than 16 000 chemicals have been identified in plastics, including hazardous substances such as per- and polyfluoroalkyl substances, brominated flame retardants, phthalates and bisphenols *(20)*. Human biomonitoring studies have detected plastic-associated chemicals in adults and children worldwide, indicating widespread exposure. Systematic reviews have linked many of these chemicals to adverse health effects, including reproductive disorders, perinatal complications, impaired cognitive development, metabolic and cardiovascular issues, and increased risks of cancer in adults *(21)*. However, for a large portion of plastic-associated chemicals, data on potential health impacts are lacking. Most of these chemicals have not undergone hazard assessments, and less than 6% are subject to global regulations (*20*, *22*).

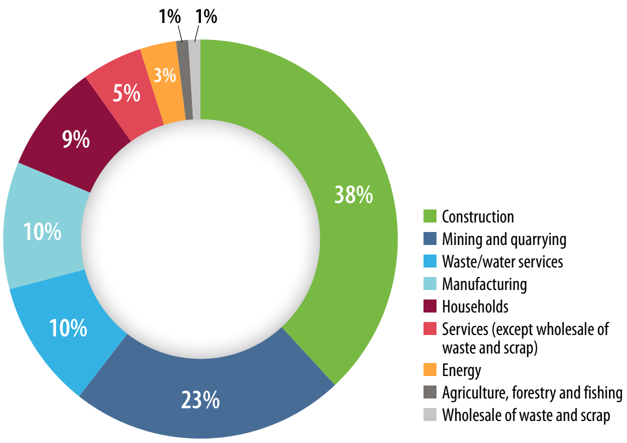
Plastic waste breaks down over time, largely through mechanical abrasion and exposure to sunlight and heat, fragmenting into progressively smaller particles that become microplastics and eventually nanoplastics. Several reviews and reports have shown that nano- and microplastic particles accumulate in the human body, potentially causing inflammation, organ damage and immune system disruption *(7, 13, 18, 19, 23, 24)*. However, analytical detection methods remain limited, and further research is needed to confirm these effects. In the meantime, these reviews and reports underscore the need for precautionary actions to curb plastic pollution – measures that would offer co-benefits for human health and for environmental sustainability *(25)*.

Way forward on ending plastic pollution

In March 2022, the fifth session of the United Nations Environment Assembly adopted a mandate to negotiate an international, legally binding global treaty to end plastic pollution, including in the marine environment (Global Plastics Treaty). The treaty aimed to reduce plastic pollution across the entire plastic lifecycle, from design and production to consumption, waste management and disposal. It focused on reducing plastic production, eliminating single-use plastics, promoting sustainable alternatives and implementing extended producer responsibility. Although a final agreement was not reached, the process raised global awareness, spurred research on the health impacts of plastic pollution and strengthened international support for action – including greater engagement from the health sector. The Lancet Countdown on health and plastics, launched in August 2025, will track progress in reducing plastic exposure and mitigating their harm to human and planetary health *(19)*.

MSW makes up a relatively small share of the total solid waste generated. For example, in the European Union, household waste accounted for around 9% of the total in 2022, much less than sectors like construction or mining and quarrying (Fig. 3). However, the amount of MSW generated globally is growing at an alarming rate. Globally, 2.1 billion tonnes of MSW were generated in 2020, and this number is projected to increase to 3.8 billion tonnes by 2050 *(3)*. In 2016, the average per capita generation of MSW was estimated at 0.74 kg per day *(16)*.

Fig. 3 **Waste generation by economic activity and household, European Union, 2022**



Source: adapted from European Commission *(4)*.

2.2 Other types of waste

2.2.1 Hazardous waste

Hazardous waste includes any waste that can harm human health, living organisms or the environment due to its hazardous constituents and characteristics. Hazardous wastes are controlled under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal *(26)*. Hazardous waste may be toxic, ecotoxic, corrosive, flammable, reactive, explosive, radioactive, infectious, etc. Examples include pesticides, paint, waste oils, e-waste, construction and demolition waste contaminated with asbestos, flammable solvents, radioactive waste and infectious waste. It was reported in 2016 that around 0.32 kg of hazardous waste was generated per person per day globally *(16)*. However, this estimation was based on strong assumptions and lack of data for several countries.

Households generate small but significant amounts of hazardous waste from everyday items such as cleaning products, paints, pesticides, vehicle oils, batteries, electronics and expired medicines. The handling of such materials requires specialized management and disposal methods. In many countries with limited waste management capacity, hazardous waste is often mixed with MSW and may not be managed safely.

2.2.2 E-waste

E-waste is an example of a waste stream that may be hazardous, depending on its content. It includes discarded electrical and electronic equipment like screens, lamps, batteries, temperature exchangers and telecommunications equipment containing hazardous chemicals. While e-waste recycling and disposal facilities have been established, mostly in high-income countries, much of the e-waste generated by households and commerce ends up in MSW streams and is sent to the same disposal sites or dumpsites. In 2022, 62 billion kg of e-waste was generated globally, equivalent to an average of 7.8 kg per capita per year. Only 22% of the e-waste generated globally is estimated to be formally collected and recycled in an environmentally sound manner *(27)*.

High-income countries sometimes illegally export e-waste to lower-income nations, which often lack the infrastructure to manage it, leading to large, unmanaged e-waste dumpsites *(28)*. International agreements – such as the Basel Convention and the Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa *(29)* – have been put in place to facilitate the reduction and elimination of illegal transboundary shipments of hazardous waste.

Batteries are an example of e-waste. By volume, the largest use of lead nowadays is in the production of lead–acid batteries. These rechargeable batteries are a fast-growing commodity as people move away from the use of fossil fuels to power cars and vehicles. While exposure to lead in the production of these batteries can be controlled in well-managed facilities, the breaking up of the batteries in recycling operations is often conducted far from the country of origin and with poor environmental controls *(30, 31)*.

Inadequate handling, recycling and disposal activities can result in releasing hazardous compounds into the environment. Over 1000 hazardous chemicals have been found in e-waste and its components. Some of these are chemicals of concern including heavy metals such as mercury, cadmium and lead, and persistent organic pollutants (POPs) such as dioxins and furans, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), polyfluoroalkyl substances, phthalate esters, bisphenols and brominated flame retardants. These can pose significant health risks, especially among children employed in the informal recycling economy *(8)*.

2.2.3 HCW

HCW encompasses all waste generated by health care facilities, research centres and households related to medical treatment and procedures. In 2014, it was estimated that about 15% of HCW was hazardous, and included sharps, infectious and pathological waste, pharmaceuticals, chemicals and radioactive or genotoxic waste *(10)*. However, definitions of infectious waste vary across countries, leading to differences in reported estimates. High-income countries generate on average up to 0.5 kg of hazardous waste per hospital bed per day, while low-income countries generate on average 0.2 kg *(32)*. The quantity of hazardous waste may be substantially higher in low-income countries where waste segregation practices are less stringent *(33)*.

The treatment and disposal methods of HCW vary by waste type, ranging from autoclaving, incineration or storage and transport to specially engineered landfills. In many low- and middle-income countries, HCW is often mixed with MSW and subjected to unsafe practices such as open dumping and burning *(32, 34)*.

2.2.4 Other solid waste

Other solid waste streams include construction and demolition waste, sewage sludge, industrial waste, agricultural waste, and end-of-life vehicles and tyres. As of 2016, industrial waste had the highest average daily generation rate, estimated at 12.7 kg/person, followed by agricultural waste averaging 3.4 kg/person, and construction and demolition averaging 1.7 kg/person *(16)*. Therefore, these waste streams are significant and require safe and effective management.

3 Managing MSW

This chapter discusses MSWM, outlining the key steps involved, common challenges related to mismanagement, and current trends and status. The focus here is primarily on technical components and infrastructure. Chapter 6 briefly addresses broader system elements essential for effective waste management, including financing, human resources and governance.

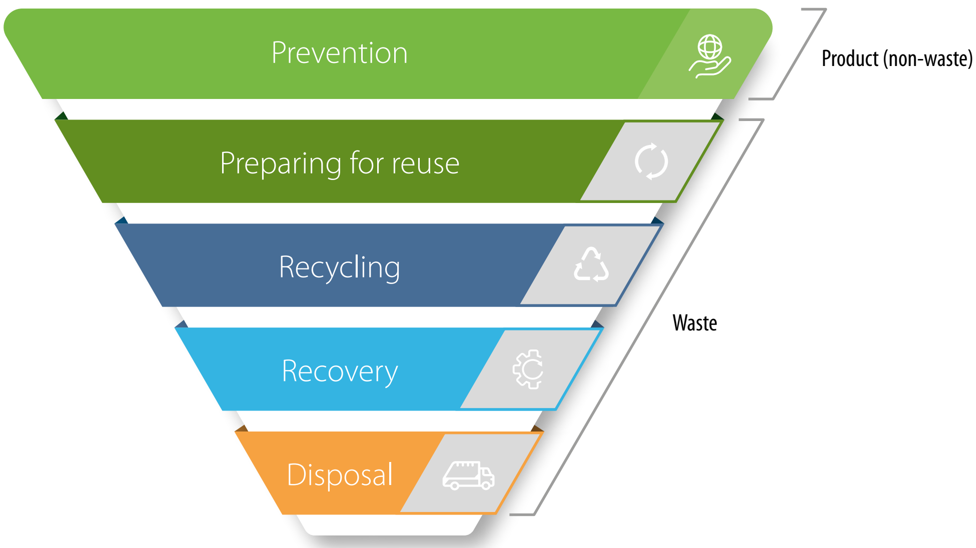
Several frameworks are used to describe SWM processes, each offering a different perspective. The waste hierarchy is the most widely used (Fig. 4). It consists of an inverted pyramid showing the most preferred option at the top and the least preferred option at the bottom. The waste hierarchy aims to encourage society to reduce waste, reuse items where possible and recycle materials to minimize the quantities that require collection and disposal. This eases the strain on natural resources by recapturing them and diverts materials away from disposal.

Waste prevention focuses on reducing waste generation at source. This approach involves promoting responsible consumer behaviour, designing products and processes that minimize waste, and encouraging the use of safer, more sustainable materials. Prevention reduces the need for reuse, recycling, recovery and disposal, making it the optimal choice to mitigate the public health and environmental risks associated with SWM.

3.1 Management process

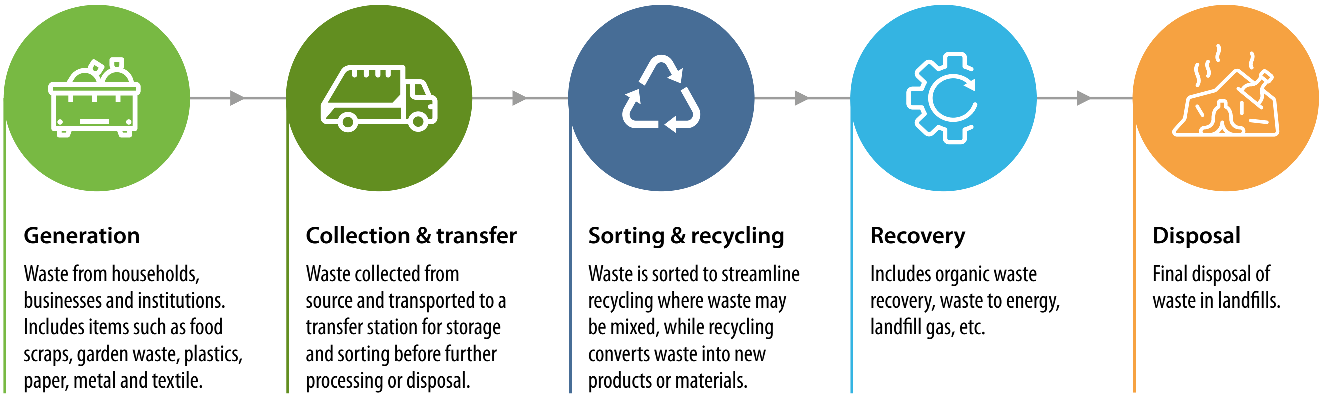
MSWM involves a series of interconnected steps as described below. After generation, the process starts with primary and secondary collection, followed by sorting and recycling at transfer stations. Recyclables are then processed and transformed into raw inputs for new products. Non-recyclable waste may undergo recovery processes such as composting, waste-to-energy

Fig. 4 **Waste hierarchy to prioritize options and reduce environmental impacts of waste**



Source: adapted from European Commission *(35)*.

Fig. 5 **MSWM value chain**



Source: adapted from German Society for International Cooperation et al. *(36)*.

conversion or landfill gas capture. The remaining waste that cannot be recovered is typically disposed of in landfills *(36)* (Fig. 5).

3.1.1 Generation and separation

Waste generation refers to the materials that are discarded from human activity. Source separation involves segregating waste into distinct categories to facilitate resource recovery, reduce cross-contamination and simplify the extraction of valuable materials. This process is carried out at the household, business and industrial levels, and in public spaces. It improves efficiency and safety for those who handle, process, transport or sort this waste. In health care facilities, source separation is particularly crucial in preventing injuries from sharps and the spread of infectious diseases *(10)*.

3.1.2 Collection and transfer

Waste collection and transfer is the gathering of waste from its source to a collection point or transfer station, for storing and sorting before it is transferred onwards for further processing or disposal. Recovering materials optimizes waste handling and reduces waste volumes requiring transport. Collection can be carried out as a door-to-door service, kerb-side or from communal collection points. Waste containers need to be placed within reasonable proximity to avoid waste dumping, with collection points recommended to be no further than 200 m from any household *(37, 38)*.

Collection and transfer to the next steps of the chain can be performed by public, private or informal sectors or communities using various systems and operator models, using mechanized or non-mechanized vehicles. Although essential, waste collection and transfer can be costly relative to available budgets *(16)*. As a result, coverage may be limited, leaving many people, communities and organizations without regular or reliable waste collection. In such contexts, self-management becomes the default, frequently leading to open dumping and burning. Informal activities often emerge to fill these gaps, providing complementary collection and recycling services and generating income, but also introducing social and regulatory challenges.

3.1.3 Sorting and recycling

Waste sorting involves categorizing mixed or separated waste to extract valorizable materials and facilitate recycling. It may be carried out at the point of generation/collection, and at material recovery facilities. Material recovery facilities further separate waste into specific material fractions, which are then baled, compacted and sent for more processing. These facilities vary in size, scale and level of technological sophistication. Recycling is the process of converting sorted waste into new products or raw materials. It plays a key role in reducing the volumes of waste sent to disposal or incineration, and supports the principles of the waste hierarchy and the circular economy.

3.1.4 Organic waste recovery

Organic waste recovery methods such as composting, anaerobic digestion, community biogas and black solider fly are biological recovery methods for converting organic waste into valuable resources *(39, 40)*. Diverting organic waste from uncontrolled disposal avoids emissions of methane, which is a powerful GHG. Organic waste diversion and recovery therefore provide an opportunity to mitigate climate change and enhance circularity.

- **Composting** decomposes organic waste, turning it into a nutrient-rich compost for soil. It can be carried out at various scales, from household to city wide. In 2016, only 5.5% of the world's organic waste was recovered in this way *(16)*.

- **Anaerobic digestion and community biogas** methods utilize microorganisms to decompose organic waste in an anaerobic environment, producing digestate for agricultural applications and biogas for energy. Digestate must be carefully managed given the high nutrient loads if disposed of into the environment.

- **Black soldier fly** larvae consume organic waste and turn it into protein-rich feed for livestock and aquaculture.

In all these organic waste recovery methods, poor-quality feedstock or improper management can lead to contamination with pathogens such as *Escherichia coli* and *Salmonella*, or the accumulation of heavy metals, posing significant health risks to humans, animals and the environment *(41–43)*.

3.1.5 Incineration

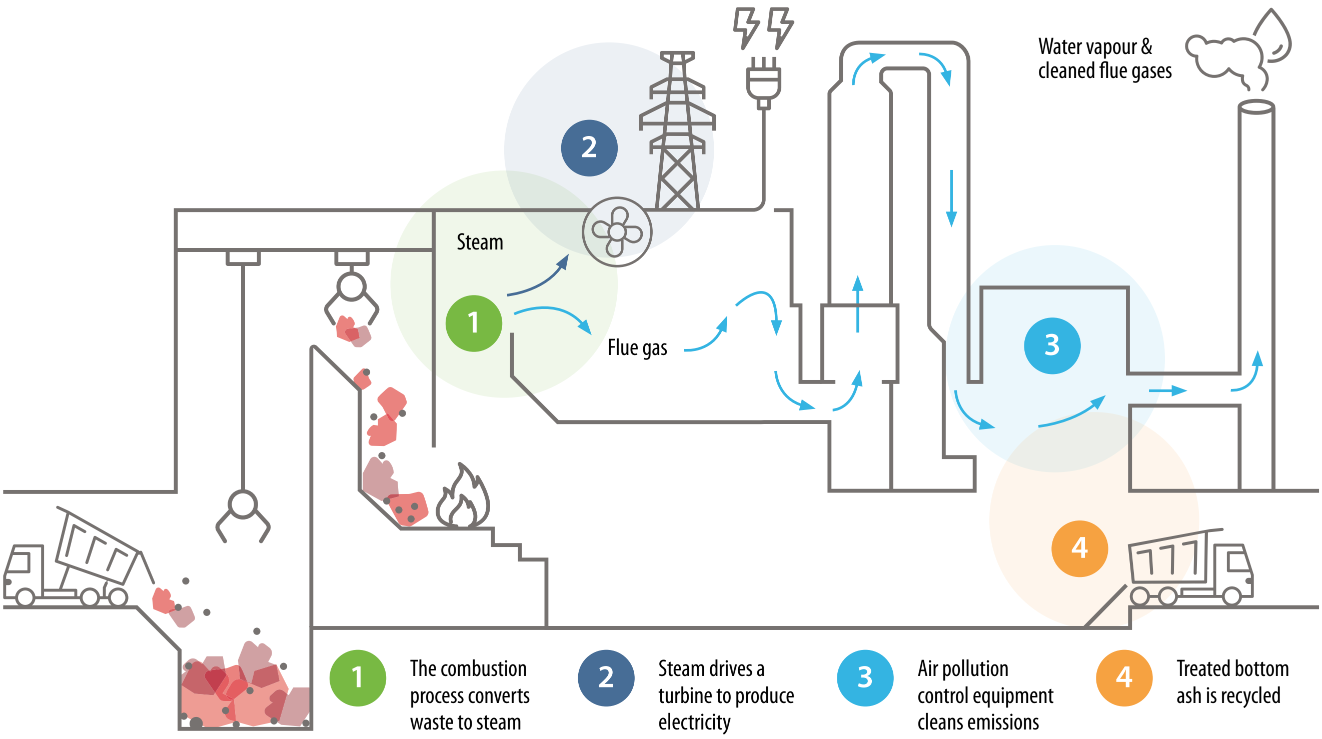
Waste incineration is the controlled burning of waste at high temperatures to reduce waste volume, and in some systems, to recover energy (waste-to-energy process) *(44)*. Modern incinerators utilize a series of combustion chambers, often supported by automated feed systems, to ensure complete oxidation of waste materials. The process results in three main products: bottom ash, flue gas and heat. Energy recovery can be achieved by capturing the thermal energy generated during combustion to produce steam, which can be used for heating or conversion into electricity. Advanced air pollution control devices are used to treat flue gases and remove particulate matter (PM), heavy metals, acidic gases and dioxins before release into the atmosphere *(45, 46)*. Bottom ash is usually disposed of in landfill as special waste. However, there have been reports of material recovery efforts, where it is processed and repurposed for use in construction materials, road base layers and aggregate substitutes *(47)* (Fig. 6).

