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# SECTOR ENVIRONMENTAL GUIDELINE SOLID WASTE

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**DISCLAIMER:**

Until and unless this document is approved by USAID as a Sector Environmental Guideline, the contents may not necessarily reflect the views of the United States Agency for International Development or the United States Government.



**FRONT COVER:**

Recycling business worker: A woman poses at a recycling business on May 21, 2013, in Port-au-Prince, Haiti, that received a grant through a USAID-funded business plan competition. Photo credit: Kendra Helma

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## ABOUT THIS DOCUMENT AND THE SECTORAL ENVIRONMENTAL GUIDELINES

This document presents guidelines for one sector of the *Sector Environmental Guidelines* prepared for USAID under the Agency’s Global Environmental Management Support (GEMS) program. Guidelines for all sectors are accessible at <http://www.usaidgems.org/sectorGuidelines.htm>.

**Purpose.** The purpose of this document is to support the Environmental Impact Assessment (EIA) process for common USAID sectoral development activities by providing concise, plain-language information regarding:

- The typical, potential adverse impacts of activities in these sectors, including impacts related to climate change
- How to prevent or otherwise mitigate these impacts, both in the form of general design guidance and specific design, construction, and operating measures
- How to minimize vulnerability of activities to climate change, as well as contributions of activities to climate change
- More detailed resources for further exploration of these issues
- How to develop environmental compliance applications.

**Environmental Compliance Applications.** USAID’s mandatory life-of-project environmental compliance procedures require that the potential adverse impacts of USAID-funded and managed activities be assessed prior to implementation via the processes defined by 22 CFR 216 (Reg. 216) and the analyses which are documented via the Initial Environmental Examination (IEE), the Environmental Assessment (EA) and the Environmental Impact Statement (EIS). They also require that the environmental management/mitigation measures (“conditions”) identified by this process be written into award documents, implemented over the life of project, and monitored for compliance and sufficiency. Internationally, this process is recognized as an EIA and it is used throughout this document to allow its application globally.

The procedures are USAID’s principal mechanism for assessment of environmental impacts associated with USAID-funded activities – and thus for protecting environmental resources, ecosystems, and the health and livelihoods of beneficiaries and other groups. They strengthen development outcomes and help safeguard the positive reputation of USAID.

The *Sector Environmental Guidelines* directly support environmental compliance by providing information essential to assessing the potential impacts of activities and to identifying and designing appropriate mitigation and monitoring measures. However, they are **not** specific to USAID’s environmental procedures. They are generally written and are intended to support environmental impact assessment of these activities by all actors, regardless of the specific environmental requirements, regulations, or processes that apply, if any.

**USAID Guidelines Superseded.** These *Sector Environmental Guidelines* replace the following guidance: Solid Waste Sector Environmental Guidelines (2014).

This document serves as an introductory tool to Agency staff for solid waste sector projects, programs and activities. This document is not intended to act as a complete compendium of all potential impacts, as contextual information is critical to determining those impacts. Further, the Guidelines are not a substitute for detailed sources of technical information or design manuals. Users are expected to refer to the accompanying list of references for additional information.

**Comments and corrections.** Each sector of these guidelines is a work in progress. Comments, corrections, and suggested additions are welcome. Email: [gems@cadmusgroup.com](mailto:gems@cadmusgroup.com).

**Advisory:** *The Guidelines are advisory only. They are not official USAID regulatory guidance or policy. Following the practices and approaches outlined in the Guidelines does not necessarily assure compliance with USAID environmental procedures or host country environmental requirements.*

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## ACRONYMS

ABD	Asian Development Bank
AD	Anaerobic Digestion
ADS	Automated Directives System
ASTM	American Society for Testing and Materials
BOD	Biological Oxygen Demand
CDE	Construction Demolition and Excavation
CEMS	Centralized Emissions Monitoring System
CFR	Code of Federal Regulations
COC	Contaminants of Concern
COD	Chemical Oxygen Demand
CRM	Climate Risk Management
CY	Cubic Yards
DBO	Design, Build, Operate
E&S	Environmental and Social
EA	Environmental Assessment
EFW	Energy from Waste
EHS	Environment, Health, and Safety
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ELV	End of Life Vehicle(s)
EMMP	Environmental Mitigation and Monitoring Plan
EOL	End of Life
EPA	Environmental Protection Agency
ESIA	Environmental and Social Impact Assessment
GDA	Global Development Alliance
GEMS	Global Environmental Management Support
GHG	Greenhouse Gas(es)
GIS	Geographic Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit (Department for International Development)
GPS	Global Positioning System
HAZMAT	Hazardous Materials
HC	Hydrocarbon
HDPE	High-density Polyethylene
HSE	Health Safety & Environment
HVAC	Heating, Ventilation and Air Conditioning
IEE	Initial Environmental Examination
IFC	International Finance Corporation

IPCC	International Panel on Climate Change
ISWA	International Solid Waste Association
IVC	In-vessel composting
LCA	Life-Cycle Analysis
LDPE	Low-density Polyethylene
LED	Light Emitting Diode
MBT	Mechanical Biological Treatment
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
NMOC	Non-Methane Organic Carbon
O&M	Operation and Maintenance
OECD	Organization for Economic Cooperation and Development
OHS	Occupational Health and Safety
OSHA	Occupational Safety and Health Administration
PAD	Project Appraisal Documents
PCB	Polychlorinated Biphenyl
PET	Polyethylene Terephthalate
PLA	Polylactic Acid
POPs	Persistent Organic Pollutants
PP	Polypropylene
PPE	Personal Protective Equipment
PPP/'P3'	Public-Private Partnership
PPS	Pollution Prevention Systems
PS	Polystyrene
PVC	Polyvinyl Chloride
RCV	Refuse Collection Vehicle
RDF	Refuse Derived Waste
RFID	Radio-Frequency Identification
SEG	Sector Environmental Guidelines
SOP	Service Operational Plan
SPV	Special Purpose Vehicle
TIA	Traffic Impact Assessment
TPM	Total Particulate Matter
TS	Total Solids
UNEP	United Nations Environment Program
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VOC	Volatile Organic Carbon
WEEE	Waste Electrical and Electronic Equipment (e-Waste)

# I CONTEXT AND INTRODUCTION

## I.1 OVERVIEW

Rapid growth in global population, urbanization, economic growth and a burgeoning middle class, are expected to lead to a correlative increase in waste generation focused in urban areas of the developing world.<sup>1</sup> At the same time, shifting patterns of production and consumption are leading to greater complexity in managing waste. Faced with such trends, and lack of funding and capacity, many solid waste management authorities in such areas will find it increasingly challenging to provide necessary services, infrastructure and facilities, while addressing the associated threats to public health, society and the environment. In this context, USAID's role in supporting the development of sustainable waste management projects, programs and activities offers significant potential for achieving a wide range of benefits, including minimizing public health risks and environmental impacts and enhancing sustainability.

This Sector Environmental Guideline (SEG) provides an overview of the solid waste management sector, types of waste, systems for reducing, collecting, treating and disposing wastes, and the planning and implementing of such systems. Additionally, this SEG introduces and outlines potential environmental and social impacts, and climate change risks, associated with the solid waste management sector and discusses potential mitigation and management measures to address these impacts and risks. As the SEG is not comprehensive, suggested further reading is provided in Section 9.

## I.2 THE SOLID WASTE MANAGEMENT SECTOR AND DEVELOPING COUNTRIES

The solid waste management sector consists of public and private entities, and informal groups delivering or supporting waste services at all levels of production and consumption. The sector employs a wide range of methods for collecting, handling, storing, transporting, treating and disposing of waste, and recovering materials and energy from waste, including developing laws, policies, infrastructure, and technologies, and undertaking activities and operations. Solid waste management is a public benefit, but inadequate management has the potential to cause environmental pollution, and can affect the health, safety and quality of life of workers and communities. For example, decomposing organic waste attracts disease vectors such as insects, rats and other vermin, and the products of decomposition can leach into the ground and watercourses making them polluted and no longer safe; open burning of waste leads to air pollution; and improper handling of hazardous materials can lead to both acute and long-lasting risks to public health and the environment. Solid waste is also a major contributor to global climate change principally through patterns of resource use, transportation and direct emissions from waste decomposition in landfills. Post-consumer waste is estimated to account for almost 5% (equivalent to 1,609 tons of CO<sub>2</sub>) of total global Greenhouse Gas (GHG) emissions.<sup>2</sup>

In developing countries, technical and financial resource limitations can adversely influence solid waste management practices, magnifying associated risks to public health and the environment. In many areas

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<sup>1</sup> World Bank 2012. What a Waste: A Global Review of Solid Waste Management. [https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What\\_a\\_Waste2012\\_Final.pdf](https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf)

<sup>2</sup> Ibid.

of developing countries, organized waste management activities can be extremely limited; leading to extensive littering of public areas, uncontrolled dumpsites and landfills, open burning of waste, and little differentiation between domestic and hazardous wastes. High population growth in urban areas can put intense pressure on available waste management infrastructure and resources, and in the worst-affected areas this situation may create near intolerable conditions for communities.

Informal participation (i.e. unofficial employment and economic activity) also makes a significant contribution to waste management in many countries, including ‘picking’ or ‘reclaiming’ recyclables at households, businesses, in streets, and at dumpsites or landfills, and in waste collection/carting, trading and reprocessing.<sup>3, 4</sup> Many impoverished people are dependent on these activities for their livelihoods, and they make an important contribution to the sector, reducing costs for public authorities; but they can also be associated with economic insecurity, social problems, and inadequate health and safety provision.<sup>5</sup> Any action affecting the informal sector can have a wide range of social, political and economic implications. For example, due to a lack of ‘formal data’ and record keeping, public authorities sometimes fail to recognize the role of informal workers in waste management systems, leading to loss of livelihoods in the process of modernization. Therefore, more data may be needed to assess the extent of the informal sector as part of waste planning activities. The informal sector can also represent a significant resource if incorporated into waste projects and programs, and this should not be overlooked.

International trade of wastes, including recyclables, e-waste and hazardous materials can also place increased burden on the environment and infrastructure of developing countries.<sup>6</sup> Developing countries often lack the ability to adequately manage imported solid waste, and a substantial amount is also illegally diverted to unregulated markets where treatment and disposal occurs in the informal sector, both of which can cause significant environmental pollution and public health risks.<sup>7</sup> Widely cited examples include ship-breaking (i.e. dismantling and scrapping of large commercial vessels) in Bangladesh, and e-waste processing in West Africa. Although the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal prohibits international trade in hazardous waste that does not comply with its strict environmental regulatory system, such practices are widely reported in the international media, particularly in relation to the trade in e-Waste (see Section 2.7).

Given the above issues, there are significant opportunities for improving solid waste management in developing countries. Priorities for sustainable waste management systems include minimizing or eliminating uncontrolled dumping and burning of wastes; provisions for proper treatment and disposal of hazardous wastes; reducing health and safety risks, as well as social and economic vulnerability, for the

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<sup>3</sup> Scheinberg et al. (2010) define the informal solid waste sector as “individuals or enterprises who are involved in private sector recycling and waste management activities which are not sponsored, financed, recognized, supported, organized or acknowledged by the formal solid public waste management authorities, or which operate in violation of or in competition with formal authorities.”

<sup>4</sup> This activity is also widely referred to as ‘scavenging’, but the term can have derogatory connotations.

<sup>5</sup> The number of informal waste workers is difficult to calculate with accuracy as they are largely undocumented and difficult to generalize. However, it is estimated that there are between 5–56 million people worldwide working in the informal sector in waste management. See: Institute of Civil Engineers (ICE) (2013)

[https://www.researchgate.net/publication/274347188\\_Role\\_and\\_size\\_of\\_informal\\_sector\\_in\\_waste\\_management\\_-\\_a\\_review](https://www.researchgate.net/publication/274347188_Role_and_size_of_informal_sector_in_waste_management_-_a_review)

<sup>6</sup> Trade in hazardous waste includes such wastes originating in developed countries, where strict regulations incentivize generators to take advantage of looser regulations and lower costs in developing countries. However, a significant amount of waste trade is between developing countries.

<sup>7</sup> Diaz-Barriga F. (2013) Evidence-based intervention programs to reduce children’s exposure to chemicals in e-waste sites. Discussion paper for WHO Working Meeting on e-waste and children’s health. 1–90.

public, workers, and the informal sector; maximizing recovery of energy and resources; and providing efficient, effective and inclusive services for all. Key principles for developing and implementing sustainable waste management systems include:

- ‘The proximity principle’ - waste should be dealt with close to where it originates.
- ‘The polluter pays principle’ - the producer should pay the full cost of managing waste sustainably, as well as the cost of managing any associated environmental impacts.
- ‘The waste hierarchy’ - the priority in which resources should be managed to reduce waste: from the most sustainable, to the least sustainable, waste management practices (see Section 3.1.1).

Provision of sustainable waste management systems requires building the capacity of public waste management authorities; investing in infrastructure; supporting the private sector; and development and implementation of robust laws, regulations and standards. Investments in solid waste management systems should be integrated, in line with strategic plans, and based on robust data and assessments of risk, cost-benefit, social return on investment, environmental and social impacts, sustainability, Life-Cycle Analysis (LCA) and others, as necessary.

### **1.3 USAID INTERVENTIONS IN SOLID WASTE MANAGEMENT**

USAID’s development and humanitarian interventions targeting the solid waste management sector help public authorities and communities in the developing world to improve the capacity, systems and infrastructure needed to manage solid waste through financial and technical assistance and partnerships. Although USAID does not categorize waste management as a ‘technical sector’ per se, such projects, programs and activities contribute to development objectives across all sectors through improvements to public health, the environment, livelihoods, and resource conservation; as well as mitigation of climate change impacts and resilience to natural disasters.

USAID interventions could include:

- Strengthening local actors through capacity building activities for public authorities and service providers.
- Developing and implementing policy, guidelines and improving regulatory enforcement.
- Raising awareness of issues and encouraging behavioral change in communities and businesses.
- Development and testing/piloting of locally-appropriate, innovative waste management technologies and processes and approaches to minimization, reuse, recycling and waste management.
- Improving communication and coordination between government institutions, civil society, researchers, and private sector entities.
- Promoting social inclusion in solid waste management by engaging groups which are underrepresented in local power structures, such as women, youth, and informal waste workers.
- Undertaking applied research to identify locally-appropriate technology and improve decision-making, gaps or obstacles in solid waste management systems.
- Enabling private sector and markets to develop and implement market-driven solutions; and facilitating new partnerships, including between public and private sector.

Illustrative examples of USAID Waste interventions include:

- The Municipal Waste Recycling Program to Reduce Plastics Pollution of the Oceans in Indonesia, Philippines, Sri Lanka, and Vietnam;<sup>8</sup>
- Facilitating the privatization of solid waste management services in Egypt;<sup>9</sup>
- Capacity building, including provision of a waste strategy, implementation plans, and training for public authorities, under the Armenia Government support program;<sup>10</sup> and
- Community Based Solid Waste Management programs in Indonesia under the Environmental Services Program, and Mozambique under the Coastal City Adaptation Project.<sup>11,12</sup>

## 2 SOLID WASTE TYPES AND STREAMS

What constitutes a solid waste is generally determined by host country legislation, or in the absence of a legal definition, a relevant internationally accepted definition, but usually includes solid or semi-solid materials that have been discarded (i.e., abandoned), disposed, stored in lieu of being disposed, or are ‘inherently waste-like’. Solid waste can be further classified by the overlapping categories of origin, constituent materials and methods of management. For this SEG, descriptions of common categories of solid waste are provided below. It should be noted that these categories are not rigidly defined, mutually exclusive or comprehensive, and may vary according to local conventions or regulations.

### 2.1 MUNICIPAL SOLID WASTE

Municipal Solid Waste (MSW) is solid waste generated by households, businesses, public institutions (e.g., schools, ministries and government offices), litter and refuse collected from street cleaning services, gully detritus, and beach cleansing. MSW is normally collected by municipal authorities but can also be undertaken on their behalf by the private sector (e.g. business or private non-profit institutions)).<sup>13</sup> MSW sometimes include bulky waste but excludes wastewater from municipal sewage networks, and construction and demolition wastes. Household hazardous waste may (or may not) be included, but industrial and other hazardous wastes are not. Waste generated at the household level is often referred to as ‘residential’ or ‘domestic’ waste.

The composition of MSW is highly variable and influenced by many factors. Urbanization and development lead to increased consumption of inorganic materials (such as plastics, paper, and metals),

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<sup>8</sup> USAID 2018. Municipal Waste Recycling Program (MWRP) to Reduce Plastics Pollution of the Oceans – Indonesia, Philippines, Sri Lanka, and Vietnam. [https://www.usaid.gov/sites/default/files/documents/1861/MWRP\\_APS\\_as\\_Amended\\_2018\\_01.pdf](https://www.usaid.gov/sites/default/files/documents/1861/MWRP_APS_as_Amended_2018_01.pdf)

<sup>9</sup> USAID Undated. Privatizing Solid Waste Management Services Challenge.

[https://www.usaid.gov/sites/default/files/success/files/cs\\_egypt\\_waste.pdf](https://www.usaid.gov/sites/default/files/success/files/cs_egypt_waste.pdf)

<sup>10</sup> Vanoyan M. et al. Undated. Solid Waste Management in Armenian Cities. [http://www.pf-armenia.org/sites/default/files/uploads/pfa\\_uploads/tasima15\\_beitrag\\_USAID\\_2010\\_08-26.pdf](http://www.pf-armenia.org/sites/default/files/uploads/pfa_uploads/tasima15_beitrag_USAID_2010_08-26.pdf)

<sup>11</sup> USAID Environmental Services Program (ESP). <https://www.globalwaters.org/HowWeWork/Activities/environmental-services-program>

<sup>12</sup> USAID 2015. IEE Approval Fact Sheet. Coastal City Adaptation Project Mozambique.

<https://ecd.usaid.gov/repository/pdf/43811.pdf>

<sup>13</sup> See glossary.



while the relative organic fraction decreases. According to the World Bank, developing countries have a high percentage of organics in the waste stream, ranging from 40 to 85%.<sup>14</sup>

High-income countries, although they only account for 16 percent of the world's population, currently account for the greatest portion of the approximately 2.2 billion tons of MSW produced annually (34% or 753 million tons).<sup>15</sup> By contrast, low-income countries account for 9 percent of the world's population but generate only about 5 percent of global waste, or 103 million tons. The East Asia and Pacific region is the largest generator of MSW producing 516 million tons in 2016.

The World Bank estimates that average per capita generation of MSW in 2016 was 1.63 lb of waste per capita per day, but this varies widely by location from 0.24 lb to 10 lb per capita per day. Generation rates are highly correlated with economic development. Sub-Saharan Africa averages 1.01 lb per day, South Asia 1.15 lb per day, and East Asia and Pacific 1.23 lb per day, compared to 4.87 lb per day in the high-income countries of the US, Bermuda and Canada.<sup>16</sup>

MSW generation is expected to rise to 3.7 billion tons by 2050, much of this growth will come from low and lower-middle income countries due to rapid population growth, urbanization, and rises in per capita generation driven by increasing consumption resulting from economic development and a burgeoning middle class.<sup>17</sup> Waste levels in low-income countries are expected to more than triple by 2050.

In most parts of the world, it is the role of public authorities (e.g., municipalities) to collect and manage MSW, and this usually accounts for a sizeable proportion of its budget. In some cases, private haulers are contracted to collect the wastes or implement treatment/disposal. However, services are often sporadic, leading to informal dumpsites, open burning and litter. Materials which have value are generally removed by informal waste pickers prior to disposal, or after disposal at landfills and dumpsites.

## **2.2 COMMERCIAL AND INDUSTRIAL WASTE**

Commercial and industrial wastes are part of the MSW stream and are often grouped together, but there are key differences in composition and characteristics between them. Both are highly variable and can be grouped into many sub-categories.

Commercial waste is generated from a wide range of sources including offices, retail, hotels, restaurants, markets, and other light industry. Construction Demolition and Excavation (CDE) wastes and agricultural wastes, are also sometimes considered to be commercial wastes, although these are usually managed separately. The composition of commercial wastes depends on the source. Markets and supermarkets produce large quantities of organic waste and corrugated cardboard, whereas waste from offices usually includes high-quality paper and plastics. Some commercial activities generate small quantities of hazardous wastes, such as laundries and vehicle servicing/repair shops.

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<sup>14</sup> World Bank 2018. What a Waste 2.0 <https://openknowledge.worldbank.org/handle/10986/30317>

<sup>15</sup> According to UNEP/ISWA 2015. Organization for Economic Cooperation and Development (OECD) countries currently generate 50% of total worldwide MSW.

<sup>16</sup> Ibid.

<sup>17</sup> Ibid.

Industrial waste is typically produced by manufacturing activities and heavy industry (e.g., power stations, processing plants). Composition of the waste stream is dependent on the industry or individual facility in question. For example, vegetable waste from a food preparation factory, metal shavings from an engineering plant, and a wide range of metal, plastic and chemical wastes from automotive manufacturing. Many industrial processes have specific wastes and by-products, some of which require special treatment due to their properties (e.g., hazardous, bulky). While others are readily recycled or reused as they have economic value (e.g., waste vegetables for animal feed, waste metals for reprocessing, and/or wooden pallets for reuse), and because quality and reliability are easier to control. Industrial wastes may also be treated on-site (e.g., incineration or anaerobic digestion of homogenous feedstocks for power generation). Certain types of waste may be suitable for beneficial uses, such as fertilizers (e.g., brewery wastes), but this should be subject to strict regulatory control.

### **2.3 AGRICULTURE, FISHING AND FORESTRY WASTE**

Agriculture, fishing and forestry waste comes from a branch of manufacturing and trade based on growing and/or harvesting of organic commodities. This includes production of agricultural crops and livestock; agro-industrial production; hunting, trapping, and fishing; fish farming; and forestry. Lumber and wood products may not be included if they are classified as an industrial or a commercial waste. Agriculture, forestry and fishing produce significant quantities of organic wastes (e.g., manure/slurry, crop biomass, and animal remains), and potentially hazardous chemical wastes (e.g., herbicides, pesticides, fertilizers and ripeners), and used oil.

Organic wastes can often be managed effectively where they are produced. Applying animal manures and crop residues to land to improve soils is practiced worldwide. Regulating where, when, how, and how much manure is added to the land at one time reduces the risk of nutrient rich materials contaminating surface or groundwater. Reuse of animal wastes can be linked to disease outbreaks (e.g., contaminated animal feed from waste causing Foot and Mouth Disease). The movement of agriculture and forestry wastes may also need to be controlled to prevent the spread of pests and tree diseases.

Agricultural wastes supply a sizable proportion of total biofuel used in developing countries. Dried animal dung and crop products are an important fuel for cooking or heating in many areas. However, uncontrolled burning in homes can lead to serious health effects. On farm composting and anaerobic digestion of organic wastes can provide financial benefits for producers from use or sale of products. For example, in the dairy industry, manure from cows can be digested, and produced biogas is used to power milking sheds. Although such systems can be capital intensive, many opportunities exist for smallholders and cooperatives to use residual products for waste-to-energy and composting. For example, utilization of crop residues instead of burning them in fields, which is common in many rural areas.

Despite the persistency of food insecurity in some regions, more than a third of total food production is wasted globally. As agricultural production in developing countries becomes commercialized, food production industrialized, and consumption patterns intensify, food losses and wastage is likely to become a more significant issue.

## 2.4 CONSTRUCTION, DEMOLITION AND EXCAVATION WASTE

CDE waste arises from activities relating to the construction or demolition of buildings and infrastructure, infrastructure maintenance, and spoils from civil engineering works. CDE waste includes materials such as excavated soils, bricks, insulation, ceramics, glass, wood, sand and aggregates, which have high potential for reuse and recycling, and technology for recovery of CDE waste is well established. Aggregates are increasingly used in construction, for example as an additive in concrete or as a road base, and beneficial use of uncontaminated excavation waste as fill material can lead to significant cost savings on construction projects.

Other materials generated during construction include empty containers and packaging (e.g., from chemicals, paints and fuels, cement packaging), and used formwork, pallets and oily rags, which may be tainted with hazardous materials. Increasingly plastics (e.g., PVC) and composite materials are used in construction, some of which may be difficult to recycle. Demolition waste can contain a range of materials, which could include hazardous materials such as asbestos, decommissioned chemical or fuel tanks, and lead. Excavated soils may contain contamination depending on previous site or upstream usages (e.g., hydrocarbons at a vehicle depot) or from natural sources (e.g., naturally occurring radioactive materials).

Construction consumes a sizeable proportion of available raw materials, including virgin wood, sand aggregate and other building materials. Many environmental and social impacts occur from the extraction of these materials, especially where they are scarce or form sensitive habitat. Transportation of wastes is often expensive and can have significant effects on traffic and the road network, due to large mass and volumes of materials. CDE wastes disposed of in landfill occupies valuable airspace and increases use of new and virgin materials. Consequently, there is a growing drive to manage resources more effectively and reduce costs in the construction sector by reducing CDE waste generation and increasing reuse and recycling.

In developing countries, the high-cost of building materials compared to labor can serve as an incentive to reduce wastage. However, management of wastes is sporadic, with materials often illegally dumped. Legislation, penalties, pricing controls and effective enforcement, and availability of formal collection and disposal systems may be required to control illegal dumping of CDE wastes.

CDE is often a major source of the total wastes requiring management, particularly in growing urban areas. Therefore, there is a need to reconcile economic progress with sustainable construction and demolition waste management.

## 2.5 HAZARDOUS WASTE

Although the definition of a hazardous waste will depend upon the host country's legislation, in general, a hazardous waste has properties that make it dangerous or capable of having a harmful effect on human health or the environment. Hazardous waste is generated from many sources, ranging from industrial process by-products and mining wastes, to batteries and common household cleaners; and can come in different forms such as solids, liquids, and sludges (US EPA). US law categorizes hazardous waste based on it having one or more of the following characteristics:

- Ignitability – something that is flammable.