The overall environmental and public health risks associated with incineration depend on the level of technical control (see Annex 2), regulatory compliance and maintenance of emission standards *(38)*. The Basel Convention established technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1 *(49)*. Poorly managed incineration facilities can emit a wide range of pollutants including carbon dioxide, PM, POPs such as dioxins and furans, and heavy metals *(50)*. Table 1 summarizes some key advantages and limitations of incineration *(44, 45)*.

3.1.6 Disposal or landfilling

Waste disposal sites are the final stage of waste management. They vary in control levels (see Annex 2): full, improved, basic, limited and uncontrolled *(38)*.

Fig. 6 **The waste-to-energy incineration process**



Source: adapted from ecomaine *(48)*.

Table 1. Key advantages and limitations of incineration

Advantages

- Reduces the volume of waste by 75–90%, thereby reducing the need for landfill space.
- Converts the heat generated during incineration into electricity or usable heat, providing a renewable source of energy.
- Can process various types of waste, including medical, industrial and some hazardous materials including infectious waste, which may not be suitable for recycling or landfilling.
- Metals can be extracted from bottom ash; residual can be reused as an alternative aggregate in concrete and in road construction.

Limitations

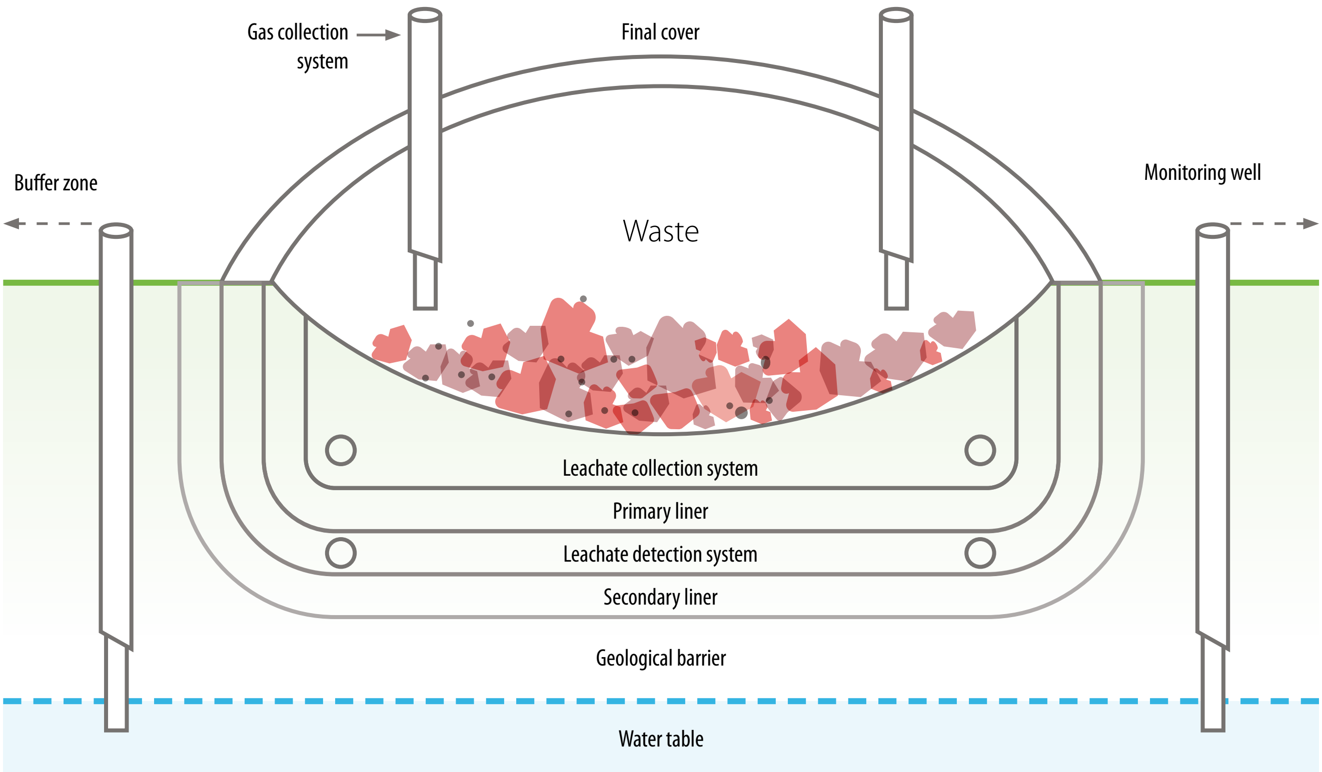
- If not adequately operated and maintained, can release pollutants, including dioxins and furans, which pollute the air and pose risks to human.
- The process generates ash, which may contain heavy metals and other toxins that require special disposal methods to avoid environmental contamination.
- There are high costs to build and operate incinerator facilities.
- While some energy is recovered, the process itself is energy intensive and may not always offset its own energy requirements.
- To remain economically viable, incineration facilities may require a steady waste stream, which can discourage waste reduction or recycling efforts.
- Not suitable for waste rich in organic content and/or high water content.

Engineered or sanitary landfills are specifically designed to minimize environmental and public health risks through a range of protective measures. These include a waterproof liner at the base to prevent contamination of soil and water, along with systems for regular monitoring of surface water and groundwater quality. Waste is compacted to reduce volume, and infrastructure is in place to collect and treat leachate, and to capture landfill gases such as methane, which can be used for energy production. Daily application of soil cover helps control odours and pests *(51, 52)*. Fig. 7 shows an example sanitary landfill structure.

In contrast, dumpsites lack these engineered safeguards. They are often uncontrolled, subject to open burning and scavenging activities by scrap collectors and animals, and may not have liners, leachate treatment systems, daily cover application and restrictions on the waste they receive. The Basel Convention has developed technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfills (D5) *(52)*.

Disposal is a common waste management method due to its relatively low cost compared with other methods *(3)*. However, depending on the scale, it requires extensive land and carries the potential for soil and water pollution. Additionally, it contributes to climate change through the release of methane from the organic waste fraction *(53–55)*. Even in sanitary landfills with biogas collection systems in place, it is difficult to capture all the biogas produced *(56)*. Table 2 summarizes some key advantages and limitations of disposal sites.

Fig. 7 **Example of a sanitary landfill structure**



Source: adapted from the Secretariat of the Basel convention *(52)*.

Table 2. Key advantages and limitations of disposal sites

Advantages	Limitations
• Less costly and less complex than other management methods. • Can accommodate different waste types including materials that cannot be easily recycled or incinerated, such as inert or bulky waste. • Modern landfills can capture landfill gas (primarily methane) produced during waste decomposition, which can be used to generate energy. • Engineered landfills incorporate techniques such as perimeter and surface drainage, impermeable liners and leachate collection systems to minimize leakage.	• GHGs (methane and carbon dioxide) are produced as organic waste decomposes, contributing to climate change. • Leachate, a liquid generated by waste decomposition, can contaminate groundwater and nearby ecosystems if not properly managed. • Birds, pests and rodents can proliferate if uncontrolled. • Require substantial land and have a finite lifespan. Once full, they must be expanded or replaced, limiting space for other urban developments and posing long-term planning challenges. • Require continued monitoring and maintenance after closure to prevent leakage and ensure long-term environmental safety. • May emit unpleasant odours and blight the landscape. • Dumping, compacting and bulldozing, especially under windy conditions, can facilitate the release of bioaerosols (e.g. dust, bacteria, viruses, fungi and spores) into the environment. • Noise from heavy machinery and trucks can disturb surrounding communities. • Low standard/cost disposal reduces incentives to recycle or compost waste, reducing circular economy potentials. • Poor management can lead to open burning, thus damaging facility assets and infrastructure, polluting the environment and endangering workers' safety.

3.2 Mismanagement

In many parts of the world, the absence of formal waste collection forces households to manage waste themselves, most often through wild dumping (the indiscriminate disposal of waste in open environments, near homes or in informal dumpsites, which is often accompanied by open burning). These practices pose serious local health risks, including blocked drains, groundwater contamination, stagnant water and increased exposure to disease vectors. They also present a risk to food supplies and domestic and wild animals. Uncollected waste accounts for 85% of microplastic pollution entering the environment and oceans *(57)*.

Open burning can occur at the household level, where it is used as a primary self-management method in the absence of formal waste collection. It can also occur at dumpsites, including large municipal and small communal sites. Both forms contribute significantly to air pollution and health hazards, but household-level burning is particularly concerning due to its proximity to living spaces and vulnerable populations.

Dumpsites are uncontrolled waste disposal areas, ranging from centralized dumping sites to scattered or wild dumping near homes. These sites contribute to soil and groundwater contamination and increased risks of infectious diseases transmission.

Globally, nearly 40% of MSW is either not collected or disposed of through open dumping, affecting millions of people, particularly in Africa, Asia and Latin America *(3)*. Open burning is a common practice at dumpsites, further exacerbating risks by releasing toxic chemicals and fine particles

Table 3. Major hazards associated with uncontrolled disposal

Uncontrolled disposal	Hazards
Open dumping	• Leachate can pollute groundwater, surface water and soil. Some pollutants can travel long distances and accumulate in the soil and other environmental media for decades. • Decomposing waste releases gases such as methane, carbon dioxide, volatile organic compounds (VOCs), hydrogen sulfide and ammonia; if unmanaged, these can accumulate and cause fires, explosions and foul odours. • PM and bioaerosols can be released into the air, especially during waste handling or under windy conditions, posing respiratory and infectious disease risks. • Scattered waste such as broken glass, sharp metal and used needles increases the risk of physical injuries. • Organic waste attracts vectors such as flies, rodents and mosquitoes, which can spread diseases like dengue, leptospirosis and cholera. • Plastic and non-biodegradable waste can block drainage systems, leading to urban flooding and stagnant water, which further promotes vector breeding.
Open burning	• Unlike controlled incineration, open burning occurs at low and variable temperatures with poor oxygen supply, resulting in incomplete combustion and the release of large amounts of pollutants (e.g. fine PM, soot, carbon monoxide and VOCs). • Acid gases (e.g. hydrogen chloride, sulfur dioxide and nitrogen oxides) are released, contributing to smog and acid rain. • Dioxins and furans can be formed, especially from plastics/chlorinated waste. • Heavy metals such as lead, mercury, cadmium and arsenic are released directly into the air and ash. The resulting ash and toxic residues are dispersed into the environment rather than contained. • Emissions are highly variable and diffuse, making them harder to monitor and control.

Sources: adapted from Ziraba, Haregu & Mberu *(50)*; Ferronato & Torretta *(60)*; Vinti et al. *(65)*; Cointreau *(66)*.

into the air *(58–64)*. This practice also significantly contributes to climate change through GHG emissions and can increase $PM_{2.5}$ concentrations by up to 30% *(61)*. Tyre fires are particularly harmful, producing dense smoke plumes and emitting a range of hazardous pollutants. Discarded tyres can also become breeding grounds for mosquitoes, thus increasing the risk of vector-borne diseases *(60)*. Table 3 shows the major hazards associated with uncontrolled disposal.

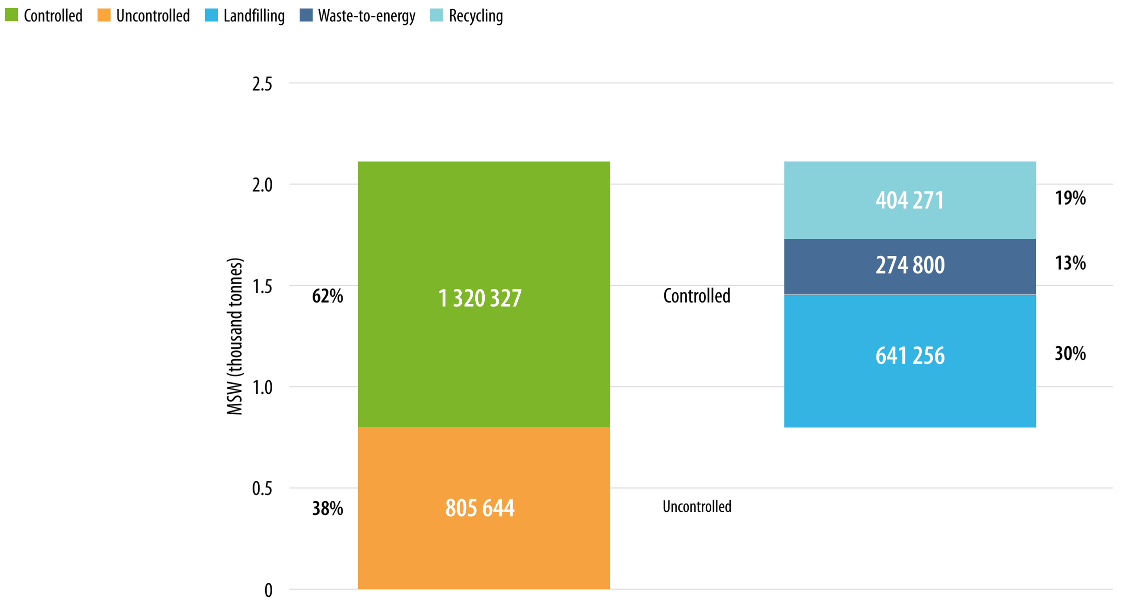
3.3 Status and trends

This section summarizes key statistics on MSWM, from the *Global waste management outlook 2024* report *(3)* and the *What a waste 2.0* report *(16)*.

Globally, 38% of MSW is either unmanaged or managed in an uncontrolled way. Of the 62% of waste collected and managed in controlled facilities in 2020, 19% was recycled, 13% was turned into energy (incineration with energy recovery) and 30% was landfilled (Fig. 8).

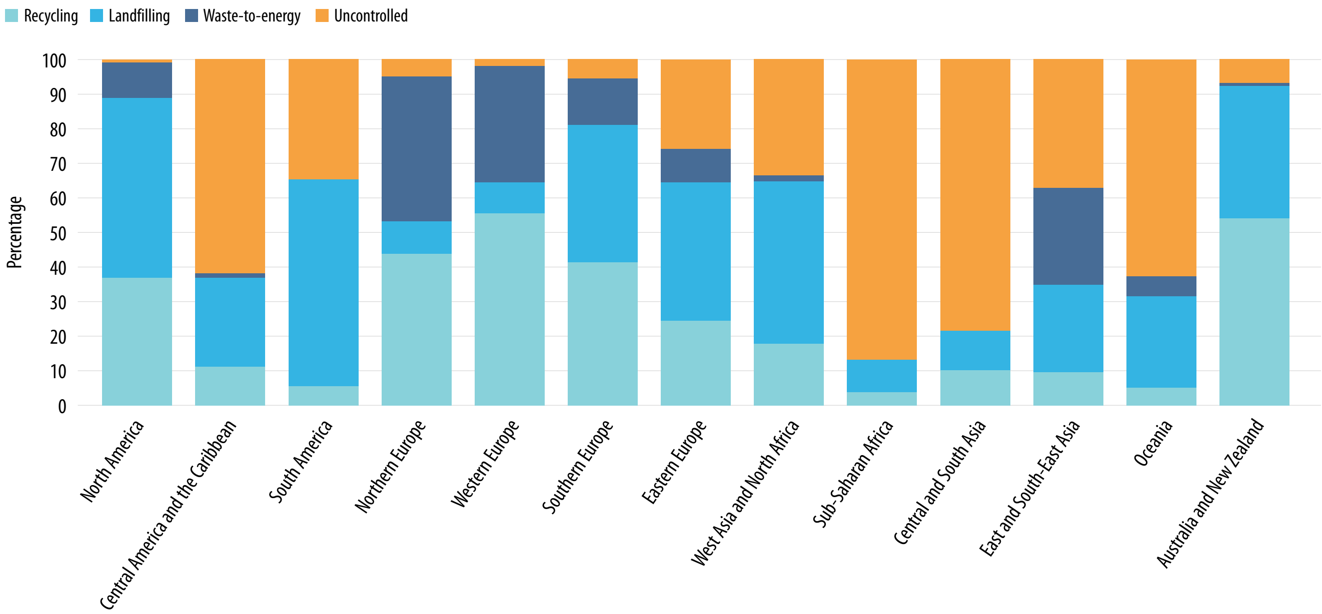
MSWM methods differ by region (Fig. 9) and income level *(16)*. In high-income countries, generally, collection services are universal, recovery facilities use high environmental controls and engineered sanitary landfills are in place. Regulatory frameworks and management systems have developed over the last 50 years. Some are even starting to experience decreasing waste generation, albeit from a high starting point, highlighting the beginning of a transition in decoupling waste generation from economic growth *(67)*. Nonetheless, achieving high levels of recycling and circularity remains a challenge. In some countries, waste generation continues to rise – driven in part by the growing use of single-use items. This includes plastics and alternative materials that often replicate the

Fig. 8 **Global MSW destinations in 2020: controlled (landfilling, waste-to-energy and recycling) and uncontrolled**



Source: adapted from UNEP *(3)*.