- Corrosivity – something that can eat away its container or has a pH that is less than or equal to 2 or greater than 12.5.
- Reactivity – something that is unstable, potentially explosive, or can release toxic gases or result in violent explosions when mixed with water.
- Toxicity – toxic materials are those that are poisonous and can potentially have long-term effects on human health and the environment. Some toxic materials can cause cancer as a result of long-term exposure.

In some countries, wastes can be predefined or “listed” as hazardous if they are a by-product associated with a specific industry or manufacturing process or contain particular chemical elements or compounds.

Examples of hazardous waste include asbestos, chemicals, such as brake fluid or print toner, batteries, solvents, pesticides, oils (except edible ones), equipment containing ozone depleting substances (e.g., fridges) and hazardous waste containers. Hazardous materials will normally be present in small quantities in MSW, but significant volumes can be generated from industrial activities, construction, demolition, contaminated land remediation, mining and agriculture.

Hazardous waste can cause significant environmental pollution and risks to public health, and must be managed appropriately, using trained/qualified personnel, licensed or registered contractors, and appropriate equipment and facilities. Each waste will need to be identified, classified, stored and either recycled, recovered, treated, destroyed or disposed of using appropriate specialist methods. In developing countries, management of hazardous wastes is often deficient, with such materials being disposed of with MSW at landfills and dumpsites. Disposal of hazardous wastes to land without detailed knowledge of the waste can significantly increase risks to public health and the environment. The introduction, management and enforcement of a regulatory process that tracks waste from producer to final disposal is an important aspect of managing hazardous materials effectively.

## **2.6 MEDICAL AND HEALTHCARE WASTE**

Medical and healthcare waste (sometimes referred to as clinical waste) is generated by healthcare facilities like clinics, hospitals, dental practices, medical laboratories and research facilities, care homes and veterinary clinics. Medical and healthcare wastes can contain a range of potentially hazardous and highly infectious materials including, body parts and fluids, unused pharmaceuticals and used containers, needles, glass products, sharps and other medical equipment.

Non-hazardous MSW arising at medical facilities may be categorized as an ‘institutional waste’. The presence of medical and healthcare wastes in the domestic waste stream and at dumpsites poses significant risks to public health, and the health and safety of waste pickers and other workers. Pharmaceutical wastes are a growing source of water pollution as pharmaceutical chemicals entering domestic sewers can bypass municipal wastewater treatment systems and enter the environment via discharge and reuse of effluents.

The introduction, management and enforcement of a regulatory process that tracks the waste from the producer to the ultimate point of disposal is an important feature of managing medical and healthcare wastes effectively.

Refer to the USAID Healthcare Waste SEG (2015) for further details on medical and healthcare wastes (see <http://www.usaidgems.org/Sectors/healthcareWaste.htm>).

## 2.7 WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT

Waste Electrical and Electronic Equipment (WEEE) (or e-Waste) covers a range of equipment containing electrical parts (e.g., they require an electrical source to operate), which has come to the end of its useful life. Examples of WEEE include used white goods (e.g., fridges, washing machines) kitchen appliances, power tools, air conditioning units, TVs, mobile phones, lighting and lightbulbs and many other devices. Other less-obvious items such as electrical cables, Radio-Frequency Identification (RFID) tags, batteries and solar panels may (or may not) be included in the definition, depending on applicable regulations. The quantity of WEEE generated is increasing in most regions due to growing consumption of electronic products, particularly in the urban areas of developing countries with fast growing economies.

WEEE can contain hazardous materials such as heavy metals, batteries, and persistent organic pollutants (POP), which can be released to the environment if not appropriately handled and managed. WEEE also includes materials which can be profitable when recovered, including small quantities of precious and 'rare-earth' metals, as well as plastic, metals and glass. Recovery of these materials can present economic opportunities and is widely carried out in developing countries such as China, India, Ghana and Nigeria. In some developing countries, much of the WEEE recycled is managed in the informal sector or in small scale reprocessing facilities. Technical, environmental, and infrastructure conditions in such countries is often highly inadequate.<sup>18</sup> The environmental and social consequences are well publicized in the international media.<sup>19,20</sup>

Despite media attention, there is contrasting information on the origin of WEEE in developing countries. For example, a study from Perkins et al (2014) found that approximately 75% to 80% of the estimated 20-50 million tons of e-waste generated annually is shipped to countries in Asia and Africa, of which, as little as 25% is recycled in 'formal' facilities.<sup>21</sup> In contrast, a study by UNEP and the US found that the majority of WEEE processed in Africa's urban dump sites originated from domestic sources.<sup>22,23</sup>

Some developing countries have introduced legislation for proper management of WEEE; however, compliance and enforcement are usually low. Improving the management of WEEE in developing countries requires development of a robust legislation and regulatory framework, infrastructure, and

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<sup>18</sup> Perkins et al. 2014. E-Waste: A Global Hazard. <https://www.sciencedirect.com/science/article/pii/S2214999614003208>

<sup>19</sup> The Guardian 2014. Agbogbloshie: the world's largest e-waste dump – in pictures.

<https://www.theguardian.com/environment/gallery/2014/feb/27/agbogbloshie-worlds-largest-e-waste-dump-in-pictures>

<sup>20</sup> The Guardian 2018. Deluge of Electronic Waste Turning Thailand into World's Rubbish Dump.

<https://www.theguardian.com/world/2018/jun/28/deluge-of-electronic-waste-turning-thailand-into-worlds-rubbish-dump>

<sup>21</sup> Perkins et al. 2014.

<sup>22</sup> Basel Convention Undated. Where are WEEE in Africa?

[http://www.basel.int/Portals/4/Basel%20Convention/docs/pub/WhereAreWeeInAfrica\\_ExecSummary\\_en.pdf](http://www.basel.int/Portals/4/Basel%20Convention/docs/pub/WhereAreWeeInAfrica_ExecSummary_en.pdf)

<sup>23</sup> US International Trade Commission 2012. Used Electronic Products: An Examination of U.S. Exports.

<https://www.usitc.gov/publications/332/pub4379.pdf>

management systems based on the principle of ‘Extended Producer Responsibility’<sup>24</sup>, as well as engagement with the private and informal sectors.

The US EPA works with international governments, and intragovernmental agencies, to support the US Government’s National Strategy for Electronics Stewardship, which plans to enhance the management of electronics throughout the product lifecycle, and to exchange best management practices in e-waste management (see Box I).

#### BOX I. CASE STUDY: US EPA PARTNERS WITH DEVELOPING COUNTRIES TO PROMOTE SUSTAINABLE E-WASTE MANAGEMENT



#### Cleaning Up Electronic Waste (e-Waste)

In support of the goals of the National Strategy for Electronics Stewardship, the US EPA works with partners in Asia/Pacific, Latin America and the Caribbean, the Middle East and Africa to develop and support projects on the sustainable management of e-Waste. In Africa, the EPA is engaged in numerous partnerships including in:

**Ethiopia:** Through cooperation with the United Nations University Solving the e-Waste Problem (UNU-Step), EPA worked in Ethiopia with government officials, as well as industry and NGO stakeholders, to strengthen the capacity of a de-manufacturing facility that can safely recycle end-of-life used electronics.

**Nigeria:** In 2015, the UNU-StEP Initiative, with financial support from EPA and the German Senior Expert Service, launched a Person-in-the Port (PiP) Project in Lagos, Nigeria. Through the PiP Project, a Nigerian e-Waste expert collected qualitative and quantitative information on imports of electronics into the Port of Lagos over a period of 6 months. This effort could serve as a model for countries with e-Waste import problems that wish to gain a better understanding of the flows of used electronics and e-Waste.

Source: <https://www.epa.gov/international-cooperation/epa-collaboration-sub-saharan-africa>

## 2.8 FECAL WASTE AND SEWAGE SLUDGE

Management and disposal of fecal waste from humans and treated sewage sludge is a key issue in areas where sanitary infrastructure is inadequate. Please refer to the USAID Water and Sanitation SEG for further information (See: <http://www.usaidgems.org/Sectors/watsan.htm>).

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<sup>24</sup> The producer, importer, or seller is responsible for appropriate handling of equipment throughout its lifecycle, including post-consumer recycling and final disposal.

### 2.8.1 HUMAN AND ANIMAL WASTE

Pit latrines, septic tanks and unsewered public toilets or open defecation gives rise to human fecal wastes which can cause localized pollution and represents a significant risk to public health. Despite considerable progress, in recent times, only around 39% of the world's population has access to safe sanitation, while 12% still practice open defecation.<sup>25</sup> Fecal waste is also used by farmers as fertilizer for crops, which risks spreading pathogens to land, waters and the food chain. Human waste can also enter the MSW stream, where both waste and wastewater management systems are underdeveloped, leading to significant cross-contamination. Conversely, when domestic waste collection services are unavailable, solid waste is often disposed of in latrines or wastewater infrastructure (up to 25% of pit latrine content by volume may be solid waste).

Management of human waste requires safe storage, collection, transport, treatment and end use or disposal of sewage to protect public health and the environment. Critically, open defecation should be eliminated where possible, and proper sanitary systems developed (see USAID Water Supply and Sanitation SEG). Where human waste needs to be recovered from latrines and unsewered toilets, this should be done using appropriate equipment (e.g., vacuum tanker), and the waste should be disposed of at a municipal sanitary facility.

### 2.8.2 SEWAGE TREATMENT SLUDGE

Sewage sludge is generated as a by-product of wastewater treatment. It is often used as a soil conditioner, in developed and developing countries. Similar considerations must be given as to fecal waste to ensure its suitably treated before its end use or disposal.

When properly managed, sewage sludge has potential for reuse and resource recovery. But if this is not feasible or cost effective, incineration or disposal in landfill are also potential management options. When designing fecal waste management systems, the end use or disposal option of sludge should first be determined, so that the treatment can be designed accordingly. In many developing countries the status of sanitation systems is inadequate. Therefore, the focus in the short term should be on critical interventions that have an immediate impact on human health and environmental protection. In the long term, markets for resource recovery and reuse products can be developed.

## 2.9 PLASTIC WASTE

Plastic waste forms a relatively substantial proportion (up to around 20%) of household waste in many urban areas of developing countries. Additionally, many developing countries import post-consumer plastics from other countries for reprocessing, most of which ends up as waste. In the absence of proper waste management systems, much of the plastic waste is improperly disposed of in informal dumpsites or as litter. As it is uncontained, most plastics eventually end up in water courses and the ocean, washing up on river banks and beaches and affecting ecologically sensitive areas like coral reefs. This is a major and persistent problem for many developing world countries. As illustrated in the case study provided in Box 2, local entrepreneurial initiatives with international development support such as

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<sup>25</sup> WHO/UNIVER Joint Monitoring Programme for Water Supply and Sanitation  
<https://data.worldbank.org/indicator/SH.STA.ODFC.ZS?end=2015&start=2000&view=chart>

Environmental Cleaning Solutions S.A. in Haiti, can play a key role in preventing and cleaning up plastic waste, while supporting local employment.

#### BOX 2. CASE STUDY: PREVENTING PLASTIC WASTE THROUGH ENTREPRENEURSHIP IN PORT-AU-PRINCE, HAITI



Haiti has been struggling with ever increasing quantities of untreated waste, including plastic waste, which is polluting the streets, parks, rivers, and the ocean. The plastic is clogging sewage systems, especially in the capital, Port-au-Prince, causing further environmental concern.

In 2010 Edouard Carrié, a Haitian entrepreneur, created a recycling business, Environmental Cleaning Solutions S.A. (ECSSA) to keep the streets, canals and vacant lots of Port-au-Prince clean, as well as to provide income to Haiti's poorest households. The scheme provides cash to people depositing bags of discarded plastic bottles at 65 collection points throughout the Port-au-Prince region. In 2012, ECSSA collected, compacted and shipped nearly 300 million bottles, close to 1 million bottles every day, for further processing into recycled plastic pellets that are used in over 120 countries to make everything from T-shirts to tables.