Fig. 9 **Regional distribution of MSW destinations, 2020**



Source: adapted from UNEP *(3)*.

same disposable model without addressing the underlying issue of overconsumption *(3)*.

In contrast, in many low-income countries, less than 40% of waste is collected, and an even smaller portion is managed in controlled facilities. Waste collection services in periurban and rural areas are often lacking. Financial constraints make these challenges even worse, with waste management consuming up to 20–50% of the public budget in low-income cities, compared with 10% in middle-income cities and just 4% in high-income cities, in 2016 *(16)*.

Several Sustainable Development Goal (SDG) targets and indicators are relevant for solid waste. MSMW is most directly linked to SDG 11 (sustainable cities) through Indicator 11.6.1: *"Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal solid waste generated, by cities"*. It also supports or has strong connections with many other goals, including SDGs 1, 3, 6, 12, 13, 14, and 15 (Fig. 10) *(68)*. Global reports have highlighted the challenges of compiling accurate data on MSWM practices *(3, 16, 69)*. Data gaps are linked to inconsistent measurement and reporting standards, including various definitions and methodologies, and lack of robust monitoring systems. Communities lacking collection services and informal waste management and recovery activities are frequently excluded from official records, and data on specific waste streams are often scarce. Furthermore, unregulated waste flows (e.g. illegal dumping and cross-border trade) complicate efforts to monitor and manage waste effectively *(70, 71)*. However, several tools have been developed to support data collection efforts in countries. For example, the United Nations Human Settlements Programme (UN-Habitat) developed the Waste Wise Cities Tool (WaCT) to help cities collect data on SWM and report on SDG Indicator 11.6.1 *(38)*.

Fig. 10 **Key SDG targets and indicators related to MSW**

SDG 15. **Life on land**

Conserve terrestrial ecosystems and reduce land degradation (Targets 15.1 & 15.3).

SDG 14. **Life below water**

Prevent and reduce marine pollution, especially plastic debris (Target 14.1, Indicator 14.1.1b).

SDG 13. **Climate action**

Build resilience to climate-related hazards (Target 13.1).

SDG 12. **Responsible consumption and production**

Halve global food waste and reduce food losses along production and supply chains (Target 12.3).

Environmentally sound management of chemicals and waste (Target 12.4) (Indicator 12.4.2: Hazardous waste generated per capita and proportion treatment by type).

Substantially reduce waste generation through prevention, recycling and reuse (Target 12.5, Indicator 12.5.1: National recycling rate, tons of material recycled), Target 12.b. removing market distortions that encourage wasteful consumption.

SDG 1. **No poverty**

Equal access to economic resources and basic services, especially for vulnerable groups (Target 1.4).

SDG 3. **Good health and well-being**

Reduce deaths and illnesses from hazardous chemicals and pollution (air, water, soil) (Target 3.9).

SDG 6. **Clean water and sanitation**

Reduce water pollution and hazardous discharges (Target 6.3).

SDG 11. **Sustainable cities and communities**

MSW collected and managed in controlled facilities (Indicator 11.6.1).

4 Hazards, exposure pathways and exposed populations

This chapter provides an overview of MSW key hazards, exposure pathways and populations at risk due to mismanagement.

4.1 Hazards

MSW can expose workers and communities to a wide range of biological, chemical, physical and psychological hazards, at various steps of the SWM value chain (Fig. 5), as summarized in Fig. 11.

4.1.1 Biological hazards

Solid waste can harbour a wide range of disease-causing pathogens, including bacteria, viruses and parasites. These pathogens can originate from decomposing organic matter and infectious medical waste. They can spread through direct contact, contaminated water or soil, and air. Some pathogens may spread via disease vectors such as flies, mosquitoes and rodents.

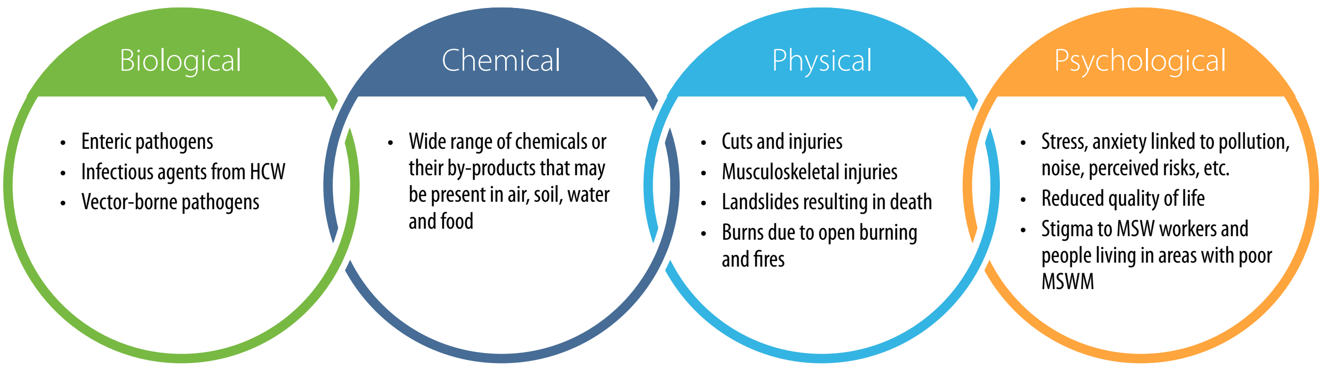
MSW landfills and dumpsites, and scattered uncollected waste, serve as reservoirs for many pathogens *(72)*. Enteric pathogens may originate from food waste, animal and human faecal sludge, and disposable products such as nappies *(73, 74)*. In addition, faecal sludge from septic tanks, pit latrines and wastewater treatment plants may sometimes also be disposed of in dumpsites and landfills. Large items such as plastics, textiles and organic debris can also block sewage pipes and drainage systems, leading to overflowing and faecal contamination of the environment. Enteric pathogens are responsible for many diseases including diarrhoeal diseases, which caused an estimated 1.2 million deaths in 2021 *(75)*.

Leachate from disposal sites and uncollected scattered waste can contaminate groundwater and surface waters, including those that may be used for recreational purposes. Agricultural crops irrigated with contaminated water or cultivated in contaminated soils can further transmit pathogens.

Some pathogens may be spread through bioaerosols *(76)*. For example, airborne bacteria (*Staphylococcus* and *Bacillus*) and fungi (*Penicillium* and *Aspergillus*) have been found in waste sorting plants, which may contribute to respiratory symptoms such as asthma and wheezing *(77)*.

Inadequate disposal of infectious medical waste can expose health care workers and waste

Fig. 11 **Biological, chemical, physical and psychological hazards of MSW**



handlers to bloodborne pathogens like human immunodeficiency virus (HIV) and hepatitis B through needle-stick injuries, or contact with contaminated dressings, gloves and surgical instruments. In 2010, unsafe injections were estimated to cause up to 33 800 new HIV infections, 1.7 million hepatitis B infections and 315 000 hepatitis C infections annually *(78)*.

Uncontrolled waste management creates favourable conditions for the spread of vector-borne and zoonotic diseases. Stagnant water from drains blocked by uncollected waste, and in discarded containers and tyres at dumpsites, provides breeding grounds for mosquitoes such as *Aedes aegypti* and *Anopheles* species, which transmit dengue and malaria, respectively, and which affect hundreds of millions of people annually *(79, 80)*. These risks are further intensified by climate change, population displacement and humanitarian health emergencies, underscoring the urgent need for effective and inclusive SWM strategies *(81)*.

Decomposing organic waste also attracts houseflies, a highly efficient vector that can spread pathogens to nearby households *(50)*. Rodents like rats and mice, which thrive in these environments, can act as reservoirs for diseases such as leptospirosis and hantavirus *(82)*. The presence of domestic animals such as cows, sheep, goats, pigs, chickens, dogs and cats is also frequently observed at dumpsites and locations of uncollected scattered waste, which may increase the risk of zoonotic diseases being spread to nearby human populations.

4.1.2 Chemical hazards

MSW can release thousands of different chemicals into the environment. During decomposition, through burning or leaking, these substances can transform into new chemical compounds, some of which are hazardous. Such emissions often occur through open burning, spontaneous fires at dumpsites or unsafe recycling practices (e.g. cable burning to recover copper). Highly toxic pollutants like dioxins are commonly produced during the incomplete combustion of plastic waste *(64)*. The number of chemicals in waste is extensive, continually growing and includes many with known or suspected harmful effects on human health *(22, 83–85)*.

Exposure to chemicals can cause acute and chronic effects, affecting various systems in the body, including the respiratory, reproductive, cardiovascular, urinary, nervous, immune and metabolic systems. It may also trigger allergies and cancers. Health impacts can emerge long after exposure, particularly when it occurs during vulnerable stages of life such as in utero, infancy or adolescence, with potential effects spanning generations. In 2019, WHO estimated that exposure to a limited subset of chemicals for which data were available could be linked to 2 million deaths globally *(14)*.

Certain hazardous chemicals are a major concern for public health because of their widespread presence in the environment, their toxicity, their ability to accumulate and intensify in natural and human systems, and the ease with which people are exposed to them, thus affecting populations. Chemicals or groups of chemicals of major public health concern include air pollutants such as PM (e.g. $PM_{2.5}$ and PM_{10}), arsenic, asbestos, benzene, cadmium, dioxin and dioxin-like substances, lead and mercury *(86)*. In addition, a wide range of contaminants are emerging as significant health concerns. This includes plastic particles (Box 1), per- and polyfluoroalkyl substances, bisphenol A and endocrine-disrupting chemicals *(22, 87–89)*.

4.1.3 Physical hazards

Injuries related to waste management can occur at various stages, including when generating, handling, processing and disposing of waste, particularly from dumpsites and uncollected waste with little or no controls on human access and use. Common injuries include cuts, abrasions, burns, puncture wounds, sprains and fractures. Waste workers are at high risk of musculoskeletal disorders due to repetitive, physically demanding tasks such as heavy lifting, pulling, dragging and bending. These can lead to injuries ranging from muscle strains to chronic back and joint pain *(66, 90)*. Women and children, who comprise a large share of the informal waste worker sector, are particularly vulnerable to such occupational injuries *(90–92)*. Furthermore, although infrequent, dump landslides have killed dozens and sometimes over a hundred people in one incident *(93, 94)*.

4.1.4 Psychological hazards

Workers and people living near waste management sites may experience anxiety, stress and depression. Fear of health risks and exposure to noise, odour and unsanitary conditions contribute to emotional fatigue and can have negative impacts on well-being *(95)*. Bad odours, even when non-toxic, can trigger symptoms such as headaches, nausea and dizziness, with individual sensitivity influenced by physiology, exposure history and perception. Prolonged exposure to odour-related annoyance can activate stress responses, potentially leading to mental health issues, sleep disturbances and secondary physical diseases like cardiovascular and respiratory conditions *(96, 97)*.

Waste workers – especially informal waste pickers – are particularly affected due to their marginalized social status, difficult working conditions and constant exposure to physical and environmental hazards. Social stigma and discrimination often lead to feelings of shame, isolation and diminished self-worth *(98, 99)*.

These challenges are compounded by job insecurity, financial instability and frequent exposure to violence or harassment, all of which contribute to chronic stress and anxiety. Over time, these conditions can lead to serious mental health issues, including depression, substance abuse and emotional exhaustion. Despite these risks, waste pickers typically lack access to mental health support and essential health care services, leaving them without the resources needed to cope or recover *(98)*.

4.2 Exposure pathways

People may be exposed to hazards through inhalation, ingestion, dermal contact or transplacental transfer.

4.2.1 Inhalation

Inhalation is a major route of exposure, especially where scattered uncollected waste is being burnt, as well as in and around uncontrolled or poorly controlled waste management sites. Open burning of waste releases harmful pollutants (e.g. fine PM, carbon monoxide and VOCs) that can damage the respiratory system and contribute to chronic conditions such as asthma, bronchitis and other respiratory infections. Additionally, dust contaminated with hazardous substances poses further inhalation risks to workers and nearby residents.

4.2.2 Ingestion

Ingestion of contaminants can occur directly through children playing among piles of uncollected waste, or indirectly through polluted water, soil or food. Leachate from uncollected waste or poorly managed disposal sites can infiltrate groundwater and surface water, contaminating agricultural and aquatic environments. Even engineered landfills with protective geomembranes may fail due to poor design or installation, allowing leachate to escape *(84, 100)*.

Contaminated soil can affect crop safety and quality, while improperly sorted waste and contaminated compost may introduce pathogens and toxic chemicals into the food chain. Burnt organic waste used in compost can lead to dioxin accumulation in plants *(41)*.

Pollutants such as heavy metals and POPs (including PCBs, polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans

(PCDFs)) can bioaccumulate in soil and aquatic sediments near dumpsites *(60)*. These substances can enter the food chain via plants and aquatic life, ultimately being ingested by humans. Vulnerable populations, such as fetuses and infants, may be exposed through transplacental transfer and breast milk *(8)*. However, measuring long-term, low-dose exposure through soil and food is a challenge *(101)*.

4.2.3 Dermal contact

Dermal contact occurs when the skin comes into contact with liquids, solids or gases during waste generation, handling, processing, transport or disposal. Hazardous chemicals can penetrate the skin and enter the bloodstream, potentially causing systemic health effects. Injuries such as cuts or needle-stick incidents further increase the risk of infection, particularly from bloodborne pathogens.

4.2.4 Transplacental transfer

Exposure to hazardous chemicals that may be present in MSW or released during its treatment can pose health risks to pregnant women and their developing fetuses. Many of these substances (including heavy metals and dioxins) can cross the placenta and accumulate in fetal tissues. Even low-level exposure during pregnancy can interfere with critical stages of fetal development, particularly during periods of rapid organ formation *(8)*. These concerns are especially acute for uncontrolled management sites, where environmental contamination increases the likelihood of exposure through air, water, soil and food.

4.3 Exposed populations

4.3.1 Waste workers

Formal and informal waste workers play essential roles across all stages of the MSWM value chain, including collection, sorting, recycling, recovery and disposal. In the formal sector, roles include collectors, facility operators, supervisors and administrators. In contrast, informal workers, such as waste pickers and recycling traders, recover valuable materials like plastics, metals and textiles, often without contracts, legal protection or social benefits *(90, 102)*.

Occupational exposure varies depending on the type of waste, facility type and equipment used, access to personal protective equipment (PPE) and awareness of health risks. Informal waste pickers are among the most vulnerable, frequently engaging in hazardous tasks with limited PPE and high exposure to contaminants *(98, 103–105)*. Those handling e-waste may be exposed to toxic substances like lead, cadmium and mercury, especially when burning cables or using chemical baths to extract metals *(8, 106–108)*.

There is also evidence that waste pickers face risks of vector-borne diseases (e.g. dengue or Zika), landslides at disposal sites, and chronic stress due to income instability, social stigma and lack of health care access *(9, 90, 109–112)*. Women and children are particularly vulnerable to injury and exploitation because they comprise a large share of the informal sector *(8, 113, 114)*.

4.3.2 Communities

Unserved or underserved communities

In communities lacking adequate MSWM services, residents are often forced to manage their own waste, generally through open burning or wild dumping *(50)*. This issue is especially prevalent in countries and communities where waste collection service coverage is low. Rural areas are even less served compared with their urban counterparts *(16)*.

Communities living near MSWM sites

Residents living near MSWM sites face varying levels of environmental exposure depending on the composition of the MSW being managed, the design and operation of the facility, and compliance with regulations and standards. The level of risk associated with MSWM is likely to decrease as systems move from uncontrolled to fully controlled approaches *(38)*. In low- and middle-income countries, where SWM is often inadequate, these risks are most severe.

However, even in high-income countries, poorer and marginalized communities are more likely to live near waste recovery or disposal sites. The siting of incinerators and landfills often faces strong opposition, triggering "not in my backyard" responses, which may lead to social tensions, protests and legal disputes *(115)*.

Communities along waste transport routes or near MSWM sites may experience chronic exposure to odour, noise and vermin. The sight of waste can lead to feelings of discomfort, helplessness and fear about potential long-term health effects *(15, 60)*. The constant movement of waste trucks (sometimes hundreds per day) can cause air and noise pollution, disrupt sleep and increase anxiety *(116)*. These environmental stressors have been linked to deteriorating mental health, including depression and reduced well-being *(96)*.

Over time, dumpsites may encroach on residential areas (and vice versa), exposing communities to serious hazards such as landfill slides. Such events have caused numerous fatalities *(117, 118)*. For example, the Payatas landfill slide in the Philippines in 2000 resulted in over 300 fatalities *(119)*, the landslide at the Koshe disposal site in Ethiopia in 2017 claimed 116 lives *(120)* and the landslide at Kiteezi disposal site in Uganda in 2024 claimed over 18 lives *(121)*.

4.3.3 Wider population

The health risks posed by inadequate MSWM on wider society may not be as immediately apparent as those experienced by waste workers, unserved or underserved communities and those living near MSWM sites. However, these effects manifest indirectly through contaminants entering the environment through air, water, soil and the food chain, affecting public health and ecosystems over time.

Inadequate waste collection leads to widespread littering, open burning, and accumulation in streets, drains, waterways and coastal areas. These conditions degrade community cleanliness, reduce property values, deter tourism and contribute to local air and water pollution. Blocked drainage systems can also increase the risk of urban flooding and disease transmission via vermin and insects.

Better management of solid waste can make a substantial contribution to climate change mitigation. Methane – primarily from organic waste decomposition in landfills and dumpsites – is the dominant GHG directly emitted *(122, 123)*. Additionally, black carbon from open burning is a concern due to its high global warming potential *(59, 124, 125)*. Indirect savings from waste reduction, reuse, recycling and energy recovery are also significant *(125, 126)*.

In 2010, the Intergovernmental Panel on Climate Change estimated that the waste sector accounted for about 3% of global GHG emissions. However, later analyses suggest this figure is a significant underestimate *(125)*. This is largely due to the Intergovernmental Panel on Climate Change's narrow, linear definition of the waste sector, which focuses mainly on methane from landfills and excludes emissions and savings from recycling, composting and energy recovery. It has been estimated that by adopting circular approaches to waste and resources management, global GHG emissions may potentially be reduced by 15–25% *(3, 125)*.

Public behaviour (e.g. consumption patterns, waste separation and recycling practices) plays a critical role in shaping MSWM outcomes. Growing awareness of environmental degradation can generate eco-anxiety, especially among younger populations and communities directly dependent on natural resources *(5)*. Ocean pollution from plastics and other contaminants can affect aquatic life, and threatens the livelihoods of communities reliant on fishing and tourism *(6)*. These psychological and social burdens are often overlooked, but are essential considerations in designing inclusive and sustainable waste management systems.

5 Health risks and impacts

This chapter summarizes the evidence on key health risks and impacts linked to MSW and its management. It draws primarily on systematic reviews of epidemiological evidence, including a WHO-commissioned review on the health effects of living near incinerators, landfills and uncontrolled disposal sites *(65)*. To complement this, a rapid literature review was conducted to capture recent systematic reviews on the topic. Annex 4 provides further information on the methods, along with summary tables of studies included in Vinti et al. *(65)*.

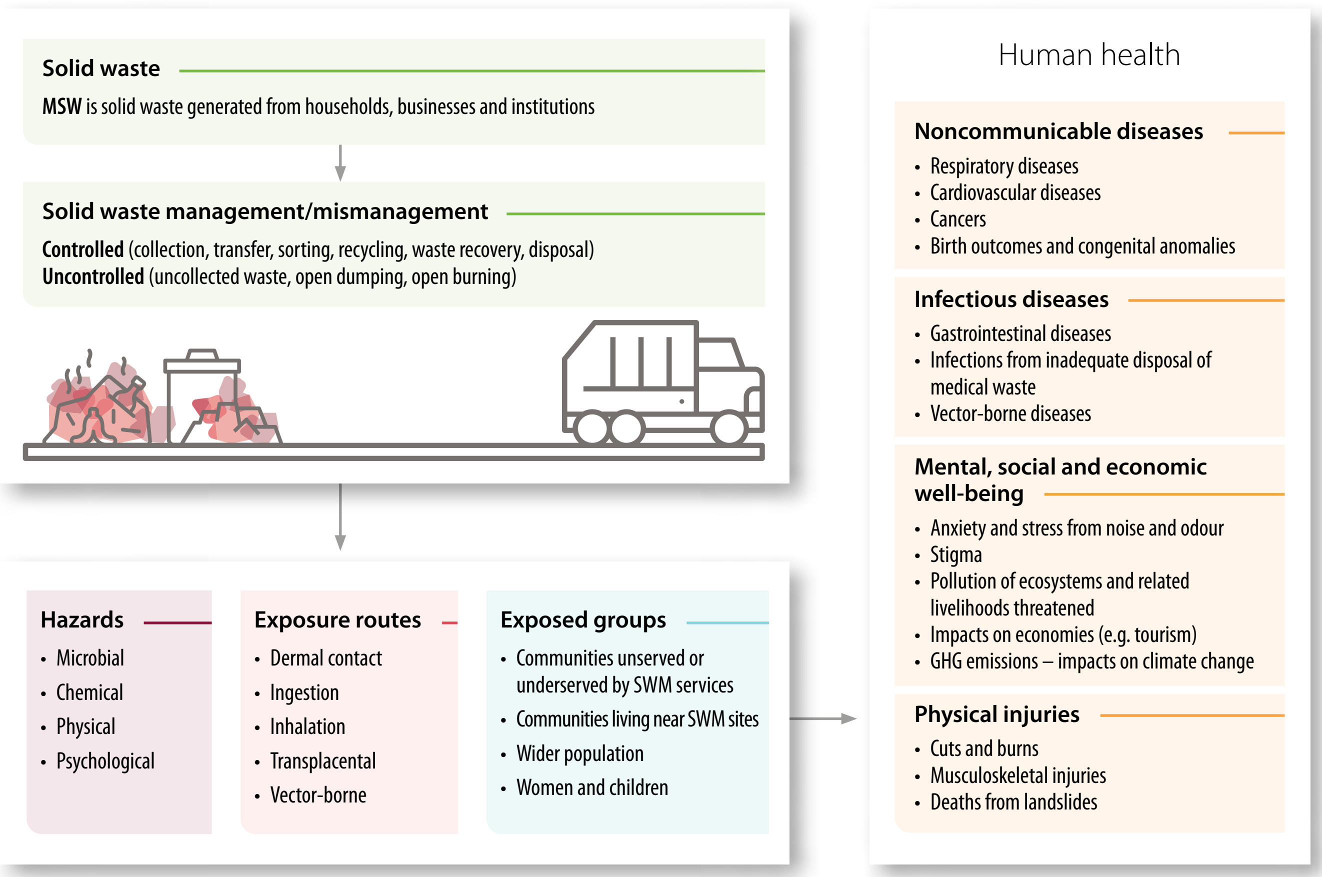
Fig. 12 summarizes the potential health impacts from solid waste.

5.1 Assessing health risks and impacts from MSW

5.1.1 Epidemiological studies

Numerous epidemiological studies have investigated the health impacts of MSW facilities, particularly among populations residing near incinerators and landfills. These studies have been conducted predominantly in high-income countries, often in response to public concerns over proposed or existing waste management infrastructure. However, evidence from countries where waste management is largely uncontrolled and where risks are likely the greatest is largely underrepresented in the literature.

Fig. 12 Summary pathways and health risks of poor SWM practices



Several systematic reviews have been published over the years, differing widely in scope, methodology and focus. Some reviews have concentrated on exposure from waste incinerators *(65, 127–134)*, while others have focused on landfills, dumpsites, open burning or a combination of these *(65, 66, 97, 135–137)*. Fewer reviews have assessed health effects of bioaerosol exposures within and near compositing facilities *(138, 139)*.

The reviews differ in the types of studies included and the time frame covered by the search. Some have incorporated a broad range of study designs, including ecological studies (or geographical studies), while others have focused on more robust observational designs such as cohort and case–control studies. Ecological studies assess exposures, outcomes and confounders at the population level, typically using proximity to SWM sites as a proxy for exposure and aggregating health outcomes from administrative data sources. While these studies are useful for large-scale assessments, they are limited by the ecological fallacy and often lack detailed exposure assessment and control for individual-level confounders *(140–142)*. More rigorous observational designs (e.g. cohort and case–control studies) allow for individual-level exposure and outcome assessment and better control of confounding.

Health outcomes examined include cancer, cardiovascular and respiratory diseases, adverse birth outcomes (e.g. low birth weight, preterm birth or congenital anomalies) and, to a lesser extent, mental health, infectious diseases and biomarkers of exposure or effect. Some reviews have focused on residents near SWM sites, while others also assessed health risks among workers, including among informal waste pickers *(64, 98)*.

5.1.2 Exposure assessments in epidemiological studies

In studies examining the health impacts of municipal solid waste incinerators (MSWIs) and landfills, exposure assessment methods vary considerably, influencing study outcomes and comparability.

Cordioli et al. *(143)* reviewed 41 MSWI studies published between 1984 and 2013. Most studies used proximity-based indicators, either qualitative (e.g. the presence or absence of a facility within administrative boundaries) or quantitative (by measuring the distance between a residence and the site). While distance-based measures offer greater precision than simple qualitative indicators, they do not account for environmental factors such as wind patterns, topography or pollution control technologies *(15, 143)*. Methods such as atmospheric dispersion modelling have been commonly applied to MSWI studies. These approaches simulate the spread of pollutants using meteorological and emission data, which provide more accurate estimates of spatial and temporal variations in exposure than those derived from distance-based metrics. However, they can be complex and depend on the quality and availability of input data. Most studies focus on stack gas emissions, while other sources – like water discharge, ash residue, odour and traffic – are rarely considered. Exposure assessments usually emphasize inhalation and often ignore other routes such as ingestion and skin contact. Many studies also do not fully account for other pollution sources and socioeconomic differences *(143)*.

In landfill studies, proximity-based indicators are also the most commonly applied. Environmental monitoring involves measuring landfill gas, PM, leachate contaminants or surface water pollutants. Atmospheric dispersion models may be used to assess landfill gas, dust and odour, while groundwater contamination modelling may be used to simulate the spread of pollutants via leachate. Most studies focus on inhalation, but ingestion of contaminated water or food and dermal contact with soil or leachate are also recognized as relevant exposure pathways, although less frequently assessed due to logistic and methodological constraints *(144)*.

Biomonitoring and environmental sampling provide direct measures of exposure, and have been increasingly applied over the past decade. However, challenges remain, including high costs, logistic constraints, small sample sizes, limited standardized methods and difficulties in capturing complex, multi-pathway exposures *(145)*.

5.1.3 Human health risk assessments

Several studies have applied human health risk assessment (HHRA) methods to predict potential health risks associated with SWM sites. HHRA is a systematic approach used to evaluate the likelihood of adverse health effects resulting from exposure to chemical, biological or physical hazards. While it can be applied to various pollutants, HHRA is most commonly used to assess risks from chemical exposure. Several guidance documents and tools are available to support the HHRA process, as summarized by Zhang et al. *(146)*. Despite differences in application, HHRA involves four key steps: (a) hazard identification, which involves determining hazards that may pose health risks; (b) dose–response assessment, which evaluates the relationship between the level of exposure and the likelihood of adverse effects; (c) exposure assessment, which estimates the extent of human contact with the hazard; and (d) risk characterization, which integrates the previous steps to describe the nature and magnitude of the health risks *(101, 147)*.

5.2 Evidence on exposure to MSWIs

Many of the epidemiological studies on MSW sites have investigated associations between exposure to solid waste incinerators and a range of health outcomes among populations residing nearby. These have often been linked to concerns associated with long-term exposure to pollutants emitted by incinerators, such as dioxins, heavy metals and PM. Health risks vary depending on the type of incinerator and its emission controls. Older facilities typically lack adequate safeguards, while newer plants are designed and operated to meet modern standards and incorporate advanced technologies to minimize emissions. This section summarizes key findings from recent systematic reviews *(65, 128–132)*.

5.2.1 Overview

The systematic review by Vinti et al. *(65)* updated earlier syntheses *(127, 135–137)* and included 13 studies on MSWIs published between 2000 and 2021 *(148–160)*. Most of these studies were conducted in Europe (10 studies), mainly from France, Italy, Spain and the United Kingdom, with the remaining studies based in Asia. Most used cohort designs (eight studies), followed by case–control (three) and cross-sectional (two) designs. The studies examined a range of health outcomes, including mortality, cancer, adverse birth and neonatal outcomes, and human biomonitoring.

The systematic review by Bottini et al. *(132)* on MSW incineration synthesized findings from 51 studies published up to April 2025. While the review included many of the studies previously analysed by Vinti et al. *(65)*, it also incorporated recent research and covered a broader range of study designs: 21 cohort studies, 15 ecological studies, 10 case–control studies and five cross-sectional studies. Most studies (n = 33) focused on adult populations, while 18 specifically examined pregnant women and newborns in relation to neonatal health outcomes. Most studies were conducted in Europe, including 19 from Italy, 11 from France and six from the United Kingdom. Additional studies were carried out in Asia (n = 10) and the Americas (n = 5; four from the United States and one from Brazil).

Other reviews have focused on specific health end-points. Baek, Park & Kwak *(131)* examined cancer risks, Campo et al. *(128)* synthesized findings from biomonitoring studies and Tait et al. *(130)* included results on health risks and health outcomes. Negri et al. *(129)* assessed health impacts by type of incinerators, categorizing them by generation, based on technological and regulatory developments. While some reviews focused on MSWIs *(65, 132)*, others included other types of waste incinerators (e.g. hazardous, industrial or medical waste) *(128, 130, 131)*. This can introduce some variability in emissions, and hence affect interpretation of results.

5.2.2 Summary by health outcome

Birth outcomes and congenital anomalies

Some pollutants emitted by waste incinerators such as dioxins and heavy metals are known to interfere with fetal development and may contribute to adverse birth outcomes. As noted in early reviews, reproductive outcomes offer a relatively short and well-defined exposure window, primarily during pregnancy, which makes them suitable for studying potential cause–effect relationships *(127)*. Health outcomes commonly investigated include congenital anomalies (also referred to as birth defects, congenital disorders or malformations), low birth weight, preterm birth, stillbirth, fetal death, neonatal and infant mortality, twinning and changes in sex ratio *(127)*.

Vinti et al. *(65)* identified eight studies reporting on the links between residential exposure to incinerators and their possible effects on birth outcomes and congenital anomalies *(148, 150–152, 154, 155, 157, 160)*. They found weak evidence of an association.

Bottini et al. *(132)* conducted a narrative synthesis of 18 studies and came to similar conclusions. Most studies were conducted in high-income countries, and most assessed exposures using proximity to incinerators or exposure to pollutants such as dioxins and PM_{10}. Studies often reported on multiple birth outcomes with mixed findings: some identified associations for specific indicators while finding no significant effects for others *(154, 155, 157, 161–170)*. Overall, most studies did not identify statistically significant associations, although a few reported notable links for certain outcomes. Hao et al. *(161)* found an increased risk of small-for-gestational-age infants among mothers living within 10 km of MSWIs, particularly when combined with low maternal body mass index. Candela et al. *(155)* reported a statistically significant association between exposure to PM_{10} and spontaneous abortion, while Candela et al. *(154)* found a significant association with preterm birth. Tango et al. *(165)* observed increased infant mortality near incinerators in Japan, and Williams, Lawson & Lloyd *(167)* reported a skewed sex ratio (higher proportion of female births) in areas near MSWIs in Scotland.

Among the studies that examined congenital anomalies *(150–152, 160, 163, 166, 168, 171)*, a few reported statistically significant associations with certain malformations. Dummer, Dickinson & Parker *(166)* found increased risks of neural tube defects, spina bifida and heart defects in relation to proximity to MSWIs in the United Kingdom. Cordier et al. *(152)* identified a significant association between early-pregnancy exposure to dioxins and urinary tract birth defects in a French case–control study. An ecological study in the same region *(171)* reported associations with facial clefts, renal dysplasia and a dose–response relationship for obstructive uropathies. Parkes et al. *(160)* observed increased risks for genital defects, hypospadias and heart defects when using proximity as the exposure metric, although these associations were not replicated when PM_{10} levels were used. Overall, while some studies have suggested potential links between MSWI exposure and specific congenital anomalies, the body of evidence remains inconsistent.

Cancer

Vinti et al. *(65)* reported inconsistent associations between incinerator exposure and cancer risk. Baek, Park & Kwak *(131)* echoed this finding in their systematic review and meta-analysis. Baek and colleagues reviewed 11 eligible studies (seven case–control and four cohort) conducted between 1979 and 2015 *(149, 153, 172–180)*. The studies examined a range of cancers including breast, lung, liver, stomach, colorectal, laryngeal, bladder, leukaemia, non-Hodgkin lymphoma (NHL), sarcoma and all cancers combined. While some individual studies reported increased risks for sarcoma, NHL, lung, laryngeal and pancreatic cancers, the meta-analysis found no significant association for most cancer types, except for laryngeal cancer in females, based on only two studies. The studies included in the review by Baek, Park & Kwak *(131)* assessed exposure from a variety of incinerator types – not only municipal waste, but also industrial, medical, sewage and hazardous waste facilities. Six of the 11 studies focused exclusively on municipal waste incinerators: two from France *(149, 172)*, three from Italy *(153, 179, 180)* and one from the United States *(178)*.

Bottini et al. *(132)* reviewed 21 eligible studies – primarily ecological and cross-sectional designs – investigating cancer risks associated with residential exposure to MSWIs. Their findings were broadly consistent with those reported by Baek and colleagues. The review found limited evidence of increased risks for NHL, particularly among women and in specific regions of France and Italy. Some isolated results indicated elevated risks for certain cancer types; however, these findings were not consistently replicated across studies. Overall, Bottini et al. concluded that the evidence remains inconsistent and is frequently constrained by methodological limitations.

Cardiovascular diseases

Cardiovascular diseases have been associated with long-term ambient air pollution, coupled with exposure to PAHs and lead *(181, 182)*. Bottini et al. *(132)* assessed nine studies on cardiovascular outcomes. Three high-quality cohort studies and one low-quality study found some associations of increased cardiovascular risk, particularly for mortality and hospitalizations *(153, 169, 180, 183)*. Specific conditions such as ischaemic heart disease, acute myocardial infarction and chronic heart failure showed borderline or significant associations in some studies, although results were not consistent across all populations. Cerebrovascular outcomes showed no significant associations in any study.