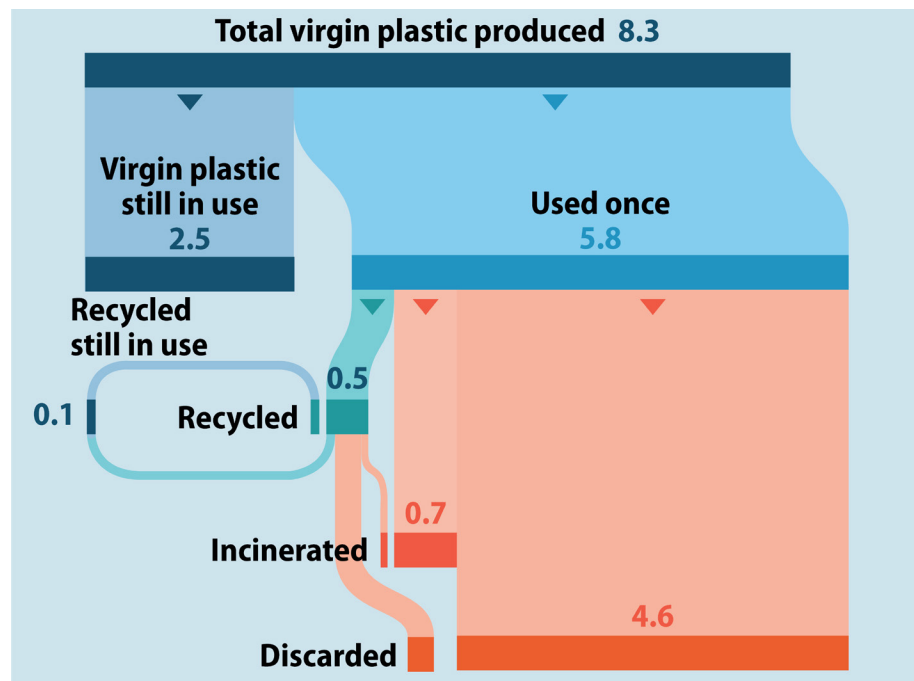
To raise capital for the next phase of business expansion, Carrié applied for a matching grant through the Leveraging Effective Application of Direct Investments (LEAD) Business Plan Competition, funded by USAID and implemented by the Pan American Development Foundation (PADF). Carrié says that *“USAID and PADF’s LEAD investment is allowing ECSSA to ramp up collection and provide more Haitian households with the opportunity to earn income”*. *“My company now has the capacity to increase its individual collectors from 6,000 people to up to 20,000. Additionally, the increase in collection points and processing capacity provide entrepreneurs the opportunity to grow their own businesses by serving as intermediary plastic collectors and suppliers for ECSSA.”*

Source: <https://2012-2017.usaid.gov/results-data/success-stories/generating-income-while-keeping-streets-clean-haiti>, and, <https://leadinvestmentshaiti.info/ecssa/>



Use of plastics has consistently grown over the last 50 years, from 1.6 million tons/year in 1950 to more than 355 million tons in 2015.<sup>26</sup> Within this time, it is estimated that cumulatively around 9.1 billion tons of plastic has been produced, most of which was used only once before being discarded, as illustrated in Figure 1.<sup>27</sup>

FIGURE 1. GLOBAL PLASTIC PRODUCTION AND USE



Source: Economist (2018), adapted from Geyer et al. (2017).

Plastics recovered in the recycling programs of major economic centers, such as North America and Europe, established a system of shipping bales of sorted post-consumer plastics for reprocessing in developing countries – predominantly China, and to a lesser extent India, Vietnam and Indonesia (where they are made into consumer products and often shipped back to the same markets). A sizeable proportion of the material has been disposed of in their landfills or due to poor regulatory, infrastructural and environmental controls has ended up polluting land and waters. Poor waste management combined with domestic production of plastic waste, means that the developing world is a major source of marine plastic pollution. According to a paper by the Helmholtz Centre for Environmental Research in 2017, up to 90% of the estimated 11 million tons per year of marine plastic pollution is said to reach the ocean via ten rivers, two of which are in Africa and the rest are in Asia.<sup>28</sup>

When dispersed by currents plastics are difficult to retrieve and can be found everywhere, from the remote shores of uninhabited islands, in Arctic ice, the deep ocean and in vast areas of ocean waste fed by currents. Plastics do not decompose like organics and accumulate in the environment for many

<sup>26</sup> Association of Plastics Manufacturers (2017) Plastics – The Facts.

[https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics\\_the\\_facts\\_2017\\_FINAL\\_for\\_website\\_one\\_page.pdf](https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf)

<sup>27</sup> Geyer et al. (2017) Production, use, and fate of all plastics ever made. <http://advances.sciencemag.org/content/3/7/e1700782>

<sup>28</sup> Helmholtz Centre for Environmental Research (2017) [https://www.ufz.de/index.php?en=36336&webc\\_pm=34/2017](https://www.ufz.de/index.php?en=36336&webc_pm=34/2017)

hundreds or thousands of years. Instead salt, sunlight and physical action cause plastics to degrade into smaller and smaller pieces, eventually becoming microplastics.<sup>29</sup>

The harmful effects of plastic on aquatic organisms, include physical hazards from ingestion and entanglement, and toxicological threats from ingestion of contaminants in plastic particles. It is estimated that plastic marine debris adversely affects at least 267 species globally, including 86% of sea turtles, 44% of seabirds, and 43% of marine mammals.<sup>30</sup>

## 2.10 OTHER WASTES

### 2.10.1 TIRES

Tires are produced in vast quantities globally, and the safe and sustainable storage and disposal of End of Life (EOL) tires are a significant issue. Up to four billion are estimated to be held in stockpiles and landfills.<sup>31</sup> In some developing countries, growing automobile use and waste tire imports from developed countries, coupled with poor management and illegal dumping means that this aspect of waste management requires urgent attention. For example, in Thailand it has been estimated that up to 40% of EOL tires were dumped in the open environment in 2012.<sup>32</sup>

Tires degrade slowly, remaining substantially intact for decades, and have a large volume and void space so they can consume valuable space in landfills. Additionally, some of their components can release pollutants, such as zinc, chromium, lead, copper, cadmium and sulfur, into the ground and waters as they degrade. They are often stored in large piles which can cause fires that are difficult to control. Fires involving waste tires cause significant atmospheric pollution which can be harmful to human health.

Landfilling of whole tires is banned in some countries (e.g., most states in the US) and recycling mandatory. Tires can be successfully recycled or recovered in several ways. The steel they contain can be removed and recycled, the tires can be combusted in a controlled way for energy generation or shredded for reuse in new tires or road aggregate. Tire-derived fuels are also commonly used in cement kilns and other industrial processes.

### 2.10.2 WASTE OIL

Waste oils such as spent engine oil, which has been removed from combustion engines during periodic maintenance, mineral oils, and waste cooking oil are a valuable resource. Waste oil can be collected through interceptors in garages and storage tanks which is normally contaminated with water and requires treatment for separation. These waste oils are typically recycled as a heating boiler fuel

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<sup>29</sup> It is estimated that as much as 51 trillion microplastic particles are contained in the oceans, including degraded plastics, fragments of polyester caused by washing clothing, industrial spills and microbeads intentionally added to consumer products (Economist 2018).

<sup>30</sup> European Commission (2011) Plastic Waste in the Environment:

<http://ec.europa.eu/environment/waste/studies/pdf/plastics.pdf>

<sup>31</sup> World Business Council for Sustainable Development (WBCSD) ELT management | A global state of knowledge on collection rates, recovery routes, and management methods.

[https://docs.wbcsd.org/2018/02/TIP/WBCSD\\_ELT\\_management\\_State\\_of\\_Knowledge\\_Report.pdf](https://docs.wbcsd.org/2018/02/TIP/WBCSD_ELT_management_State_of_Knowledge_Report.pdf)

<sup>32</sup> Ibid.

following filtering and analysis to ensure their combustion would not cause pollution. Where the oils are too contaminated they are typically burned for heating in more advanced systems which can reduce/capture pollutants produced. If the oils are heavily contaminated, they may be disposed of in an incinerator with appropriate emission controls.

### 2.10.3 END OF LIFE VEHICLES AND SCRAP

End of Life Vehicles (ELVs) are vehicles such as cars, light commercial vehicles, trucks, buses, and mobile plant, which have come to the end of their useful life. Materials and components in ELVs have economic value, and typically around 80% or more can be salvaged for spare parts or recycled (mostly metals, rubber, glass, plastics). ELVs also contain fluids (e.g., petrol and diesel fuels, oils, brake fluid, coolant, antifreeze) and components (e.g., batteries, gearboxes, mercury switches, catalytic converters, airbags) which are hazardous or potentially polluting, and require special storage, handling and disposal at appropriate facilities. Good practice during recovery includes draining fluids and removing hazardous parts from ELVs in a covered hard-standing, then storing them in a separate dedicated and controlled area, prior to recovery or disposal at an appropriate facility (such as a double-lined landfill).

In developing countries, recovery of ELVs usually takes place at small workshops and scrap yards or in the informal sector (e.g., at dumpsites). Governance issues and lack of resources mean that activities may take place using sub-standard processes and equipment in the absence of environmental controls and worker welfare provisions. In this situation the recovery and disposal of ELVs can represent a significant risk to public health and the environment. Hazardous materials can leak directly into ground during breaking, when abandoned, or when disposed of at uncontrolled dumpsites. Exposure of workers to hazardous materials and physical injuries due to poor health and safety provisions can also lead to occupational health and safety impacts for workers, while unregulated use of salvaged parts can cause traffic accidents.

Due to growing population and increasing per capita ownership of vehicles, the requirement for management of ELVs is rapidly expanding, leading to increasing pressure on public waste management authorities and environmental risks.

## 3 WASTE MANAGEMENT SYSTEMS: REDUCTION, COLLECTION, TREATMENT AND DISPOSAL

### 3.1 WASTE REDUCTION

Waste generation is increasing rapidly due to globalization, unsustainable consumption and production patterns, economic development and population growth. The World Bank has estimates that the amount of MSW will rise from 2.2 billion tons per year in 2016 to 3.4 billion by 2050.<sup>33</sup> Its long-term forecast is for waste volumes to triple by the end of the century. The greatest proportion of the average annual increase will come from rapidly growing cities in developing countries. Urbanization is also

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<sup>33</sup> World Bank. 2012. What a Waste: A Global Review of Solid Waste Management. Available at [http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What\\_a\\_Waste2012\\_Final.pdf](http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf)

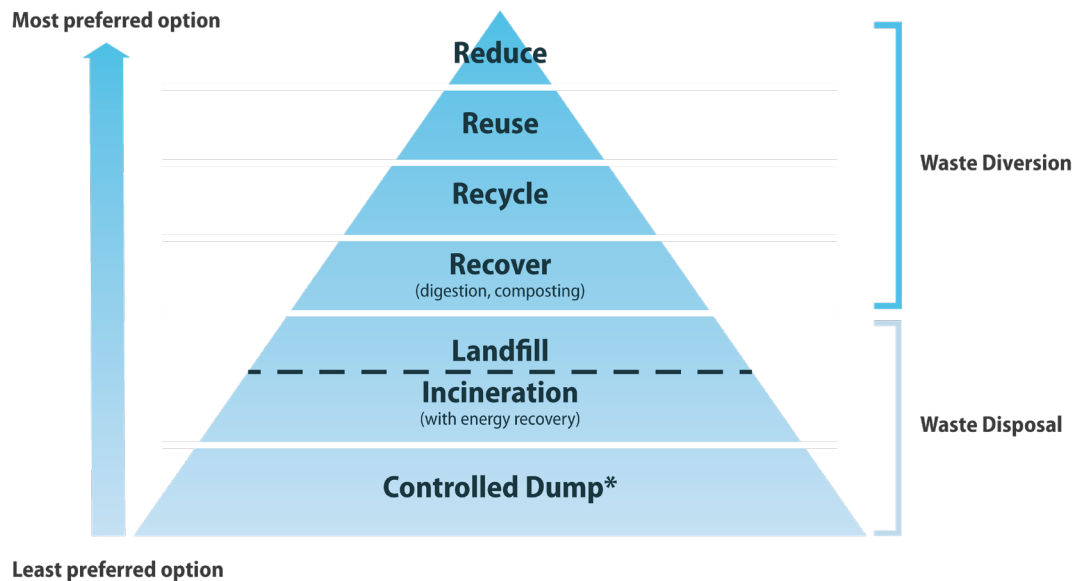
resulting in increasing CDE waste being generated from development of new buildings and infrastructure; as well as increasing waste tires and ELVs from a rising number of vehicles, and industrial waste from growth in manufacturing. In 2012, non-Organization for Economic Co-operation and Development (OECD)<sup>34</sup> countries generated around 29% of the global waste, but the share from these countries is expected to rise to 71% by 2025.<sup>35</sup> This contrasts with most OECD countries where total waste generation has stabilized over the past decade.

Infrastructure for managing and disposing of waste in some developing countries is often inadequate and developing new infrastructure is expensive. Budgetary and capacity constraints can affect the ability of waste authorities to respond to population growth and development by expanding and modernizing their waste systems and assets, leading to environmental and social consequences. Reducing the wastes at source, including difficult to manage wastes such as hazardous waste, tires and CDE waste, is therefore a vital strategy to reduce waste impacts under these circumstances.

### 3.1.1 WASTE REDUCTION AND THE WASTE HIERARCHY

Waste reduction typically sits at the top of the waste hierarchy in regulatory and planning frameworks, as shown in Figure 2.<sup>36</sup> This is because reducing waste saves natural resources, conserves energy, reduces pollution, and greenhouse gas emissions, and saves money for consumers and businesses alike. Reducing the quantity of waste generated also lowers demand for land, hazardous waste generation and associated waste management impacts (see Section 5).

FIGURE 2. THE WASTE HIERARCHY



Source: World Bank 2012. What a waste: A Global Review of Solid Waste Management.

\* A controlled dumpsite (landfill) is the minimum level of waste management which should be expected.

<sup>34</sup> Most OECD members are high-income economies with a very high Human Development Index (HDI) and are regarded as developed countries.