Respiratory diseases

Pollutants emitted from incinerators such as PM and toxic compounds can impair lung function and increase susceptibility to diseases like asthma, chronic obstructive pulmonary disease (COPD) and infections. Bottini et al. *(132)* reviewed seven studies on total respiratory diseases, with four – three of which were high-quality cohort studies from Italy *(153, 170, 183)* – reporting significant associations with increased mortality or hospitalization. For COPD, six studies were assessed. Two high-quality studies *(168, 184)* found significant associations, limited to males. Asthma was examined in seven studies: one Italian cohort reported increased hospital admissions *(168)*, while studies from Japan *(185)* and the Republic of Korea *(186)* found higher prevalence or hospitalization rates, particularly among children and older adults. However, several studies reported no associations. Evidence for acute respiratory conditions, allergic rhinitis and general symptoms was mixed.

Biomarkers

Vinti et al. *(65)* reported on three studies that used human biomonitoring to assess exposure to emissions from MSWIs. Two cross-sectional studies from China found significantly higher levels of dioxins (PCDD/Fs) in the blood of children and in the breast milk of mothers living near incinerators compared with control groups *(158, 159)*.

Campo et al. *(128)* systematically reviewed 132 publications (representing 82 studies) on pollutant levels in people living near or working at solid waste incinerators. The review examined pollutants such as dioxins (PCDD/Fs), PCBs, metals, PAHs and VOCs, along with their biological effects. Studies focused on the general population (67 studies), workers (52 studies) or both (14 studies), with Europe being the most common study location, followed by Asia and the Americas. Almost two thirds of studies reported on exposure to MSWIs, while others reported on hazardous waste incinerators. Blood was the main biological sample investigated, followed by urine and breast milk. The review found that older studies often reported elevated pollutant levels, particularly among workers, whereas more recent studies (post-2000) generally showed biomarker levels within reference ranges, suggesting limited exposure from modern incinerators. The need for further research in low- and middle-income countries, standardized methods and the investigation of emerging pollutants was emphasized. Recent studies have begun examining compounds such as per- and polyfluoroalkyl substances in the context of incineration, although biomonitoring data remain limited *(187)*.

5.2.3 Evidence from health risk assessments

Numerous studies have reported on HHRA. The systematic review by Tait et al. *(130)* examined the impacts of waste incinerators on health outcomes and health risks. Health risks were assessed by measuring pollutants in environmental media (e.g. air, soil, water and food) or in biological samples. Of the 93 publications retrieved, 55 reported on health risks based on pollutants in environmental media. Most studies were cross-sectional, ecological or simulation based. Most followed the United States Environmental Protection Agency guidelines on HHRA *(101)*. The review found 23 studies that reported exposure levels within regulatory limits, 25 indicated potential health risks and an additional seven made no judgement. Dietary ingestion was consistently identified as the dominant exposure pathway. Eleven studies reported reduced exposure with newer incinerator technologies, but many studies lacked detailed information on incinerator design and did not account for other sources of pollution in the area.

5.3 Evidence on exposure to MSW disposal sites

Disposal sites include controlled disposal sites (e.g. sanitary landfills) and uncontrolled sites where open dumping and burning occur. While the types of pollutants and exposure pathways are similar in both settings, the presence of control measures (e.g. liners, leachate collection systems and gas capture technologies) generally reduces risks for populations living near sanitary landfills. Key exposure routes include inhalation of airborne pollutants and ingestion of contaminated water or soil.

5.3.1 Epidemiological evidence from landfills

Vinti et al. *(65)* reviewed nine studies on health impacts associated with living near MSW landfills. These studies, conducted primarily in Europe and North America, with one from China and one from South Africa, included retrospective cohort and cross-sectional designs. Evidence was mixed but indicated some risks, particularly from older-generation sites.

Birth outcomes and congenital anomalies

Vinti et al. *(65)* reviewed four studies examining the relationship between landfill proximity and congenital anomalies. Among them, Palmer et al. *(188)* found a statistically significant increase in congenital anomalies in Wales after the opening of landfill sites for residents living within 2 km. However, other large-scale studies did not replicate these findings. Elliott et al. *(189)*, analysing over 4.5 million births in England and Wales, found no significant association between landfill proximity and congenital anomalies. Similarly, Jarup et al. *(190)* reported no increased risk of Down syndrome near landfills. In Denmark, Kloppenborg et al. *(191)* also found no consistent pattern of increased risk across distance zones.

Cancer

Among the reviewed studies, only one high-quality Italian cohort study reported a statistically significant increase in mortality from lung cancer associated with higher hydrogen sulfide exposure, used as a proxy for landfill emissions. However, the same study found no significant associations for other cancer types, including colorectal, liver, pancreas, bladder, kidney, brain and haematopoietic cancers. Other studies either did not assess cancer outcomes or found no evidence of increased risk. Importantly, most of the landfills studied were older-generation sites, predating modern environmental regulations in these countries.

Respiratory diseases

Ambient air pollution from dumpsites may trigger asthma, persistent coughs and hypertension in communities and individuals living and working on or near these sites *(192)*. The review identified five studies examining respiratory health outcomes in populations living near MSW landfills. The evidence suggests a potential association between landfill proximity and increased respiratory disease, particularly among children. Mataloni et al. *(193)* reported a statistically significant increase in respiratory diseases and acute respiratory infections in children under 14 years exposed to higher levels of hydrogen sulfide. Gumede & Savage *(194)* found reduced lung function in South African children exposed to elevated $PM_{2.5}$ levels near a landfill, while Kret et al. *(116)* in Missouri, United States, reported increased respiratory symptoms, including shortness of breath and bronchitis. Heaney et al. *(96)* also observed a significant association between landfill odour and upper respiratory symptoms. However, not all studies found consistent associations with asthma or COPD.

Other health outcomes

Vinti et al. *(65)* found limited evidence linking landfill exposure to cardiovascular, gastrointestinal and mental health outcomes. Mataloni et al. *(193)* reported no significant associations with cardiac, ischaemic or cerebrovascular diseases. Heaney et al. *(96)* found no link between landfill odour and gastrointestinal symptoms, but did report significant associations with negative mental health outcomes, including altered daily activities and mood disturbances. Notably, no studies were found using biomonitoring of populations living near landfills, highlighting a key gap in understanding long-term exposure to landfill-related pollutants.

5.3.2 Epidemiological evidence from dumpsites/open burning

Vinti et al. *(65)* reviewed seven studies examining the health impacts of living near open dumpsites or areas with open burning of waste, comprising three cohort and four cross-sectional designs. These studies were conducted across Latin America (Brazil: *195*), North America (Alaska: *196, 197*) and Africa (Eswatini: *198*; Sierra Leone: *199*; Ghana: *200*; Nigeria: *201*).

Birth outcomes and congenital anomalies

One study suggested that residing near dumpsites may be associated with increased risk of low birth weight and intrauterine growth retardation in Alaskan villages *(196)*. However, no significant associations were found for congenital anomalies in either Alaska or Brazil *(195, 197)*, nor for preterm birth, fetal death or neonatal death in Alaska. However, there were few studies limited to two locations, which is not enough evidence to draw conclusions.

Infectious diseases

Limited but suggestive evidence was found linking dumpsites to infectious diseases. Four cross-sectional studies in Africa reported higher malaria prevalence among residents living near dumpsites, although none showed statistically significant results *(198–201)*. Similarly, increased cases of diarrhoea, cholera and typhoid were observed in some studies, but findings were inconsistent and based on self-reported data *(198, 201)*.

While not covered in the Vinti et al. *(65)* review, other studies have examined the broader health impacts of exposure to hazardous substances at inadequately managed disposal sites, including those containing e-waste. Exposure to heavy metals such as mercury and lead, and POPs like PCBs (commonly found in e-waste), has been associated with neurodevelopmental impairments in children. POPs are also known to be endocrine disruptors and can cause immunotoxicity, neurotoxicity and thyroid dysfunction *(8)*. Air pollution from such sites, containing cadmium, lead, mercury and compounds like PCDDs, PCDFs, PAHs and polybrominated diphenyl ethers, poses additional risks to cognitive development in infants and children. The WHO e-waste and child health report details these associations *(8)*.

5.3.3 Evidence from health risk assessments

Several health risk assessments have examined emissions from landfills and dumpsites, with findings varying depending on pollutant type, exposure pathway and site conditions. Examples from selected studies are given in the following.

In Italy, a study on landfill gas combustion found hazard indices for cancer and non-cancer effects to be below thresholds set by WHO and other agencies *(202)*. Similarly, ambient air monitoring at a landfill in Serbia showed that PAHs and POPs posed no significant inhalation risk *(203)*. In contrast, a study in China identified potential carcinogenic risks from aromatic compounds – particularly toluene – despite negligible non-carcinogenic effects *(204)*.

Other studies have focused on heavy metals and POPs in soil, air and water near disposal sites. In Nigeria, soil contamination near landfills exceeded acceptable risk levels for carcinogenic and non-carcinogenic effects *(205)*. In Pakistan, POPs across multiple environmental media posed low to moderate lifetime cancer risk to the nearby population *(206)*. In India, toxic metals bound to PM from open burning were linked to cancer risks several times above acceptable levels *(207)*, while groundwater contamination at another site also exceeded safe limits via ingestion pathways *(208)*.

Several studies have also estimated or measured emissions from uncontrolled disposal sites. For example, Ferronato & Torretta *(60)* reviewed eight case studies and found pollutant concentrations – especially heavy metals – and chemical oxygen demand exceeding WHO limits by more than tenfold at some sites. Other research has modelled leachate flow and heavy metal risks *(84)*, assessed contamination in groundwater and soil *(209, 210)* and evaluated pollutants in nearby water bodies *(211)*. Emissions from open burning of MSW have also been estimated, including PM, dioxins and VOCs *(212, 213)*. Additional studies have examined leachate cytotoxicity *(214)* and the presence of POPs in various environmental media *(206)*, highlighting the widespread and diverse nature of pollution from such sites.

5.4 Evidence on exposure to other MSWM facilities

Evidence on health effects related to other stages of the MSWM chain (e.g. at transfer stations, recycling centres, composting facilities and anaerobic digesters) is limited *(65, 138, 139)*. Workers engaged in waste collection and sorting are potentially exposed to elevated levels of airborne dust, vehicle emissions and bioaerosols. Several studies have reported a higher prevalence of respiratory symptoms among these workers, including coughing, increased phlegm production, wheezing and shortness of breath *(77, 215, 216)*. Bioaerosols released from composting operations may contribute to chronic bronchitis and cause irritation of the skin and eyes. Additionally, endotoxins from bacteria present in dust are believed to trigger throat, eye and nasal irritation, particularly among individuals with compromised immune systems *(138, 139)*.

5.5 Limitations in evidence

Assessing the health impacts of MSW presents significant challenges. These stem from the complexity of exposure pathways, the diversity of pollutants involved and the long latency periods of many health outcomes. In addition, substantial data gaps and methodological inconsistencies across studies make it difficult to draw robust conclusions. The key limitations are outlined below.

5.5.1 Limited evidence from settings where MSWM is largely uncontrolled

Most epidemiological studies have been conducted in high-income settings among people living near incinerators and landfills. While this body of evidence is valuable, it reflects contexts where waste management systems are more advanced and better monitored. In contrast, there is a significant lack of data from low- and middle-income countries, where waste management is often informal, poorly regulated or entirely uncontrolled. These are precisely the settings where the risks to human health and the environment are likely to be most severe – due to open dumping, open burning and the widespread presence of scattered waste in close proximity to humans.

The underrepresentation of such contexts in the scientific literature limits understanding of the full extent of health risks associated with inadequate waste management, especially among the most vulnerable populations. Several factors contribute to this gap, including the absence of systematic health surveillance, environmental monitoring and exposure records. Moreover, the diffuse and informal nature of waste handling makes exposure assessment especially difficult. Informal waste activities frequently occur outside official oversight, involve multiple and overlapping sources of pollution, and affect populations with limited access to health care and environmental protections. As a result, the scale and the severity of health risks in these contexts are likely underestimated.

5.5.2 Limited details on technology and operational aspects

Many studies do not specify the type of incinerator or landfill, the nature of the waste processed, the presence and effectiveness of emission or leachate control systems, or the regulatory and operational standards under which these facilities operate. This lack of granularity severely limits the interpretability and comparability of findings across studies.

For incinerators, technological variation is substantial. Facilities range from older, first-generation plants with minimal pollution controls to modern, third-generation systems equipped with advanced flue gas cleaning technologies, continuous emissions monitoring and stringent regulatory oversight. Without distinguishing between these systems, it is difficult to determine whether observed health effects are linked to outdated, high-emitting technologies or persist even with newer, cleaner alternatives. Similarly, the type of waste incinerated – municipal, industrial, medical or hazardous – significantly influences the composition of emissions.

Landfills also vary widely in design and environmental performance. Older or informal dumpsites often lack engineered liners, leachate collection systems or infrastructure to capture gas, leading to uncontrolled releases of methane, VOCs and contaminated leachate into surrounding air, soil and water. In contrast, modern sanitary landfills are designed with multiple containment and monitoring systems to minimize environmental and health risks. However, many studies do not differentiate between these types of facilities, nor do they report on key factors such as waste composition, landfill age and depth, gas management practices and proximity to groundwater sources, nor do they provide detailed information on existing pollution control measures or compliance with standards.

This limitation is particularly problematic when comparing findings across studies conducted in different countries or at different points in time. For example, while earlier studies (pre-2000) often reported increased health risks near incinerators and landfills, more recent studies involving upgraded facilities have shown reduced emissions and weaker or no associations with adverse health outcomes. The lack of consistent reporting on technological upgrades and operational practices makes it difficult to determine whether these differences reflect real improvements or simply methodological inconsistencies.

5.5.3 Limitations with study designs and exposure assessments

Assessing health impacts among communities living near incinerators or waste disposal sites is more challenging than that among workers. Exposures in communities are often lower, intermittent and influenced by multiple sources such as air, soil, water and diet. Direct measurement is difficult, requiring modelling or assumptions, and residents differ in age, lifestyle and socioeconomic status, introducing confounding factors. Mobility further complicates long-term studies. Moreover, MSWM facilities and landfills are often situated in areas already affected by other sources of pollution, making it particularly difficult to attribute health outcomes to specific sources.

The diversity of study designs also limits the comparability of findings across studies. A substantial number rely on ecological designs, where exposures and outcomes are assessed at the population level, which introduces the potential for ecological fallacy (where associations observed at the group level may not accurately reflect relationships at the individual level). Moreover, many studies do not adequately control for critical individual-level confounders such as smoking status, socioeconomic status, or occupational or other co-exposures. In addition, few studies incorporate long-term follow-up or account for latency periods, which are essential when investigating chronic outcomes such as cancer.

As detailed earlier in this chapter, exposure assessment is often imprecise, typically based on residential proximity rather than direct measurements or validated models, which can lead to misclassification. More accurate methods such as dispersion modelling and biomonitoring are underused. Epidemiological studies that rely solely on health outcomes frequently face significant limitations in low- and middle-income settings due to constrained technical and financial resources and the lack of comprehensive medical records. In such contexts, biomonitoring offers a complementary and often more feasible method for assessing exposure and characterizing risks, as demonstrated in several studies on the health impacts of e-waste *(217–219)*. In addition, further research is needed on pollutant bioaccumulation, as for example done by Cordier et al. *(152)*, who explored the link between local food consumption and dioxin exposure from MSWIs and urinary tract birth defects.

5.5.4 Underresearched health outcomes

Some health outcomes are underresearched, including infectious diseases from uncontrolled disposal, as well as mental and social well-being among workers or communities living near these facilities, and also the wider community at large.

Notwithstanding the limitations in epidemiological studies noted above, further research may be needed to better characterize and quantify the full burden associated with solid waste. Nonetheless, a growing body of evidence highlights the types of contaminants released from MSW, the environmental exposure pathways and the biological mechanisms of action. Many of the contaminants present in MSW – whether released through emissions or leachate – are known to pose risks to human health. Given the potential for long-term, low-level exposure and the uncertainties surrounding long-term impacts, a precautionary approach is warranted *(220)*. This approach includes strengthening protective regulations, enhancing environmental and health monitoring systems, and investing in safer MSWM systems and technologies, particularly in low- and middle-income countries, where the risks are often greatest.

6 Ways forward

Addressing the current and future challenges of SWM requires coordinated efforts across various sectors and actors at global, regional and national levels. Collaboration among governments, businesses, industries, municipalities and civil society is essential to reduce waste, enhance reuse and recycling, prevent environmental pollution, minimize health risks, and improve economic and social outcomes. The health sector has a key role to play in ensuring SWM services effectively protect public health. This chapter outlines key action areas, reinforcing existing recommendations in the SWM sector, and highlighting the role of the health sector to prevent and manage health risks from inadequate SWM.

6.1 Applying integrated sustainable waste management principles and the waste hierarchy

The *Global waste management outlook 2024* report highlights the significant societal costs if the current trajectory of waste generation and management remains unchanged *(3)*. It calls for urgent, large-scale changes to prevent unmanageable waste volumes that could cause irreversible damage to human health, biodiversity and the climate. The report advocates for enhancing waste management capacity in rapidly growing areas, adopting zero-waste and circular economy policies and practices, and leveraging high-level initiatives to drive global action.

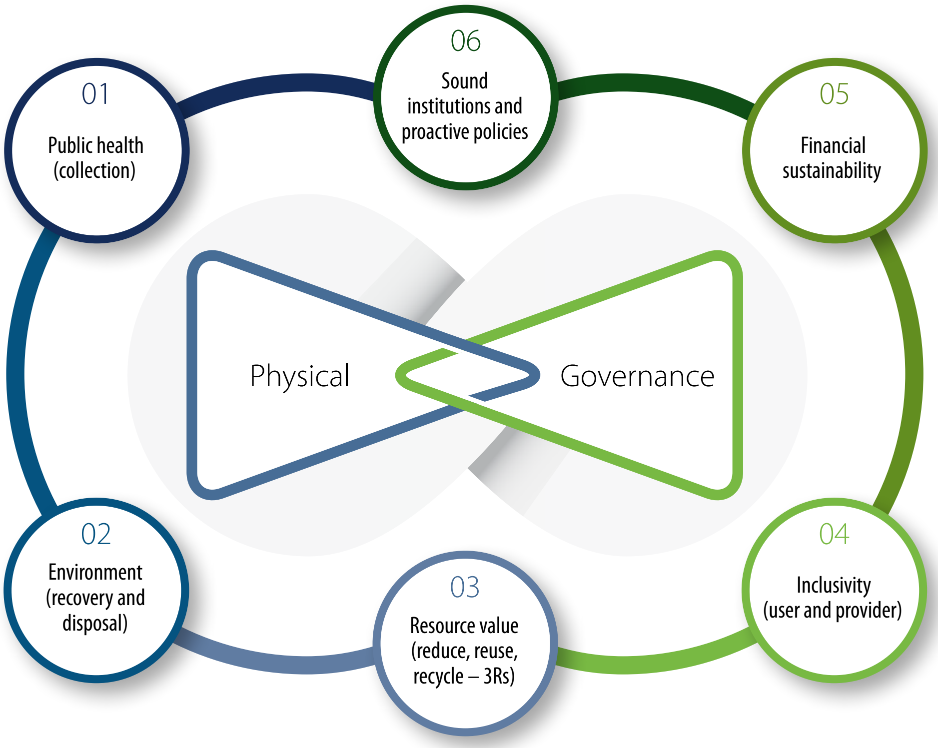
Integrated sustainable waste management offers a holistic framework for delivering waste and recycling services that are financially, socially and environmentally sustainable across generations *(221)*. It emphasizes prevention, behavioural change, efficient service delivery, robust infrastructure and strong environmental governance, all underpinned by principles of social equity (Fig. 13).

To meet SDG Target 11.6, key priorities include expanding waste collection coverage and ensuring at least basic levels of controlled recovery and disposal, with the elimination of open dumping and burning. Reliable collection services reduce the need for unsafe self-disposal practices and can be implemented at varying service levels *(38)*. Disposal remains a necessary component of any waste management system. Establishing basic controlled disposal is an urgent global priority. Once this baseline is achieved, efforts can progress towards full control and environmentally sound management (ESM), as represented in the UN-Habitat WaCT landfill ladder of control *(38)* (Fig. 14).

SWM is complex to govern. Key challenges include inadequate policy and regulatory frameworks, public buy-in and uptake, insufficient funding and finance, economic constraints, poor technical systems, lack of awareness of skill shortages and competition with non-renewable products. Without regular and reliable waste collection services, the informal sector often steps in to manage waste with partial or ad hoc methods, posing potential health risks for the workers, communities and individuals involved. Low collection rates contribute to increased open dumping and burning, causing environmental degradation that affects other sectors, and leads to sanitation crises.

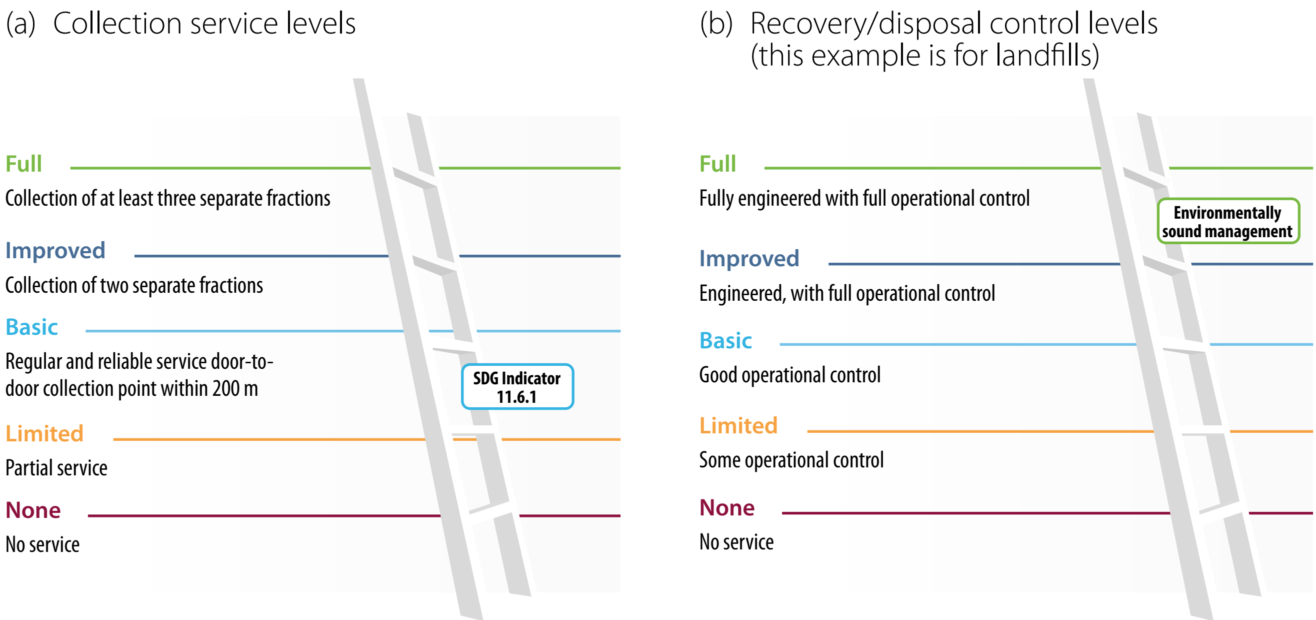
Key actions to improve waste management practices across sectors have been outlined in various publications, including the *Global waste management outlook 2024 (3)*.

Fig. 13 **Simplified "two triangles" representation of the integrated sustainable waste management framework**



Source: adapted from Wilson, Velis & Rodic *(222)*.

Fig. 14 **Collection service ladder and landfill ladder of control**



Sources: adapted from UN-Habitat *(38)*; Whiteman, Hennessy & Wilson *(223)*.

6.1.1 Strengthen waste governance and policies that promote the waste hierarchy

Effective waste governance is essential for sustainable waste management. In low-income contexts with low per capita waste generation, ensuring safe collection, treatment and disposal is a critical step to protect public health and the environment – particularly by preventing uncontrolled dumping, open burning and inadequate handling of hazardous waste. At the same time, governments can begin to adopt comprehensive policies that prioritize the waste hierarchy – reduce, reuse and recycle – as part of a shift towards a circular economy. This approach builds on existing systems and helps reduce reliance on virgin resources while improving health, environmental protection and sustainability.

A key component of this transition is the promotion of integrated sustainable waste management, supported by robust oversight and monitoring mechanisms across all stages of the waste value chain. Effective governance requires strong regulatory frameworks at local, national and international levels to prevent uncontrolled and illegal waste disposal and to protect environmental and public health. Targeted measures should address problematic waste streams, particularly single-use plastics – and single used items in general – in sectors such as retail, hospitality and tourism. Achieving this requires coordinated action among policy-makers, industry stakeholders and the public.

6.1.2 Encourage sustainable and safe behaviours

Public awareness and community engagement are essential to drive behavioural change and promote responsible waste management. Changing consumer habits requires a combination of education, incentives and accessible infrastructure to make sustainable and safe choices easier and more appealing.

Modern awareness and engagement initiatives should not only highlight the environmental and health impacts of poor waste practices but also provide practical guidance for reducing, reusing and safely disposing of waste. This includes practices such as reusing items, choosing durable products, participating in sharing or repair schemes, and segregating waste to ensure safe handling and disposal. Promoting safe disposal practices – such as avoiding illegal dumping, using designated collection points and following local guidelines for hazardous or medical waste – helps prevent environmental contamination and health risks.

Behavioural insights, social marketing and community involvement can reinforce these habits, making sustainable and safe practices more visible, socially accepted and culturally relevant. Authorities can support this shift through incentives, regulations and partnerships with businesses to expand access to sustainable products, services and safe disposal options. Inclusive infrastructure, such as conveniently located recycling and reuse facilities, composting stations and hazardous waste drop-off points ensures all members of the population, including marginalized groups, can participate in and benefit from improved waste practices.

6.1.3 Improve SWM services

MSW collection services should be extended to the entire population. Universal access is fundamental to protecting public health, reducing environmental degradation and promoting equitable service delivery, particularly in underserved and informal communities. Alongside this, existing uncontrolled disposal sites should be upgraded to controlled facilities that meet environmental and safety standards. This includes implementing adequate site engineering, leachate and gas management systems, and operational oversight to minimize health and ecological risks.

A strong emphasis should be placed on promoting waste separation and storage at source. Encouraging households and businesses to sort waste into organic ("wet") and recyclable ("dry") streams enables more efficient processing, reduces the volume of waste sent to landfills, and supports recycling and composting initiatives. Establishing dedicated organic waste collection schemes further enhances this effort. Processing the organic fraction diverts significant waste from disposal sites, reduces GHG emissions and facilitates the production of valuable by-products such as compost, biogas, insect-based protein and fuel briquettes. In addition, the quality of the compost produced is usually improved, reducing the presence of contaminants.

To support these efforts, governments must invest in modernizing waste management infrastructure and adopting best available techniques and best environmental practices across all facilities. This includes upgrading dumpsites to engineered landfills in terms of infrastructure and operations, enhancing emissions control systems at incinerators and recovery facilities, and implementing stringent measures for hazardous waste management. The adoption of newer technologies and improved operational practices can significantly reduce the health hazards associated with waste management, particularly from incineration and open burning. While the financial costs of these upgrades can be substantial, they are critical for achieving long-term sustainability, environmental protection and public health outcomes. If facilities are not properly operated, equipment and infrastructure can quickly deteriorate, requiring relevant investments for substantial restoration, largely exceeding any initial saving.

Improving the health, safety and working conditions of all actors in the waste value chain – including waste generators, collectors, handlers and recyclers – is essential. This involves providing appropriate training, PPE and formal recognition of informal workers to ensure safe, dignified and inclusive working environments. Such measures contribute to social equity and the overall effectiveness of waste management systems.

6.1.4 Improve data collection and planning

Governments should develop integrated city-level waste management plans that address infrastructure and governance. These plans must align with land-use, service delivery, financing and regulatory frameworks to ensure coordinated and efficient waste handling.

Strengthening national and local systems for collecting reliable data is essential for effective planning and monitoring. This involves routinely collecting and maintaining data on waste generation, including quantities, composition and material flows along the SWM value chain. This information helps identify trends, gaps and opportunities for system improvement. Data collection must also cover communities without waste services and areas near major waste facilities, applying a consistent methodology with clear definitions.

6.1.5 Enhance financial sustainability

Governments must ensure adequate and sustained funding for the operation and maintenance of waste management services and facilities. Strengthening and diversifying financial resources are essential to support infrastructure upgrades and service expansion, with particular attention to operational costs that underpin daily system functionality. Public budgetary allocations and transfers should be used to address financing gaps, especially in areas where service charges alone are insufficient. Additionally, international development financing and technical assistance remain vital for tackling global waste challenges, including climate mitigation and plastic pollution.

6.1.6 Implement extended producer responsibility

Governments should develop and enforce extended producer responsibility policies that shift the financial and operational burden of post-consumer waste management from municipalities to producers. Extended producer responsibility encourages companies to design more sustainable products, reduce waste at source and demonstrate corporate social responsibility. International implementation of extended producer responsibility supports financial sustainability in waste systems and aligns with the polluter pays principle, ensuring fair cost allocation and introducing new technical and financial resources into the sector. Extended producer responsibility systems can be designed to ensure inclusivity of informal waste pickers, providing fair remuneration and addressing occupational health issues. Payments should cover all services, including environmental costs, training, infrastructure, legal compliance and social protection for service providers *(224)*.

6.1.7 Strengthen human resources capacity

Formalizing employment for waste workers and ensuring access to fair wages and social protection are critical steps towards inclusive and equitable waste management. Governments should establish and enforce occupational health and safety standards, provide regular training and ensure the routine use of PPE. Public awareness campaigns can help reduce stigma and discrimination against waste pickers, supporting their transition into formal employment and/or strengthening their membership-based organizations such as cooperatives, and recognizing their essential role in community health and environmental protection.

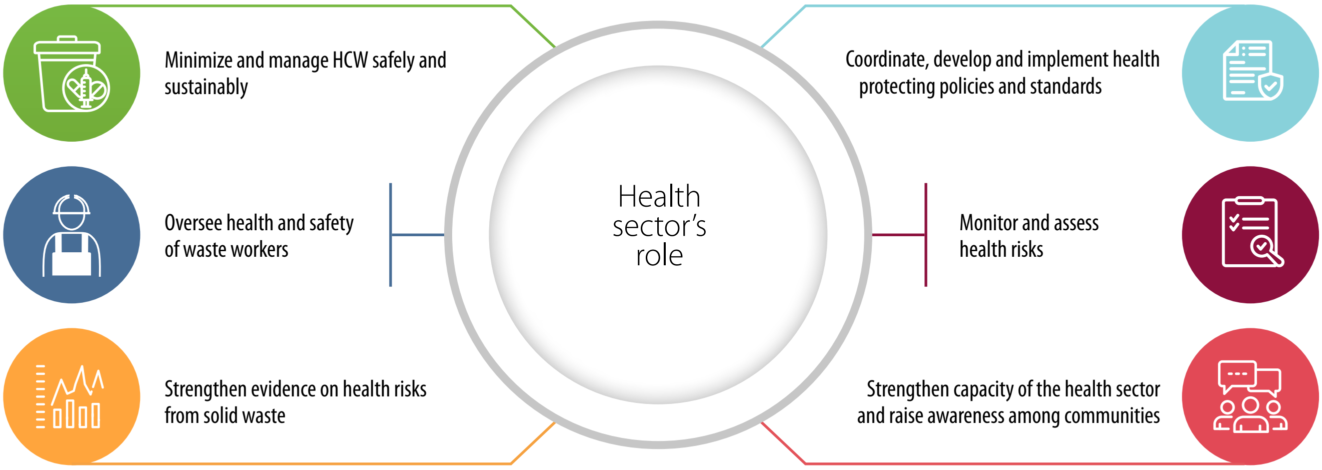
6.1.8 Drive innovation in circular economy practices

Governments should actively stimulate innovation in circular economy practices by supporting resource-efficient business models and sustainable product design. Regulatory frameworks and incentives should be put in place to encourage industries to adopt environmentally responsible practices and inclusive models that recognize existing circularities in local contexts. Innovation in materials, technologies and service delivery models can accelerate the shift towards more sustainable and resilient waste management systems.

6.2 Strengthening health sector engagement

As a major waste generator, the health sector must first ensure its own waste is adequately managed, to prevent adverse impacts on health workers, waste workers and communities at large. The health sector must also engage more in preventive action with other stakeholders to support the wider community. Other essential functions include: advocating for improved SWM; developing and enforcing health-protective policies and norms; overseeing the safety of SWM service delivery; protecting the health of waste workers; conducting health risk assessments; enhancing monitoring, awareness-raising and behaviour changes; and strengthening the evidence base (Fig. 15). Box 2 provides examples of key actions at local, national and international levels.

Fig. 15 **Key health sector roles in SWM**



Box 2

Health sector actions at local, national and international levels

Local

- Assess health risks associated with SWM practices and exposure to hazardous materials including through human biomonitoring or environmental monitoring.
- Inform about the health risks from poor waste management and promote safe practices.
- Respond to health crises linked to poor waste management.
- Provide public health oversight to ensure safe SWM service delivery.

National

- Contribute to development and implementation of national policies and regulations for safe and sustainable waste management.
- Implement the WHO chemicals road map.
- Implement international agreements on SWM such as the Basel Convention, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade *(225)*, the Stockholm Convention on Persistent Organic Pollutants *(226)*, the Minamata Convention on Mercury *(227)* and the SDGs *(228)* (see Annex 3).
- Build capacity to improve local waste management practices and protect worker health.
- Monitor and assess exposures and health risks related to SWM to inform policy and practice.
- Collaborate with the labour sector to track the number of informal workers and the risks they encounter.
- Advocate for better designed products, extended product life cycles and alternatives to hazardous materials.
- Identify best practices at the local level, promoting their dissemination and replication in other health care facilities.

International

- Support adoption and enforcement of international accords on SWM.
- Inform research needs on the health impacts of waste management and advocate for improved practices and regulations.
- Support countries and collaborate with organizations in developing and implementing safe waste management strategies.

6.2.1 Manage HCW safely and sustainably

Waste management in the health care sector presents a significant challenge due to the diverse nature of its by-products. It is estimated that around 85% of waste generated in health care facilities is classified as general waste, while the remaining 15% is considered hazardous, including infectious, toxic or radioactive materials *(10)*. However, many facilities, particularly in low-income settings, lack the capacity to manage it safely. Globally, three out of 10 health care facilities do not implement source separation and one in three lacks safe HCW management practices *(229)*.

The situation becomes more challenging during public health emergencies, as demonstrated during the coronavirus disease (COVID-19) pandemic. In such crises, tens of thousands of tonnes of additional waste are generated in a short period, placing immense pressure on already strained waste management systems. This surge includes a wide range of materials such as PPE, single-use plastics and packaging from medical supplies. For example, based on United Nations supply portal data, of the 87 000 tonnes of PPE shipped during COVID-19, close to half (36 000 tonnes) was gloves – much of which became waste that could have been avoided with good hand hygiene. Many of these materials are avoidable or could be minimized through better planning, sustainable procurement and the use of reusable or biodegradable alternatives *(230)*.