<sup>35</sup> World Bank 2012. What a Waste: A Global Review of Solid Waste Management

<sup>36</sup> Ibid.

### 3.1.2 KEY ELEMENTS OF WASTE REDUCTION

The table below describes some of the key elements which can be considered when developing strategic plans for waste reduction.

KEY ELEMENT	DESCRIPTION
Decoupling Economic Activity and Waste Generation	Historical trends in most industrial economies suggest that resource use and the resulting waste generation are linked to economic activity. However, it is possible to decouple economic growth from resource use through resource efficiency by “doing more with less”. Decoupling implies using less resources and generating less waste per unit of economic activity. Effective decoupling can only be achieved by understanding the drivers for waste generation (e.g., lifestyle, household size, waste management costs, population, consumption). Several measures can be employed to enhance decoupling such as economic instruments (e.g., taxes, fees, extended-producer reliability schemes), cooperation (e.g., voluntary and government agreements), and information-based instruments (e.g., ecolabels). <sup>37</sup>
Residential Organics Management	Implementation of home composting (e.g., food and yard waste) and waste reduction programs can significantly reduce the overall tonnage of waste generated within a community. Home composting programs can be facilitated by providing equipment to residents (e.g., food scrap containers, composting bins). In areas where economic activity is more prevalent and agricultural and livestock programs have been further developed, composting programs can be implemented at a much larger scale.
Materials Reuse Programs	Materials reuse programs, intended to continue the utility and lifespan of lightly used goods, such as electronics, construction materials, clothing, can reduce the generation of waste. These programs provide availability of products that may no longer be of use to one group but can have ample utility for others. For example, there are markets where used household furnishings, appliances, unused but serviceable construction materials are available free, or at a significantly reduced price. There are also electronics and computer recycling programs where serviceable, yet unwanted or refurbished equipment is donated to developing countries for education programs.
The Circular Economy	The concept of a Circular Economy is defined as “a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing energy and material loops; this can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, recycling, and upcycling”. <sup>38</sup> Its application is based on business models that can achieve both financial benefits and resource efficiencies at various stages of the production cycle.

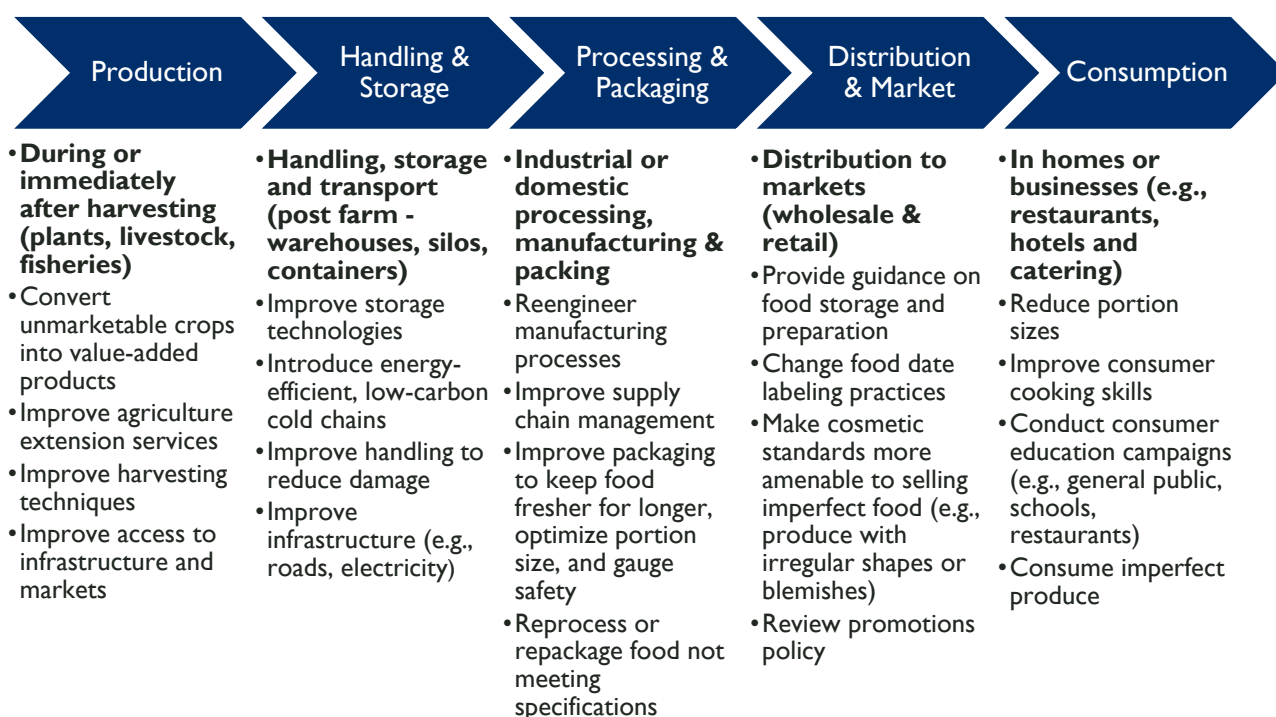
<sup>37</sup> Bain et. al. October 2012

<sup>38</sup> Geissdoerfer, Martin; Savaget, Paulo; Bocken, Nancy M. P.; Hultink, Erik Jan (2017-02-01). "The Circular Economy – A new sustainability paradigm?". *Journal of Cleaner Production*. 143: 757–768

### 3.1.3 MINIMIZING FOOD LOSS AND WASTE

According to estimates compiled by the Food and Agriculture Organization (FAO) of the United Nations (UN), approximately a third of all food produced globally is lost or wasted.<sup>39</sup> Food losses and waste occur in the process of harvesting, transporting, storing, and retailing (e.g. supermarkets), and during consumption and post-consumption. Food that is harvested but ultimately lost or wasted consumes about a quarter of all water used by agriculture each year, requires land area greater than the size of China, and generates about 8 percent of global greenhouse gas emissions annually.<sup>40</sup> Reducing food loss and waste can save money for farmers, companies, and households; it can help feed more people; and it can alleviate pressure on water, land, and climate. In recognition of these benefits, the UN has called for the halving of per capita global food waste at the retail and consumer levels and reducing food losses along production and supply chains (including postharvest losses) by 2030, under its Agenda for Sustainable Development, Sustainable Development Goals (SDGs).<sup>41</sup> Examples for reducing food waste and losses at each stage in the production/supply chain are shown in Figure 3.

FIGURE 3. FOOD VALUE CHAIN AND EXAMPLES FOR REDUCING WASTE



<sup>39</sup> FAO 2011 Global Food Losses and Food Waste: Extent Causes and Prevention. Available at: <http://www.fao.org/docrep/014/mb060e/mb060e00.pdf>

<sup>40</sup> Ibid.

<sup>41</sup> In September 2015, The UN General Assembly adopted a set of 17 SDGs as part of the 2030 Agenda for Sustainable Development. SDG No. 12 seeks to promote sustainable consumption and production patterns. Cutting food loss and waste falls under Target 12.3.

## 3.2 COLLECTION, TRANSFER AND TRANSPORTATION SYSTEMS

Public waste management authorities are typically responsible for managing the collection of solid waste and recyclables that are generated within a city or region. Waste collected may be transported directly to treatment or disposal destinations, or through transfer stations for more efficient bulk transportation of wastes to distant sites. Recyclables are transported to material recovery and processing facilities prior to delivery to markets.

In many developing countries these activities may be challenging due to lack of funding or technical capabilities, or other specific constraints (e.g., terrain or armed conflicts). Collection of wastes in urban areas is typically unreliable, irregular and inefficient, whereas in rural areas it may be absent. Long-distance transportation of wastes can be hampered by inadequacies in transport infrastructure, such as roads, rail or ports.

### 3.2.1 WASTE AND RECYCLABLES COLLECTION SYSTEMS

Timely, efficient, and regularly scheduled waste collection can protect human health and the environment because it minimizes the potential for attracting disease vectors and reduce the likelihood of contaminating nearby environmental receptors such as water bodies, groundwater, and surface water.

Due to availability of inexpensive labor, developing countries typically rely on labor-intensive methods for waste and recyclables collection. In these regions, waste and recyclables are usually collected by manually loading them on to collection vehicles, which can be as basic as a conventional pickup truck or an open dump truck. Front-loaders or other plant are also used to remove trash collected in heaps in urban areas.

Waste collection services in developing countries are often only available in central or more affluent areas, and high-density low-income housing areas are often neglected. While service provision in some areas of major cities may reach 30 to 50% or more of the population, in smaller provincial towns coverage is likely to be much lower. In areas without service provision, waste is often dumped or burned as described in Section 3.7.

Many types of storage containers are used in developing countries. Some examples of commonly used containers are provided in Figure 4. Storage containers should be selected which allow ease of loading onto collection vehicles, are safe, hygienic and appropriately sized for collection frequency. While household containers can often be lifted and emptied manually, community bins may require mechanical emptying systems (e.g., roll-on roll-off containers).

FIGURE 4. EXAMPLES OF HOUSEHOLD AND COMMUNITY WASTE STORAGE

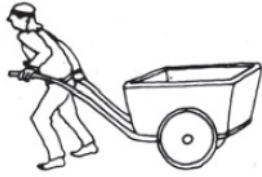


Source: UN-HABITAT 2010. Collection of Municipal Solid Waste in Developing Countries: <https://unhabitat.org/theme/solid-waste/>

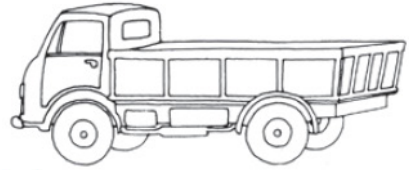
Figure 5 illustrates typical types of vehicles which make up the majority of those used by public waste management authorities and the private sector for waste and recyclables collection in developing countries.



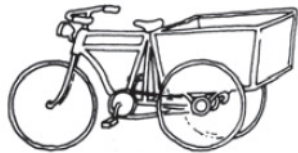
FIGURE 5. EXAMPLES OF WASTE COLLECTION VEHICLES AND CARTS



*Handcart – human power*



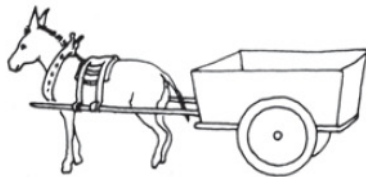
*Standard truck*



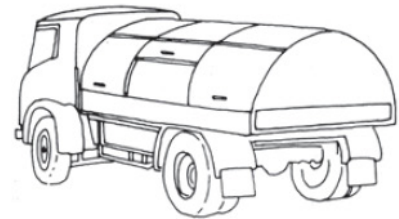
*Tricycle – human power*



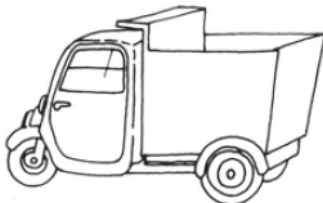
*High-sided open-top truck*



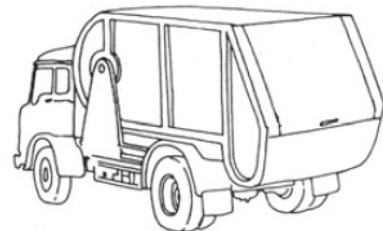
*Animal cart*



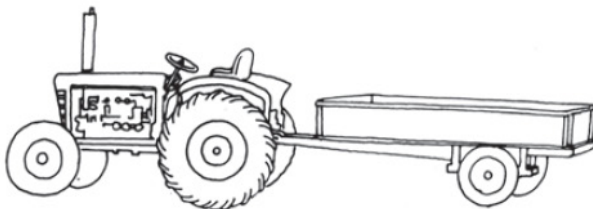
*Roll-top truck*



*Three-wheel auto-rickshaw*



*Fore and aft tipper*



*Tractor and trailer*



*Compactor truck*

Source: UN-HABITAT (2010) *Ibid.*

Collection programs can vary based on many factors, including community size, space availability, climate and behavioral factors. Some examples of collection programs are outlined below:

- **Community programs:** Community collection programs are geared towards multi-family dwellings (e.g., apartment buildings, townhomes, etc.) where it is impractical for all residents to stage their individual waste and recyclables containers in preparation for collection. These programs typically involve a shared area where large (e.g., 20 Cubic Yard) waste and recyclables containers, provided by the complex management, are stored. The residents manually carry their waste and recyclables to these areas for deposit into the appropriate container;
- **Convenience centers:** These are designated areas in public spaces, at which public authorities or third parties install and operate separate containers for the public to deposit recyclables;
- **Non-containerized collections:** For bulky materials (white goods, mattresses, carpets, small CDE quantities) or WEEE, which cannot be containerized or collected by compactor trucks, collectors can offer special collections with tipper trucks, either on call or scheduled;
- **Self-service schemes:** The generators transport and deposit the wastes and recyclables themselves to designated sites, such as disposal, civic amenity, transfer stations, and bring sites;
- **Contracted services:** Non-household waste streams, which can also include healthcare, industrial, large scale commercial, hazardous are collected directly from the generators from appropriately equipped and permitted collectors;
- **Curbside programs:** A curbside collection program typically involves collection for single family dwellings. Waste and recyclables generated within the dwelling are placed into secure containers. Municipal curbside recycling programs are not widely practiced in developing countries, as recycling collection are usually carried out in the informal sector; and,
- **Underground waste storage systems:** have been adopted to avoid amenity impacts associated with storing refuse prior to collection in urban areas, especially in hot climates. These bins are emptied by collection vehicles after they are brought to ground level via hydraulic lifts.

Vehicles and collection programs should be chosen based on provision of efficiency, cost minimization, size of population served and its material generation volume, size of collection area, and accessibility constraints that could impede its maneuverability.

### 3.2.2 WASTE TRANSFER STATIONS

Waste management sites are often far from the residential areas they serve. Long distances to disposal or treatment destinations impact negatively on the efficiency and economics of collection operations, as waste trucks spend long times carrying collected wastes to and returning empty from waste receptors. The longer the transport distance, the lower the utilization of trucks and operatives (as the operatives remain idle during transfer rather than collecting waste) and the greater fuel consumption and costs per ton collected. When the break-even transfer distance threshold is reached, there is an operational and economic need for transfer station facilities, linking collection, treatment and disposal to achieve economies of scale.

There is a large variety of designs and functional options for transfer station facilities. The main types of transfer station facilities are outlined as follows:

- **Rural transfer stations** - These are typically smaller scale facilities in remote areas and not enclosed in buildings. Typical layouts are split level with hoppers, where collection trucks empty directly into transfer truck containers.
- **Mobile transfer stations** - An alternative to split level for small scale operations is the use of mobile plant comprising of a vertical hopper and a reclining conveyor belt, where waste is offloaded by the trucks into the hopper and then transported via the conveyor and loaded from the top onto waste transfer vehicles.
- **Direct dump** - The smallest scale transfer option is the direct dump. Small and satellite collection trucks can dump their waste directly on the on-board hopper outlet in the rear of the transfer vehicles.
- **Tipping floor type** - This is a layout option widely employed in small and medium scale facilities. Waste is deposited by the collection trucks on a flat surface (yard or floor) and then loaded by wheel loaders on to transfer trucks.
- **Hopper with/without compaction** - Hoppers are widely used in transfer stations. These are built typically within large buildings and collection trucks empty into the them directly to load transfer vehicles.

### 3.2.3 BULK AND LONG-HAUL TRANSPORTATION

Wastes and recyclables need, in many cases, to be transported long distances to be correctly disposed of. Bulk and long-haul transportation via road, rail or water is used to increase the efficiency of long-distance transportation and prevent the need for collection vehicles to travel long distances. In countries where roads are in poor condition, even short-distance travel can be slow and difficult. In such cases, the development of bulk transport links to facilities offers efficiency improvements, allowing collection vehicles to focus on core services and disincentivizing informal or illegal dumping.

- **Road** - wastes are transported by large Heavy Goods Vehicles (HGV) via road networks. Most transportation is undertaken using HGVs; however, use of articulated vehicles, with or without draw-bar trailers, can increase vehicle capacity, with potential cost savings;
- **Rail** - wastes are loaded on to trains and transported via the rail network to destinations with appropriate loading facilities;
- **Water** - wastes are loaded on ships or barges (the latter are preferred for inland waterways). Typically, they are containerized (standard shipping containers) and employed for very large quantities of hauled wastes. This is also an extensively used method for international transport of recyclable wastes from generation countries to re-processors in Asia and Africa.

International transportation of hazardous wastes, including several WEEE types, is regulated under the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal*. International haulage of wastes and recyclables which are destined for recovery or processing is controlled under *OECD Decision C (2001) 107/FINAL on the Control of Transboundary Movements of Wastes Destined for Recovery Operations*.

### **3.3 MATERIAL RECOVERY**

A Materials Recovery Facility (MRF) is a facility at which the separate components of a mixed waste stream are extracted using mechanical and manual separation. MRFs are operated and proven worldwide as government and businesses seek to extract recyclable materials from the waste stream to recover value, manage waste in a more sustainable way, and reduce the amount of residual waste that requires treatment or disposal. The viability of a MRF depends on the presence of sufficient markets for separated recyclables. Providing the quality meets reprocessors' specifications, there are usually markets for plastics, metal and paper.

Typically, MRFs are designed with capacity to handle between 3,000 and 250,000 tons of input materials per year. The technologies and systems employed can be complex or simple, depending on the sophistication of plant, the equipment employed and the numbers of operational staff. In low-technology facilities, a MRF may consist of a warehouse or shelter with equipment for manual sorting such as conveyor, tables and bins, scales or a weighbridge, equipment to compress recyclables into bales, and handling vehicles such as front loaders or forklift trucks to move bales or other waste. In more technologically advanced MRFs, conveyors are used to move waste between a range of sorting equipment such as magnets, eddy currents, and sieves. Such plants may have advanced automatic control systems and optics for separating different plastic resin types. High-tech facilities are capital intensive and in developing countries where labor costs are low, low-tech solutions are more common.

MRFs are sometimes referred to as 'Dirty' or 'Clean' facilities. Dirty MRFs are facilities that sort waste streams with little or no segregation (i.e., commingled MSW). They are often designed to sort high-value and relatively easy to sort materials from the waste stream (e.g., metals and cardboard) or to pre-process waste prior to it being used as a feedstock for waste-to-energy plants. The organics fraction from a Dirty MRF is often treated by in-vessel composting. Clean MRFs are facilities that sort recyclables that have been segregated at source or mixed recyclables. As the proportion of organic and non-recyclable waste in mixed recyclables is lower than mixed general waste, it is easier to sort recyclables into separate streams with an acceptable level of contamination for the material pre-treatment or manufacturing sector.

MRFs can be flexible compared to other waste processes, as the cost and disruption to service of increasing capacity are relatively low. For example, throughput can be increased by the extension of shift time or patterns, to use automated equipment or manually sort, or re-configuring and/or adding to sorting equipment and picking stations.

### **3.4 ORGANIC WASTE TREATMENT**

Composting and Anaerobic Digestion (AD) are two widely used and proven methods for treatment of organics from waste. Three main types of composting are windrow, in-vessel (see Figure 6) and vermicomposting. AD can be carried out at a small-scale (say on a single farm) or at large industrialized facilities processing more than a thousand tons of food waste in a day.

FIGURE 6. WINDROW AND IN-VESEL COMPOSTING SYSTEMS



In-vessel  
Source: Green Mountain Technologies



Windrow  
Source: Wikimedia

Windrow composting is widely employed for treatment of low odor / low pathogen organics including landscaping waste from gardens, municipal public areas, although sometimes food waste is also accepted with additional controls. Under this process, shredded organic waste is arranged in a pile (a ‘windrow’) with a roughly triangular cross section, where it decomposes aerobically for a defined period (up to 3 months) until treated. Piles are usually aerated by intermittent turning (e.g., with a back-hoe or specialized plant). Windrows should be arranged on an impermeable hard-standing (e.g., concrete pad) with drainage, and in arid countries moisture controlled. Following treatment, composted material is typically screened to achieve an even product size. The final product can be recycled to land as a soil-conditioner, mulch or horticultural soil.

In-vessel composting (IVC) is widely used for the treatment of organic wastes which potentially have either human health or odor issues affecting their treatment, such as food waste. In this system the composting process is fully enclosed in a ‘tunnel’, drum or other structure. Processes are controlled using mechanical systems such as forced aeration. The process is more capital intensive than windrow composting, but residence time for composting is lower than windrow (typically 4 to 6 weeks). IVC systems can be designed to achieve specified temperatures to facilitate pathogen destruction and control, odor, leachate and vectors.

Vermicomposting is the process of using worms and micro-organisms to turn food waste into a black, nutrient rich soil. The process is only viable on a small scale and takes around 4 to 6 months to get the compost ready for use. The main drawback is the practical application as the worms and micro-organisms are susceptible to contamination in the food waste, which can lead to slowing or complete shutdown of the composting process.

Regardless of the process employed, the quality of compost is related to the input feedstock. To produce a high-quality compost product, a consistent feedstock from source segregated waste source is required. Quality may also rely on management and additives, such as nitrogen, phosphorus, and potassium, and bulking agents for structure such as wood chips.

Anaerobic digestion was developed primarily in the domestic waste water treatment and farming industries for the safe and environmentally controlled treatment of animal and sewage wastes. More recently, AD has become widely used to treat organic waste separated from MSW. AD is a complex biochemical process for the treatment of biodegradable waste which takes place in a tank in the absence of oxygen. It results mainly in the formation of a carbon dioxide and methane gas mixture known as 'biogas', which is typically used to provide electrical power generation, heat, and a solid and liquid digestate.

AD is a more complex system to manage than either windrow or in-vessel composting. An important design parameter of an anaerobic digester is the Total Solids (TS) concentration in the digestion reactor, expressed as a fraction of the wet mass of the prepared feedstock. The remainder of the wet mass is water. Anaerobic digestion systems vary by supplier, but systems can be classified by the following categories:

- Moisture content of feedstock - Wet (<20% Total Solids) / Dry (20-40% Total Solids)
- Temperature in digester tanks - Mesophilic (86-95°F) / thermophilic (113-149°F)
- Number of digestion stages - Single or multi-stage
- Input waste feedstock - in batches or fed into the process continuously.

The capital cost of building AD systems is greater than IVC, whilst the operational costs would be likely to be less than IVC systems if there is an income from the sale of gas/electricity. AD typically becomes financially viable where there is a robust market or on-site use for biogas / heat and power.

### 3.5 THERMAL TREATMENT

Thermal treatment is widely used because it significantly reduces the mass and volume of the waste, allows a range of materials to be combusted producing relatively consistent by-products and typically allows heat and/or power recovery. For waste to be suitable for thermal treatment it needs to be combustible. This means that inert materials (e.g., concrete and steel) are not suitable (and they reduce the efficiency of the process), although sometimes they are recovered from the process. The main types of thermal treatment are:

- **Incineration** - combustion of waste in presence of oxygen. By-products of combustion include ashes and flue gases. Flue gasses should be 'cleaned' using emission control technologies, and the hazardous residues removed require special handling.
- **Gasification** - thermal treatment of waste in a depleted oxygen environment. Synthetic gas is produced that contains hydrogen, carbon monoxide and methane, which is cleaned and combusted to generate energy.
- **Pyrolysis** - thermal treatment of waste in complete absence of oxygen. Thermal decomposition of waste results in synthetic gas and/or liquid oil depending upon the temperature used. The process requires temperature to be maintained, and this is typically achieved by recirculating the exhaust gases from combustion of synthetic gas and heat exchangers.
- **Autoclave** - a thermal technology that subjects waste to high-temperature and pressure inside a vessel. The high-temperature and pressure requires the vessel to meet stringent safety standards

and the process is more suitable for medical waste where waste infrastructure is not fully established. The process is also energy intensive with little or no recovery when compared to other thermal treatment technologies discussed above.

Pyrolysis and gasification are capital intensive and complex technologies requiring highly skilled operatives. These technologies also require a highly homogenous waste feedstock with low moisture content. Both processes are not well-proven at commercial scales and generally absent from the waste management mix of developing countries.

### **3.6 ENERGY RECOVERY**

Energy is a by-product from waste treatment technologies such as AD and thermal treatment. Biogas from anaerobic digestion, landfill gas capture, gasification or pyrolysis can be used in a gas engine (or turbine) to generate heat and electricity, injected into a gas distribution network, or compressed or liquified for use as transport fuel. For most uses, biogas must undergo a cleaning process to remove the moisture, trace gases and carbon dioxide resulting in an increase of the calorific value of the gas. The source of the fuel being close to the end-user reduces the transport burden commonly associated with fossil fuels.

Heat from incineration of waste is used to generate electricity via steam turbines. The efficiency of energy generation increases with the use of combined heat and power systems. For recovered energy to be utilized, it should be proximate to energy markets or complementary on-site uses. Many energy-from-waste (EfW) operations generate electricity for a combination of on-site use and sale to the local grid. Typical end users of heat (hot water or steam) from CHP schemes include paper manufacturing, food processing, desalination plants and hospitals. However, it is often challenging to find end users for heat especially in warm climatic conditions.

### **3.7 LAND DISPOSAL**

#### **3.7.1 UNCONTROLLED OR LIMITED CONTROL OF WASTE DISPOSAL**

In developing countries, technical and financial resource limitations can adversely influence solid waste disposal practices. In the least developed countries, the residents of central urban areas may be the only people to benefit from municipal waste collection and disposal services. Following collection, the wastes are likely to be disposed of at sites which lack basic infrastructure, containment and environmental controls. There is often little differentiation between MSW and hazardous wastes, wastes are purposefully set on fire, and the sites are frequented by informal waste-pickers and animals. In marginal areas, without access to basic sanitary services, solid waste is often dumped indiscriminately in public areas and waterways. A vast quantity of solid waste litter and debris enters, circulates and accumulates in surface water bodies, waterways, the ocean and beaches. Much accumulates in area that ecologically sensitive such as wetlands, swamps, and coral reefs. This system of waste disposal leads to many problems, including pollution of air, and surface/groundwaters, fires, litter, odor, and proliferation of disease carrying vectors.