Moreover, the rapid accumulation of infectious and hazardous waste during health emergencies poses serious risks to public health and the environment, especially in areas lacking adequate infrastructure for safe collection, treatment and disposal. Informal waste workers, who often operate without protective equipment or formal recognition, are particularly vulnerable.

Improving HCW management requires coordinated action at local and national levels. Progress should be driven simultaneously within hospital departments and wards, as well as through networks of facilities and national systems. Health systems must implement comprehensive action plans that include setting clear targets, training staff, strengthening coordination and monitoring, investing in infrastructure and maintenance, and raising public awareness to drive behaviour change – as set out in WHO guidance on HCW management *(10)*.

Adhering to guidance outlined in the Basel and Stockholm Conventions can significantly reduce hazardous waste emissions, limit the release of harmful chemicals into the environment, and provide guidance on effective waste recovery and disposal methods *(11)*. Box 3 and Box 4 provide examples of initiatives aimed at improving management of waste from health care facilities.

Box 3

Country commitments and partner support for safer and more sustainable HCW

Countries and partners have committed to supporting better management of HCW through various global initiatives. The 2023 United Nations General Assembly resolution on water, sanitation, hygiene, waste and electricity in health care facilities, adopted by Member States, emphasizes the need to integrate these efforts with health policies, planning and financing. It calls for the development and implementation of costed roadmaps and the regular monitoring of services and user acceptability *(231)*.

This initiative is further supported by the WHO/United Nations Children's Fund global framework for action on water, sanitation, hygiene, waste and electricity in health care facilities, which establishes targets and tracks progress specifically related to HCW services, standards and financing *(232)*. Additionally, nearly 100 countries have made commitments through the United Nations Climate Change Conference of the Parties to develop climate-resilient and low-carbon sustainable health systems, which includes a significant focus on enhancing the safety and sustainability of HCW management *(233)*.

Box 4

Elimination of mercury measuring devices in health care

Mercury is toxic to human health, posing a particular threat to the development of the child in utero and early in life. Human exposure occurs mainly through inhalation of mercury vapours. To prevent environmental releases and human exposure, health care facilities are encouraged to switch to non-mercury thermometers and sphygmomanometers.

WHO supports Member States with implementation of the Minamata Convention, focusing on health aspects. WHO advocates for phasing out mercury devices in health care to reduce exposure risks and improve waste management. Active efforts to phase out mercury-based thermometers and sphygmomanometers used in health care range from the procurement of mercury-free alternatives to the safe and environmentally sound interim storage of mercury-containing wastes to minimize the uncontrolled release of mercury *(234, 235)*.

6.2.2 Coordinate, develop and implement health protecting policies and standards

At the national level, the health sector should participate in overall SWM coordination and policy development. It should play a specific role in developing and enforcing policies that protect public health, setting health and safety standards, and conducting risk assessments. It should also monitor compliance, provide training for waste management professionals, raise public awareness about health risks, support research for evidence-based policy and prepare for health emergencies related to waste.

Policies and legislation are needed to establish health, safety and working standards in workplaces, including those of semi-formal waste pickers in cooperatives with recycling facilities. Essential regulations should define employee rights and employer responsibilities for maintaining safe practices. Additionally, progressive policies are required to support the integration of the informal sector into inclusive and sustainable waste management systems.

The health sector supports the adoption and implementation of international accords, such as the Basel, Minamata, Rotterdam and Stockholm Conventions, as well as the SDGs (Annex 3). By adding the health sector's voice (e.g. as described in Box 5), these international agreements can better address the health impacts of waste management and promote safer, more sustainable practices globally.

6.2.3 Oversee occupational health and safety

Occupational health and safety aims to protect workers from exposure to hazardous substances, physical injuries and biological risks. While employers are directly responsible

Box 5

Examples of WHO actions to promote sound chemical management worldwide

In 2017, the World Health Assembly endorsed a chemicals road map to enhance health sector involvement in international chemicals management towards the 2030 SDGs and beyond. The WHO *Chemicals road map* report *(236)* thus identifies concrete national actions where the health sector has either a lead or important supporting role to play in the sound management of chemicals and waste, recognizing the need for multisectoral cooperation. The actions are organized into four areas: risk reduction, knowledge and evidence, institutional capacity, and leadership and coordination. The associated WHO chemicals road map workbook helps governments develop an implementation plan for priority areas of focus and highlights where collaboration and support is needed.

WHO is also the Secretariat for the Inter-Organization Programme for the Sound Management of Chemicals partnership of 10 international organizations, which promotes national actions to manage chemicals, waste and pollution.

for implementing safety measures, including providing PPE, training and safe working conditions, the health sector holds overarching responsibility for ensuring these standards are met. This includes setting national occupational health and safety policies, monitoring compliance and coordinating across sectors to ensure all workers – including those in informal roles – are protected.

Key components of occupational health and safety include: development of and training on safety protocols; adequate provision and use of PPE; regular health check-ups and formalization of waste workers to ensure legal recognition; and social protections such as health insurance, pensions and job security.

Integrating informal waste workers into formal SWM systems is essential for building inclusive and sustainable services. This involves recognizing their role in resource recovery, improving working conditions and providing support such as skills training, legal assistance and access to health care and childcare. Organizing workers into cooperatives or unions, ensuring fair wages and improving safety standards are also key to promoting income security and long-term workforce development.

Employers must ensure safety protocols are in place and that PPE (e.g. masks, gloves, boots and protective clothing) is suited to the working conditions and is actually used, particularly in hot climates. Comprehensive training should accompany PPE provision to build awareness and reinforce safe practices among waste workers.

Improving access to health services for waste workers includes ensuring affordable and quality care, regular medical check-ups, treatment for work-related injuries and preventive services such as vaccinations. These services should be integrated into occupational health programmes and made accessible to formal and informal waste workers.

Capacity-building across all levels – from policy-makers to frontline workers – should focus on equipping stakeholders with the knowledge and tools to manage health and environmental risks. This includes monitoring in the workplace, providing training on health and safety, providing technical support and conducting risk assessments, all of which contribute to a culture of safety, accountability and environmental responsibility.

6.2.4 Monitor and assess health risks

Health impact assessments play a critical role in evaluating the potential health effects of waste management practices and policies. These assessments help identify health risks and vulnerable populations, provide evidence-based recommendations to inform decision-making, promote safer waste management practices and engage communities in addressing local health concerns. They also support the monitoring and evaluation of health outcomes associated with SWM strategies, ensuring they effectively protect and improve public health *(237)*.

A variety of approaches can be used in the assessments, including human biomonitoring, which measures the concentrations of pollutants and their metabolites in human tissues and fluids. This method provides valuable insights into human exposure to chemicals from multiple sources, through various pathways, and at different life stages *(238)*. It is particularly useful for assessing exposure among high-risk groups such as waste workers, residents of underserved settlements, communities living near uncontrolled SWM facilities, and vulnerable populations like children and pregnant women. When combined with environmental monitoring of air, water and soil, biomonitoring enhances the ability to track health risks and implement preventive measures *(238)*.

Collecting data on the number of formal and informal waste workers, as well as hospital admissions related to waste work, is essential for assessing the scale and severity of health risks in the sector. This requires collaboration with labour market stakeholders at national and global levels *(8)*, and helps quantify the health costs of inadequate SWM. In particular, the informal sector often faces higher exposure to hazards but remains underdocumented *(8)*.

6.2.5 Strengthen the evidence on health risks and impacts

As discussed in Chapter 5 on the limitations of epidemiological evidence, the health burden associated with unsafe SWM is likely to be significant. However, quantifying this burden accurately remains extremely challenging due to a range of methodological and data-related issues.

Below are some key actions that can help address these challenges and strengthen the evidence base for informed decision-making.

Improve understanding of pollutants and exposure pathways

- Investigate pollutants found in MSW and its by-products, including contaminants of emerging public health concern such as per- and polyfluoroalkyl substances, endocrine disruptors, nano- and microplastics, and complex hydrocarbons.

- Standardize detection methods by developing and harmonizing techniques for identifying these substances in environmental and biological media.

- Explore how contaminants move through ecosystems and across human and animal membranes to better understand exposure risks.

Strengthen epidemiological research

- Improve and standardize exposure measurements in epidemiological studies.

- Conduct research on modern SWM technologies to reflect recent innovations or updated emission control measures, and reassess the performance, safety and sustainability of SWM technologies.

- Reassess evidence on well-studied health outcomes considering new studies and investigate understudied ones such as infectious diseases, vector-borne diseases, neurological disorders, and mental and social well-being.

- Prioritize studies on communities unserved or underserved by basic MSWM services, informal waste workers, children, pregnant women and communities living near uncontrolled treatment and disposal sites, and associated with unregulated waste operations.

Evaluate impacts of MSWM policies and programmes

- Conduct impact evaluations of initiatives aimed at improving the working conditions and health of informal waste workers, particularly in low- and middle-income countries.

- Explore practical solutions. Research low-cost, context-appropriate interventions such as emission control for open burning, leachate management, source separation use of reusable items and renewable energy, and safer disposal options in rural and underserved areas.

Assess the use of risk assessment and management frameworks along the SWM value chain

- Encourage the use of structured risk assessment and management tools to evaluate health risks across the SWM chain.

- Assess the use and performance in reducing health risks and environmental impacts of structured frameworks such as environmental management systems in SWM systems such as in municipalities and health care facilities.

- Support the creation and implementation of waste safety plans through interdisciplinary collaboration among health, environmental and policy experts *(239, 240)*.

- Ensure these tools are embedded in SWM planning and decision-making processes to monitor and reduce health risks.

Better understand the link between SWM, climate change and health

- Explore the links between SWM, climate change and public health. This includes studying how extreme weather events influence waste accumulation and disease outbreaks, as well as the contribution of open burning to air pollution and climate change. This also includes studying how climate change is affecting formal and informal workers at their workplaces *(241)*.

Document economic benefits of effective SWM

- The economic impacts of improved SWM, including potential reductions in health care costs and broader societal savings, are not well documented. Research quantifying these benefits could support more cost-effective and health-centred policy decisions.

6.2.6 Strengthen the health sector capacity and raise awareness among communities

Raising awareness about the health risks linked to poor waste management and consumer behaviour is essential for driving behavioural change. As trusted figures in primary care and community health, health professionals can help raise awareness, detect early signs of exposure and advocate for safer SWM policies. Their responsibilities include identifying exposure hotspots, conducting environmental health assessments and educating the public, especially vulnerable groups such as children, pregnant women and informal waste workers. To fulfil these roles effectively, environmental health training should be integrated into the education of all health professionals.

In coordination with different institutions such as ministries of health, environment, education and social affairs, public education campaigns and tailored outreach can empower communities to adopt safer practices and demand improved services.

Governments and institutions must invest in health sector capacity and bridge the gap between national waste policies and local implementation. This includes strengthening institutional coordination, investing in infrastructure and fostering multisectoral collaboration. Integrating informal waste workers into formal systems – with training, protective equipment and recognition – can further improve health outcomes and service efficiency.

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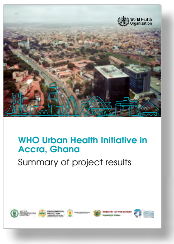
Annex 1. Key WHO resources related to solid waste and health

E-waste

Children and digital dumpsites: e-waste exposure and child health. World Health Organization; 2021

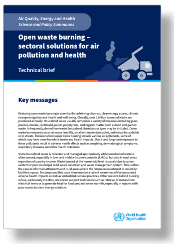
(https://iris.who.int/handle/10665/341718)

Waste and urban health



WHO Urban Health Initiative in Accra, Ghana: summary of project results. World Health Organization; 2023

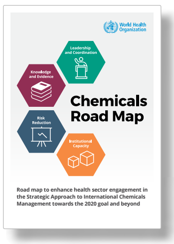
(https://iris.who.int/handle/10665/365238)



Open waste burning: sectoral solutions for air pollution and health. World Health Organization; 2025

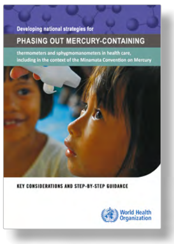
(https://www.who.int/publications/i/item/B09367)

Chemicals

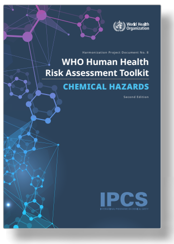


Chemicals road map. World Health Organization; 2017

(https://iris.who.int/handle/10665/273137)

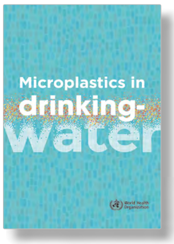


Developing national strategies for phasing out mercury-containing thermometers and sphygmomanometers in health care, including in the context of the Minamata Convention on Mercury: key considerations and step-by-step guidance. World Health Organization; 2017
(https://iris.who.int/handle/10665/259448)

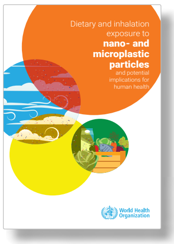


WHO human health risk assessment toolkit: chemical hazards, 2nd ed. World Health Organization; 2022
(https://iris.who.int/handle/10665/350206)

Plastics



Microplastics in drinking-water. World Health Organization; 2019
(https://iris.who.int/handle/10665/326499)



Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health. World Health Organization; 2022
(https://iris.who.int/handle/10665/362049)

HCW

Safe management of wastes from health-care activities. World Health Organization; 2014
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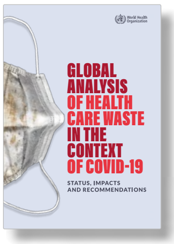
Overview of technologies for the treatment of infectious and sharp waste from health care facilities. World Health Organization; 2019
(https://iris.who.int/handle/10665/32814)



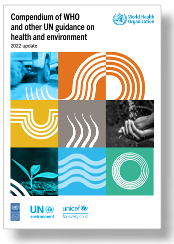
Global analysis of healthcare waste in the context of COVID-19: status, impacts and recommendations. World Health Organization; 2022

(https://iris.who.int/handle/10665/351189)

Safe management of pharmaceutical waste from health care facilities: global best practices. World Health Organization; 2023

(https://iris.who.int/handle/10665/380586)

WHO and United Nations guidance on solid waste



Compendium of WHO and other UN guidance on health and environment, 2022 update. World Health Organization; 2022

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Waste and health in the circular economy

Assessing the health impacts of waste management in the context of the circular economy. World Health Organization; 2023

(https://iris.who.int/handle/10665/366667)

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(https://iris.who.int/handle/10665/365579)

Annex 2. Control levels of SWM services and facilities

This annex refers to the UN-Habitat WaCT, which aims to support data collection for reporting against SDG Indicator 11.6.1 ("Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal solid waste generated, by cities") and which provides a "ladder of control level" of waste management facilities, designed to guide operational improvements of different waste management facilities. Table A2.1, Table A2.2 and Table A2.3 show the levels of control for collection, disposal sites and incineration, respectively.

Table A2.1 Levels of control for collection

Level of control	Definition
Full	Provides basic collection regularity and frequency without significant littering. Three or more fractions of waste are separated, and collection points are 200 m or less from residential areas. This is the highest level.
Improved	Provides basic collection regularity and frequency without significant littering. Waste is separated into two fractions, and collection points are 200 m or less from residential areas. Compared with the full service, this level shows a good level of waste management, but with fewer segregated fractions.
Basic	Provides basic collection regularity and frequency, without significant littering, but does not include waste separation. Collection points within 200 m from residential areas have a service.
Limited	Basic collection regularity and frequency are lacking, resulting in significant littering. Collection points may or may not be within 200 m of residential areas, and may or may not be served, indicating a reduced level of waste collection service.
None	Represents areas without a waste collection service, indicating a lack of organized waste management in these areas, with significant littering.

Source: adapted from UN-Habitat *(1)*.

Table A2.2 Levels of control for disposal sites

Level of control	Definitions
Full	This highest level represents ESM. It offers efficient slope stabilization to prevent landslides and erosion, 24/7 supervised access, and thorough water and leachate control. Waste has clear operational areas that are compacted and covered immediately. Strict fire control, landfill gas management and full-time staffing by qualified individuals are further features. There are strong environment health and safety (EHS) protocols, including regular reporting, ablutions and risk assessments. Thorough site planning, a site boundary, waste type and quantity recording using a weighbridge, and plans for post closure are available.
Improved	This offers efficient slope stabilization to prevent landslides, supervised access, and water and leachate control. Waste has operational areas that are compacted and covered periodically. Strict fire control, with landfill gas management and staffing by qualified individuals are further features. There are EHS protocols, including regular reporting and ablutions. Site planning, a site boundary, waste type and quantity recording using a weighbridge are available.
Basic	This offers slope stabilization to prevent landslides and supervised access. Waste has operational areas, with some compacting in areas and some cover. There is zero burning on the surface, and there is staffing during business hours. Basic PPE and ablutions are provided. Some site planning, a site boundary and a weighbridge are available.
Limited	Some supervised access to minimize open dumping. Some machinery is ready for use for a minimal amount of compaction and levelling. There is some burning on the surface, and staff who regularly visit the site. Basic PPE is provided, and incoming waste is recorded.
Uncontrolled (dumpsite)	The lowest level, identified by the lack of supervised access, no machinery, compaction or levelling equipment. There are frequent fires and no staff, and waste is not recorded.

Source: adapted from UN-Habitat *(1)*.

Table A2.3 Levels of control for incineration

Level of control	Definitions
Full	This highest level represents ESM. These facilities are registered, licensed, have defined boundaries and are supervised 24/7. They have designed buildings with process controls that adhere to environmental regulations, and continuously record and monitor operational parameters and emissions. Operational control is ensured by thorough maintenance and having the relevant plans in place, asset management, emission sampling and routine calibration of process controls and systems. Energy is recovered and used. Residue, effluent management, flue gas and de-ashing adhere to environmental regulations. Strong fire safety and control protocols are in place, and the facility is managed by qualified staff. Professional EHS procedures, ablutions and materials are weighed, and thorough records are in place.
Improved	These facilities are registered, have defined boundaries and are supervised. They have designed buildings with process controls that adhere to environmental regulations, and continuously monitor operational parameters and emissions. Operational control is ensured by maintenance, having the relevant plans in place and routine calibration of systems. Energy is recovered and used. Residue, effluent management and flue gas adhere to environmental regulations. Fire safety and control protocols are in place, and the facility is managed by trained staff. EHS procedures, ablutions and materials are weighed, and records are in place.
Basic	These facilities are registered and have defined boundaries. They have designed buildings with process controls, and continuously monitor operational parameters such as smoke and temperature. The site is maintained and there is occasional calibration of systems. Some flue gas management takes place. Basic PPE and hand-washing facilities are provided.
Limited	These facilities have defined boundaries. Operational parameters are recorded. Equipment is somewhat maintained. Basic PPE and hand-washing facilities are provided.
Uncontrolled	These are unregistered facilities without defined boundaries. Operational procedures, maintenance and EHS measures are absent.

Source: adapted from UN-Habitat *(1)*.

Reference

1. Waste Wise Cities Tool: step-by-step guide to assess a city's MSWM performance through SDG Indicator 11.6.1 monitoring. Nairobi: United Nations Human Settlements Programme; 2021 (https://unhabitat.org/wwc-tool), accessed 5 December 2025.

Annex 3. Key international agreements and frameworks related to SWM

Table A3.1 Key accords and their descriptions

International accord	Description
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal *(1)*	Addresses the movement of a wide range of hazardous waste for the protection of human health and the environment. It seeks to reduce hazardous waste generation, promote ESM, restrict transboundary movements and prevent illegal waste shipments from high- to low-income countries. Encourages responsible waste management, waste reduction at source, and recycling and reuse of valuable resources.
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade *(2)*	Covers hazardous pesticides and industrial chemicals that have been restricted or banned in countries. Encourages cooperative and shared responsibility for the international trade of specific hazardous chemicals; and ensures the environmentally sound use of hazardous chemicals and pesticides by ensuring an exchange of information for the countries involved, so they can make informed decisions regarding their import, export and management.
Stockholm Convention on Persistent Organic Pollutants (POPs) *(3)*	Protects human health and the environment against POPs. These chemicals usually persist in the environment for long durations and may become geographically widespread, accumulate in the fatty tissue of living organisms, pose a risk of adversely affecting human health or the environment, and can be found in e-waste, certain plastics, older pesticides and obsolete products. Aims to restrict or eliminate the production and release of POPs.
Minamata Convention on Mercury *(4)*	Protects human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds, which may be present in light bulbs or batteries in MSW. Main provisions are to reduce and eliminate mercury emissions from anthropogenic sources, implement measures to control the supply of mercury, reduce or eliminate emissions from industrial sources and manage waste containing mercury.
Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes with Africa *(5)*	Prohibits the import of hazardous waste into Africa and controls its transboundary movement within the continent. Established due to concerns arising from the dumping of toxic waste in low- and middle-income African countries from high-income countries, and emphasizes ESM of this waste.
SDGs *(6)*	Advocate for comprehensive global progress across various sectors. Goals, targets and indicators where contributions can be made include SDG 3 on health, SDG 6 on safely managed water and sanitation, SDG 7 on clean and affordable energy, SDG 12 on responsible consumption and production, SDG Target 1.4 on access to basic services, SDG Target 6.3 on eliminating dumping to improve water quality, SDG Indicator 11.6.1 on MSWM, SDG Target 12.3 on reducing food waste, SDG Target 12.4 on ESM of chemicals and hazardous waste, including e-waste, SDG Target 12.5 on recycling and SDG Target 14.1 on reducing marine litter.
Future international legally binding instrument on plastic pollution, including in the marine environment *(7)*	Proposed global agreement aimed at addressing plastic pollution in the environment. Seeks to establish a comprehensive approach for the reduction, management and associated clean-up costs for plastic waste. Aims to hold stakeholders accountable for their plastic production and use across the plastic value chain to protect human health and the environment.

International accord	Description
Intergovernmental Science-Policy Panel on Chemicals, Waste and Pollution *(8)*	The United Nations Environment Assembly resolution 5/8 (2022) called for the establishment of a new science-policy panel to support the sound management of chemicals and waste and the prevention of pollution.
Global Programme of Action for the Protection of the Marine Environment from Land-based Activities *(9)*	Safeguards marine ecosystems from land-derived pollutants. Targets nutrient, sewage and habitat disruption, advocating for prevention, reduction and elimination of pollution. Promotes sustainable practices across freshwater, land and coastal areas, and fosters international collaboration to enhance marine environmental health, engaging civil society and private sectors in conservation.

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2. Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade [website]. Secretariat of the Rotterdam Convention; 1998 (http://www.pic.int).
3. Stockholm Convention on Persistent Organic Pollutants (POPs) [website]. Secretariat of the Stockholm Convention; 2023 (https://www.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx).
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Annex 4. **Methods**

A4.1 Overview of key studies included by Vinti et al.

The review by Vinti et al. *(1)* was an update of previous reviews assessing the epidemiological evidence on health risks associated with living near MSW treatment or disposal sites *(2–5)*. The systematic review by Vinti et al. included 29 studies published between 2005 and 2020. The studies examined the health impacts of landfills, incinerators and dumpsites, focusing on outcomes such as mortality, cancer, adverse birth and neonatal conditions, cardiovascular and respiratory diseases, vector-borne diseases, mental health and biomarkers of disease.

Table A4.1, Table A4.2 and Table A4.3 summarize the studies included in the systematic review by Vinti et al. *(1)*, including nine studies assessing the health outcomes of populations living near landfills, 13 studies of populations near incinerators and seven studies assessing the impacts of open dumping/open burning.

Table A4.1 Landfills (nine studies)

Study location	Study design	Study participants	Study period	Exposure source	Outcomes investigated	Reference
England (United Kingdom)	Cohort study (retrospective)	10 064 382 live births, 52 532 stillbirths and 12 373 terminations	Births between 1983 and 1998	8 804 landfills, including 607 that handled special (hazardous) waste	Risk of congenital anomalies in relation to an index of geographical density of landfill sites (within 2 km from landfills)	Elliott et al. *(6)*
South Africa	Cross-sectional study	23 children aged 6–12 years residing within 2 km of the landfill site for at least 5 years	Study conducted between November 2013 and January 2014	Bisasar Road MSW landfill	$PM_{2.5}$ concentration in indoor environments of the subjects involved in the study and its association with lung function patterns	Gumede & Savage *(7)*
North Carolina (United States)	Cross-sectional study	23 participants among people living within 0.75 miles (1.21 km) of a landfill	January to November 2009	An MSW landfill	Relationships between hydrogen sulfide, odour and health outcomes in a community living close to a landfill	Heaney et al. *(8)*
England and Wales (United Kingdom)	Cohort study (retrospective)	4 584 541 births in England and Wales	Births between 1989 and 1998	6 289 landfill sites processing special (hazardous), non-special and unknown waste	Risk of giving birth to a child with Down syndrome associated with residence near landfill sites (within 2 km)	Jarup et al. *(9)*
Denmark	Cohort study (retrospective)	2 477 live births with congenital anomalies in Denmark in three different zones of distance from landfills (0–2 km, 2–4 km, 4–6 km)	Births between 1997 and 2001	48 landfills	Risk of congenital anomalies combined and congenital anomalies of the cardiovascular and nervous systems with maternal residence as a function of distance from landfills	Kloppenborg et al. *(10)*
Missouri (United States)	Cross-sectional study	Health survey through 170 households within a 3.2 km radius from a landfill and 173 households more distant (comparison group) from the landfill	February to March 2016	Bridgeton Landfill in St Louis County, in which MSW is disposed of	Respiratory symptoms and diseases though household interviews	Kret et al. *(11)*
Italy	Cohort study (retrospective)	242 409 people living within 5 km of landfills	Residents between 1996 and 2008, followed for mortality and hospitalizations until 2012	9 MSW landfills operating in the Lazio region, in which the exposure to landfills was assessed using hydrogen sulfide as a tracer in air (calculated with a model)	Association between landfill hydrogen sulfide exposure and mortality (natural and cause specific) and hospital admissions for cardiorespiratory diseases	Mataloni et al. *(12)*

Table A4.1 *continued*

Study location	Study design	Study participants	Study period	Exposure source	Outcomes investigated	Reference
Wales (United Kingdom)	Cohort study (retrospective)	542 682 births in Wales between 1983 and 1997; 97 292 births in Wales between 1998 and 2000	See previous column	24 landfill sites for commercial, industrial and household waste	Increased risk of births with at least one congenital malformation in a population living within 2 km from landfill sites, comparing it with a population living at least 4 km away	Palmer et al. *(13)*
China	Cross-sectional study	951 children from primary school studying and residing near a landfill; 4 schools within 5 km of the landfill (exposed area); 1 school (non-exposed area) more distant (5.8 km away)	Not specified	MSW landfill	Association between air pollutants and respiratory health in an exposed area, considering lysozyme and secretory immunoglobulin A (which are typically considered as the first line of defence from air pollutants and higher levels show good related health conditions)	Yu et al. *(14)*

Source: adapted from Vinti et al. *(1)*.

Table A4.2 Incinerators (13 studies)

Study location	Study design	Study participants	Study period	Exposure source	Outcomes investigated	Reference
Italy	Cohort study (retrospective)	21 517 births in women (aged 15–49 years) residing within 4 km of an incinerator	Residents between 2003 and 2010	8 MSWIs operating in the Emilia Romagna region	Assessment of the effects of air emissions from MSWIs (simulated with a dispersion model) on reproductive outcomes[a]	Candela et al. *(15)*
Italy	Cohort study (retrospective)	11 875 pregnancies with 1 375 miscarriages from women (aged 15–24 years) residing within 4 km of an MSWI	Residents between 2002 and 2006	7 MSWIs operating in the Emilia Romagna region	Assessment of the effects of air emissions from MSWIs (simulated with a dispersion model) on spontaneous abortions	Candela et al. *(16)*
France	Case–control study	Comparison of 304 infants with urinary tract birth defects with a control group of 226 infants randomly selected in the same region	Between 2001 and 2004	21 MSWIs active in the Rhône-Alpes region	Association between the risk of urinary tract birth defects and living near MSWIs, using a model to predict exposure to dioxins	Cordier et al. *(17)*
Great Britain (United Kingdom)	Cohort study (retrospective)	1 025 064 births and 18 694 infant deaths; incinerator emissions within 10 km were considered	Births and deaths between 2003 and 2010	22 MSWIs (operating between 2003 and 2010)	Associations between modelled ground-level PM from incinerator emissions within 10 km and selected reproductive/birth outcomes	Ghosh et al. *(18)*
Taiwan	Cohort study (retrospective)	6 697 neonates assessed 1 year before the MSWI started, and 6 282 neonates assessed 5 years after incinerator opening	Neonates in 1991 and in 1997	MSWI of Taipei	Relationships between exposure to elevated PCDD/PCDF concentration generated by an MSWI (using a model) and various birth outcomes	Lin, Li & Mao *(19)*
Spain	Cohort study (perspective)	104 exposed subjects (living < 1 km from the MSWI) and 97 non-exposed subjects (living > 3 km from the incinerator) were randomly selected From 1999, one additional group (100 unexposed subjects, in Arenys de Mar, about 11 km from the incinerator) was selected	7 different campaigns were performed between 1995 and 2012	MSWI of Matarò (activated in 1995)	To monitor PCDD/PCDF and PCB levels in blood samples in the different exposed groups	Parera et al. *(20)*
England and Scotland (United Kingdom)	Cohort study (retrospective)	219 486 births, stillbirths and terminations of pregnancy for fetal anomaly, in which 5 154 were cases of congenital anomalies; incinerator emissions within 10 km were considered	Birth and adverse birth outcomes between 2003 and 2010	10 MSWIs in England and Scotland (operating between 2003 and 2010)	Associations between modelled ground-level PM from incinerator emissions within 10 km and selected reproductive/birth outcomes	Parkes et al. *(21)*

Table A4.2 *continued*

Study location	Study design	Study participants	Study period	Exposure source	Outcomes investigated	Reference
Italy	Cohort study (retrospective)	31 347 residents within a 3.5 km radius of two incinerators	Residents between 1990 and 2003	An MSWI and a hospital waste incinerator in Forlì	Health outcomes among people living close to incinerators (using a dispersion model for exposure assessment)	Ranzi et al. *(22)*
France	Case–control study	434 incident cases of invasive breast cancer diagnosed (case group) compared with 2 170 controls randomly selected	Between 1996 and 2002 (cancer diagnosis in the case group); 1999 (control group)[b]	MSWI in Besançon	Association between dioxins emitted from an MSWI (air exposure using a model) and invasive breast cancer risk among women residing in the area	Viel et al. *(23)*
Italy	Cohort study (retrospective)	Women residing or working near an MSWI in Modena	Residents or workers between 2003 and 2006	MSWI of Modena	Rates of spontaneous abortion and prevalence of birth defects among women living or working near an MSWI, modelling incinerator emissions exposure	Vinceti et al. *(24)*
Italy	Case–control study	Women (aged 16–44 years) residing near MSWIs, assessing 228 cases of congenital anomalies	Birth defects between 1998 and 2006	MSWI of Reggio Emilia	Relationship between exposure to emissions from an MSWI and risk of birth defects, modelling incinerator emissions exposure	Vinceti et al. *(25)*
China	Cross-sectional study	82 children living near an MSWI in China and 49 from a control area, both in Zhejiang Province	Samples collected in October 2013	MSWI in Zhejiang Province	PCDD/PCDF levels in blood in different exposed groups	Xu et al. *(26)*
China	Cross-sectional study	14 mothers living near an MSWI (exposure area) and 18 mothers from a control area, both in Zhejiang Province	Samples collected in September and October 2013	MSWI in Zhejiang Province	PCDD/PCDFs and PCBs in the breast milk of mothers in different exposed groups	Xu et al. *(27)*

[a] The estimated annual average exposure to PM_{10} from incinerators in the study areas was 0.96 ng/m^3 in 2003, decreasing to 0.26 ng/m^3 in 2010 because of improvements in the plant during the study period.

[b] There were some weaknesses in the study: controls were residents in 1999, whereas cases were diagnosed between 1996 and 2002, introducing a time lag in the sampling for some matched sets.

Source: adapted from Vinti et al. *(1)*.

Table A4.3 Dumpsites and open burning (seven studies)

Study location	Study design	Study participants	Study period	Exposure source	Outcomes investigated	Reference
Eswatini	Cross-sectional study	78 residents in an area very close to a dumpsite and 39 people close to (<200 m) and 39 farther away (>200 m) from the dumpsite	Period of the questionnaires not specified	Dumpsite in Manzini city	Health effects of a dumpsite on the surrounding human settlement through self-administered questionnaires	Abul *(28)*
Nigeria	Cross-sectional study	100 household residents within 250 m radius of a dumpsite and 100 household residents 250–500 m from the same dumpsite	Data collected from 23 October 2015 to 5 November 2015	Dumpsite in Lagos	Health effects of a dumpsite on the surrounding human population through self-administered questionnaires	Babs-Shomoye & Kabir *(29)*
Brazil	Cohort study (retrospective)	People living within 2 km from the 15 landfills in the municipality of São Paulo	Between 1998 and 2002	15 solid waste landfill sites within the municipality of São Paulo (all, except one, were controlled dumpsites with no waterproof layer at the bottom)	Association between living close to a controlled dumpsite and occurrences of deaths for cancer or congenital malformations	Gouveia & do Prado *(30)*
Alaska	Cohort study (retrospective)	10 073 infants born in 197 villages close to dumpsites (ranked in high, intermediate and low hazards)	Infants born between 1997 and 2001	197 dumpsites	Adverse birth outcomes (low and very low birth weight, preterm birth, and intrauterine growth restriction) in infants born close to dumpsites	Gilbreath & Kass *(31)*
Alaska	Cohort study (retrospective)	10 360 infants born in 197 villages close to dumpsites (ranked in higher and lower hazards)	Infants born between 1997 and 2001	197 dumpsites	Rates of adverse pregnancy outcomes as fetal death, neonatal death and congenital anomalies, close to dumpsites	Gilbreath & Kass *(32)*
Sierra Leone	Cross-sectional study	398 residents near to (<50 m) and 233 residents farther away from (>50 m) a dumpsite	Period of the questionnaires not specified	Dumpsites in Freetown	Health effects of a dumpsite on the surrounding human population through self-administered questionnaires	Sankoh, Yan & Tran *(33)*
Ghana	Cross-sectional study	150 residents in a community near dumpsites, comparing three distances between people and disposal sites: less than 5 min, 5–10 min, 11–15 min[a]	Period of the questionnaires not specified	Dumpsite in Ashanti region	Health effects of dumpsites on the surrounding human population through self-administered questionnaires	Suleman, Darko & Agyemang-Duah *(34)*

[a] It was not specified how many of the people interviewed lived in each zone.

Source: adapted from Vinti et al. *(1)*.

A4.2 Complementary literature search

A targeted rapid search was conducted to identify systematic reviews published after that of Vinti et al. *(1)*, or key publications that could be used for the narrative synthesis of the report. Searches were carried out in Scopus (June 2023) using combinations of “waste” and “health” with specific health outcomes. Abstract screening and thematic grouping resulted in 124 selected papers. A follow-up search in Google Scholar (May 2025) identified 11 additional publications, which were incorporated as appropriate in the synthesis.

A4.3 Declaration of potential conflict of interest

All external experts submitted declarations of interest to WHO, disclosing any potential conflicts that might affect – or be perceived to affect – their objectivity and independence regarding the subject matter of this report. WHO reviewed each of the declarations and concluded that none could give rise to a potential or reasonably perceived conflict of interest related to the topics addressed.

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