Operated or 'semi-controlled' dumpsites may be in place in some areas as the primary disposal method. At such sites, incoming wastes may be inspected and recorded, controlled and compacted at a tipping

face, and there may be some application of daily soil cover to prevent animals and vermin. However, such sites do not use environmental control measures such as leachate and landfill gas<sup>42</sup> management systems. As cities grow and produce more waste and solid waste collection increases, impacts from open dumpsites can become intolerable.

Photographs in Figure 7 show examples of an informal dumpsite in Aruba and an engineered land disposal site in Greece.

**FIGURE 7. EXAMPLES OF DISPOSAL OF SOLID WASTE TO LAND**



Typical dumpsite in Aruba (left), and new engineered landfill site in West Macedonia, Greece (right).  
Source: Mott MacDonald

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<sup>42</sup> Landfill Gas is Landfill gas is a mix of gases created by when organic wastes decompose in a landfill. It is approximately 40-60% methane, with the remainder being carbon dioxide, and a small amount of non-methane organic compounds.



BOX 3. CASE STUDY: CLEANING UP THE STREETS WITH SUSTAINABLE WASTE MANAGEMENT, GUAPI, COLOMBIA



Guapi is an isolated municipality on Colombia's Pacific coast with little waste infrastructure, landfill capacity and recycling facilities. Waste is mostly disposed of as a material to make new roads at the periphery of the town, causing significant public health and environmental hazards, and impacting deforestation.

Colombia's Ministry of Housing, Cities and Territories supported by United Kingdom Foreign and Commonwealth Office identified safe recycling and disposal options which considered the views of local waste management stakeholders. An assessment toolkit was developed to support other towns with similar issues.

Introducing sustainable waste management systems in Guapi will improve public health, safeguard the local environment and boost economic prosperity for local communities that have been impacted by a longstanding civil war.

Source: Mott MacDonald

### 3.7.2 SANITARY LANDFILLS

Landfilling may be suitable in some developing countries, due to its relative simplicity and low cost, if integrated with material recovery, environmental controls and good management practices. The development of, or conversion of open or operated dumpsites to, 'sanitary landfills' is an essential step for many developing countries to prevent and reduce impacts to environment and human health.

The definition of a 'sanitary landfill' can be specified in terms of engineering measures and performance requirements, with such sites typically satisfying the following conditions:

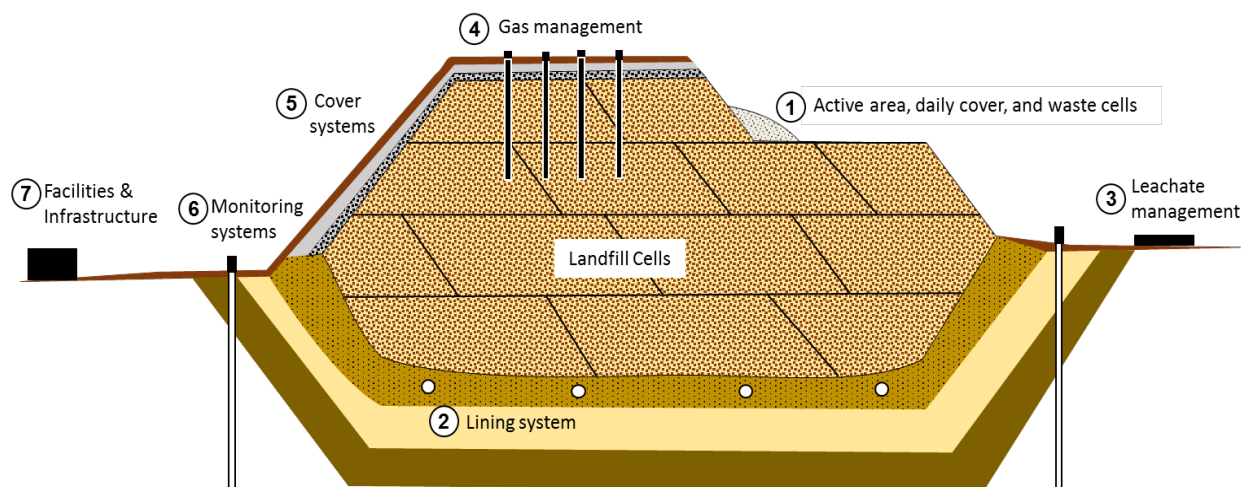
- Consolidation of wastes into a working face, and compaction to conserve land resources;
- Design and operation of the fill to control settlement and optimize chemical and biological processes; and
- Control or prevention of adverse environmental impacts to land to soil, water and air and their impacts to public health and safety

Meeting all conditions may be impractical in some developing countries due to lack of resources and capacity. In such cases, the short-term, or immediate, goal should be to meet the conditions to the extent possible under existing circumstances, with the aim of full compliance in the long-term.

There are several types of landfills, and the complexity of their respective components (e.g., lining and environmental collection, treatment and monitoring systems) are driven by the types of waste each will receive. Landfills are usually categorized into inert (e.g., construction and demolition waste), non-hazardous (e.g., MSW) and hazardous (e.g., medical, and industrial), but can include multiple designations within a single site. Substantial amounts of hazardous wastes must be disposed in specially designed hazardous waste landfills with robust management, containment and monitoring systems.

A diagram showing a typical sanitary landfill cross-section and key aspects, is shown in Figure 8, and discussed in elements 1 to 7 in the table below.

**FIGURE 8: SIMPLIFIED CROSS-SECTIONAL DIAGRAM OF A SANITARY LANDFILL**



Source: Mott MacDonald

No.	Element	Description
I.	Active area, daily cover, and waste cells	The active area of a landfill, or tipping face, is where solid waste is tipped, spread and compacted. Daily coverings of soil are often used to minimize odor, litter and vectors. Compacted waste is covered with soil, which is then compacted to form a cell. The cells are formed sequentially to create layers or 'lifts' which form the landfill body. The sides are graded to provide a stable structure and drainage.

No.	Element	Description
2.	Lining system	Liners are used to protect groundwater from contamination. <sup>43</sup> The need for a bottom liner depends on hydrogeological and climatic conditions, and leachability of contained waste. Liner systems may be single, double, or composite layers, and are constructed from natural (e.g., soil, clay and gravel) and/or synthetic (e.g., plastic sheets, geotextiles) materials. The liner should impede leachate flow and provide a structurally stable base for overlying waste. The lining is sloped to collect leachate above it.
3.	Leachate management	Leachate management is needed to prevent contaminants from entering groundwater, or connected water bodies, and sometimes to protect the integrity of the landfill lining.  Leachate can be managed through reduction, containment and treatment. Generation can be prevented or reduced by screening liquid and high-moisture wastes, reducing infiltration of precipitation through final and intermediate cover, and implementing drainage features. <sup>44</sup> A typical leachate collection system includes a drainage layer formed of sand or gravel, and evenly-spaced perforated pipes which collect the leachate and divert it to a low-lying collection point. Accumulated leachate is transferred for storage, treatment or disposal. Leachate treatment methods include physical-chemical and biological treatment, evaporation and recirculation of leachate within the landfill.
4.	Gas management	When solid waste is buried, organic material decomposition occurs under anaerobic conditions, resulting in generation of landfill gas. Provisions for managing landfill gas, which is comprised mostly of methane and carbon dioxide, should be considered by landfill designers and operators. If not managed properly, landfill gas migration can lead to nuisance odors, greenhouse gas emissions, and serious safety issues such as fires and risk of explosion. Landfill gas collection and management systems typically consist of horizontal or vertical collection wells connected to a transfer piping system and blowers. Collected landfill gas can be used as a fuel source to generate electricity or burned (i.e., flared).
5.	Final cover	When the landfill cell or unit is filled, a final cover system (or 'landfill cap') should be installed to providing secure, long-term storage. Final covers provide a physical barrier over buried waste preventing human contact, minimizing problems with vectors and odor; prevent erosion that could expose waste; reduce infiltration and generation of leachate; and provide a foundation for possible reuse of the landfill. Final cover systems range from simple to complex, and may include layers for vegetation, hydraulic barriers, drainage, filtration and gas collection/ventilation.
6.	Monitoring systems	Environmental monitoring systems are required to measure and evaluate impacts from landfills on the environment and human health so that they can be prevented, managed or rectified. The scope of monitoring is site dependent but may include installation of groundwater monitoring wells, and sampling of surface waters. Air quality (dust and gasses), noise and odor may be issues during operation which should be monitored depending on the proximity to people. Closed landfills may include monitoring of landfill gas, for fire prevention or as part of gas collection and management systems.
7.	Facilities and infrastructure	Landfills contain a variety of infrastructure and facilities, which are vital to operations including roads, drainage, utilities, buildings, fencing, industrial weighing scales and other equipment and facilities. Maintenance of roads and drainage are a major activity for operators.

<sup>43</sup> Leachate is liquid discharged from a landfill that contains chemicals or constituents from wastes it has contacted. It is a potentially a significant pollutant and is usually very odorous. Composition varies widely depending on type and age of wastes.

<sup>44</sup> Leachate treatment can be one of the largest operating costs for a landfill. Therefore, minimizing generation of leachate at the front-end can be an effective way to reduce costs.

Sanitary landfills are operated as systems. Each element requires operation, maintenance, management, monitoring, and evaluation to ensure efficient, safe and environmentally sound practices. Landfill operating procedures are determined by many site variables but typically include:

1. **Receipt of wastes:** Wastes are delivered to the site, and inspected, weighed, and screened. Incoming waste details are recorded. Most formal landfills charge tipping fees, but the charge is often below the cost of operating. High tipping fees may incentivize illegal dumping of wastes.
2. **Handling and placement of wastes:** Wastes are processed, tipped, spread, compacted and covered at a working face in a designated area. Recovery of recyclable materials is good practice as it recovers revenue from the waste stream and reduces airspace in the landfill cells.
3. **Equipment Operation and Maintenance (O&M):** Landfills commonly employ heavy equipment and other mechanical, hydraulic, and electrical equipment. Such equipment should be properly operated and maintained. Procurement (and donations) of equipment must be accompanied by training, and capacity building, as well as a source of funds for maintenance.
4. **Infrastructure O&M:** Roads need to be constantly maintained to cope with heavy wheeled and tracked machinery and provide access to a moving working face. Access to landfills should be controlled to prevent unauthorized waste picking and illegal dumping. Drainage systems also require constant modification and maintenance to manage surface water in the dynamic landfill environment.
5. **Environmental control:** collection (e.g., gas, leachate), monitoring (e.g., groundwater) and treatment systems (e.g., leachate) are installed (phased), operated and maintained. Fires typically result from poor handling practices and are often set deliberately to create more space.

### 3.7.3 WASTE PICKING

Waste picking is a widespread occurrence at urban land disposal sites in developing countries and is to be expected at sites unless measures to prevent it are implemented. Waste pickers and informal workers at landfills and dumpsites can pose a safety hazard, interfere with operations and start fires. The negative impacts of waste picking have been reduced in some places by formalizing this work, either by employing waste pickers directly or by engaging contractors to do their work. However, as pickers normally are part of the socioeconomic structure, their displacement from an existing disposal site can result in workers being made unemployed, homeless and cutting off a valuable income for them and their families. Examples of programs aimed at formalizing the role of waste pickers through establishment of cooperatives include the Linis Ganda (Clean and Beautiful) program in Metro Manila, Philippines and the EcoCitizen program in Curitiba, Brazil.<sup>45,46</sup>

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<sup>45</sup> <http://www.wiego.org/content/linis-ganda>

<sup>46</sup> [https://e360.yale.edu/features/in\\_brazil\\_a\\_citys\\_waste\\_pickers\\_find\\_hope\\_in\\_a\\_pioneering\\_program](https://e360.yale.edu/features/in_brazil_a_citys_waste_pickers_find_hope_in_a_pioneering_program)

FIGURE 9. INFORMAL WORKERS AT WASTE SITES IN ARUBA



Lack of PPE for informal waste workers at waste transfer and dump sites  
Source: Mott MacDonald

### 3.7.4 LANDFILL STABILITY AND LANDSLIDE RISK

Landfills are designed to clearly defined gradients to ensure that the sites do not become unstable and collapse. Whilst this is observed within the developed world, in other parts of the world this is not adhered to, mainly because the sites have not been correctly engineered and so the waste volumes continue to build up. Within these developments, informal settlements are frequently found at the edges of landfills (many of whom are working in informal waste sector). The occupants of these settlements may be at risk from pollution, fires and landslides. Figure 10 shows before and after images of the collapse of a dumpsite in Payatas, Quezon City, Philippines, following a typhoon on July 10, 2000, which buried squatter houses and then went up in flames, reportedly killing more than 200 people and leaving many homeless.<sup>47</sup>

FIGURE 10. PAYATAS LANDFILL COLLAPSE - BEFORE AND AFTER



Source: Geoengineer.org

<sup>47</sup> Jafari. 2013, [https://www.geocasehistoriesjournal.org/pub/article/download/IJGCH\\_2\\_3\\_3/156](https://www.geocasehistoriesjournal.org/pub/article/download/IJGCH_2_3_3/156)

### 3.7.5 SITE CLOSURE

When the landfill is complete, a closure plan should be developed and implemented which considers long-term containment of the site, including capping materials and vegetation, proposals for after-use of the site (if appropriate), leachate and gas control, environmental monitoring and inspections, and engineering aspects such as settlement and slope stability.

Existing informal dump sites or semi-formal landfills may be capped, or the contents moved to a sanitary landfill to reduce their impacts. In some cases, it may be necessary to clean-up (remediate) existing dumpsites and landfills which contain hazardous wastes and pollutants that impact human health and the environment. Many methods of site remediation are available including removal, containment, stabilization, and chemical, biological and thermal treatments. Remediation of landfills and dumpsites is usually very costly and requires careful planning and management to avoid spreading the contamination during implementation.

### 3.8 HAZARDOUS WASTE TREATMENT AND DISPOSAL

In developing countries, technical and financial resource limitations, minimal political and governmental commitment, and lack of training and awareness can adversely impact hazardous waste management practices. In these countries, there may be little legislation, technical guidance, or training programs available for entities that engage in hazardous waste generation (i.e., producers), transport, and disposal or treatment. Deficient management of hazardous waste can expose handlers and their communities to substantial health and safety risks or place local environmental receptors at risk of contamination. In the least developed countries, actual quantities of hazardous waste available for treatment and disposal are unknown because the waste streams are not properly documented and commingled with conventional solid waste. This mix of hazardous and non-hazardous waste can end up being disposed in an unsafe, unsecure, and uncontrolled manner, perhaps through burial, burning, or surface dumping.

Hazardous wastes management requires robust regulation and enforcement to ensure safe, responsible management from “cradle to grave”. Wastes should be subject to screening to identify potentially hazardous materials, and characterization to determine the type and properties of any identified materials present, so that the proper handling, storage, transportation, processing and disposal protocols can be followed. Strict regulations should be in place to establish general operational and management standards, minimum design standards, and provide direction on contingency and emergency planning, recordkeeping and monitoring.

In many developing countries, weak governance, lack of awareness, deficient financial, technical and infrastructural resources can lead to mismanagement of hazardous wastes including:

- Commingling of hazardous waste with MSW;
- Lack of record keeping audit trail and liability;
- Disposal in uncontrolled landfill or dumpsite;
- Uncontrolled intermediate storage;
- Handling and transportation by unlicensed/unregistered haulers and uncertified personnel; and
- No provision of Personal Protective Equipment (PPE) or training for workers handling hazardous waste.

Improper management of hazardous materials may potentially result in spills, leaks, fires, and contamination of soil and groundwater or drinking water.

Many hazardous wastes can be recycled safely and effectively, while other wastes require treatment or secure disposal. Recycling hazardous waste reduces consumption of raw materials and the volume of waste materials that must be treated and disposed. Examples of hazardous waste materials that may potentially be appropriate for recycling include batteries, mercury-containing equipment, lead paint, and strip lamps.

Hazardous waste can be treated by a variety of technologies such as chemical, biological, thermal, and physical processes. However, not all treatment methods are effective for all types of hazardous wastes and the most appropriate technology should be determined based on the targeted materials' characteristics and chemical composition. Chemical treatment methods are intended to cause a chemical reaction which breaks down the hazardous constituents into non-toxic materials or to alter the chemical properties of the waste. Biological treatment typically involves mixing the targeted waste with soil, spreading across a suitable tract of land, and amending the mixture with microbes and nutrients which metabolize the waste (i.e., consume it as a food source). Thermal treatment, such as incineration, involves heating the waste to very high-temperatures resulting in thermal destruction of its hazardous constituents and a reduction in waste volume. Although high-temperature incineration is an effective treatment technology, emission control systems are required to mitigate air quality impacts.

Hazardous waste can also be disposed in a lined landfill which offers secure long-term containment. These facilities should be robustly designed and constructed and include double impermeable liner systems, double leachate collection and extraction systems, leak detection systems, and a network of groundwater monitoring points. There are other land disposal options for storage of hazardous waste such as surface impoundments and waste piles. These lined and berm-surrounded land disposal options offer secure, albeit temporary storage of hazardous waste until it can be treated or disposed in a landfill.

## **4 PLANNING AND IMPLEMENTING WASTE MANAGEMENT SYSTEMS**

To plan and implement waste management systems effectively and efficiently, it is important that solid waste strategies are developed by authorities at various geographic scales. Waste management strategies should include a vision and specific objectives to meet the waste management needs of the territory, and solutions and plans to achieve those objectives. Realistic targets and indicators for monitoring progress should also be specified. A strategy should be consistent with the principles of the waste management hierarchy, and resource recovery and conservation objectives. It should include integrated and sustainable waste management practices; and be aligned to other national plans and policies including those relating to environment, economy, energy and land. A waste strategy should:

- Clearly set out objectives and service standards, along with specific and measurable targets, and associated indicators;
- Identify a preferred solution for collection, treatment and disposal;
- Provide a framework for procurement, development and operation of waste infrastructure and facilities; and
- Communicate these plans to government, key stakeholders, partners and the wider community.

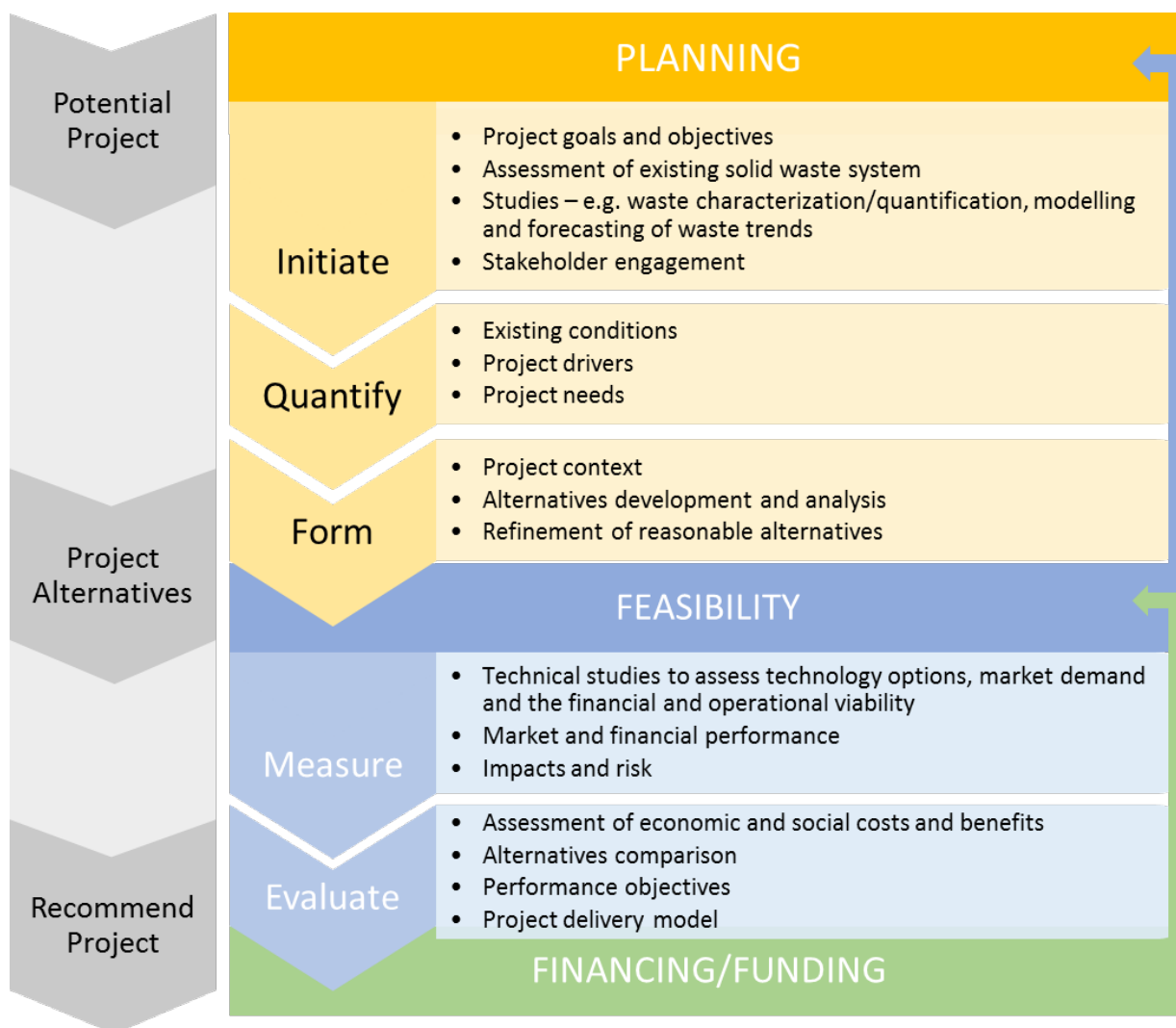
Not all regions will have a strategy in place, and further/additional technical reviews of potential waste solutions will be required in the subsequent planning and feasibility stages.

#### 4.1 PLANNING AND FEASIBILITY

Project planning and feasibility should be carried out in line with the relevant contracting and procurement legislation of the host country. Increasingly new waste infrastructure is being delivered under the public private partnerships (PPP or ‘P3’) procurement model (see Section 4.2.3).

Feasibility studies are required to demonstrate the practicality of the proposed project or activity to stakeholders including investors, lenders, contractors, regulators and the public. Feasibility studies vary in scope and size depending on the project or activity, but often include the key elements shown in the Figure 11.

FIGURE 11. PROJECT PLANNING AND FEASIBILITY PROCESS





Through these aspects, stakeholders will evaluate the feasibility of the project, based on preferred technical and commercial configuration.

## 4.2 PROJECT PREPARATION

The preparation of the project will take the findings of the feasibility study and build them into a structured information memorandum document which considers each stage of the procurement process. This will identify the project program/schedule and ensure that there is an in-place agreement on the overall finances of the project prior to its commencement. The development of an information memorandum can be preceded by a 'market sounding' study to test market interest in the project, and make sure there are sufficient investors, partners and suppliers. Market studies and enquiries are followed by issue of a 'Notice' which may include the date of a bidders' day for interested contractors to hear more about the project.

### 4.2.1 ENGINEERING DESIGN

In design-build contracts, a contractor is responsible for design, procurement of materials, financing, and construction of waste management facilities and infrastructure in accordance with specifications and performance requirements. The engineering design process typically includes the stages in Box 3:

#### BOX 4. TYPICAL ENGINEERING DESIGN STEPS FOR DESIGN BUILD PROJECTS

1. Preparation and design brief
2. Concept design (30% design stage)
3. Developed design (60% design stage)
4. Technical design (100% design stage)
5. Construction
6. Handover to owner/operator
7. Operational use

Waste PPP projects (see Section 4.2.3) are often procured through a design, build, finance and operate contract. The contractual documents produced by the waste authorities usually cover the first two stages.

- **Preparation Brief** – This develops the project objectives and outcomes, project budget and development of an initial project brief including undertaking the feasibility study described in Section 4.1.
- **Concept Design** – This includes the preparation of the outline proposals for structural design, outline specifications, and preliminary cost information together with an outline layout of the plant.

The remaining stages are undertaken by the contractor in the response to tender and the subsequent design phase on contract close.

#### 4.2.2 PUBLIC SERVICE DELIVERY

Waste management infrastructure is an essential part of the services and public waste management authorities have the right to publicize or disclose information regarding Projects. Projects usually affect multiple stakeholders and conflicts may arise where interests diverge. To manage conflicts and develop solutions and outcomes that are acceptable to all stakeholders. Workshops can be undertaken to explain, discuss and draw together ideas.

#### 4.2.3 PUBLIC PRIVATE PARTNERSHIPS

The PPP Knowledge Lab defines a PPP as "*a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance*". The PPP development model is increasingly being used to deliver public infrastructure projects and services and is widely used for delivery of waste management facilities and collection services. In developing countries, development of large scale and technologically sophisticated waste facilities often requires private sector participation as the capacity of public authorities to deliver such projects alone is limited. USAID recognizes the importance of the private sector in delivering development projects. Since it launched its public-private alliance program, Global Development Alliance (GDA), in 2001, USAID has delivered thousands of development assistance projects under the PPP model (Brookings Report 2016).<sup>48</sup>

A key feature of a PPP is that the assets or services provided are specified in terms of outputs, that is, defining what is required, rather than specifying how exactly how it should be done. Through PPPs the private sector can provide valuable technological and management expertise or partnerships to the development of infrastructure and facilities. Partners are expected to invest financially, leveraging donor funding at least 1:1 with USAID contributions, increasing resourcing and sharing risk.

However, using the PPP model to deliver and operate public infrastructure or services is not appropriate in all cases. In some situations, the benefits of a PPP do not sufficiently offset political, procurement, delivery, or revenue risks. Projects or programs are often funded by tolls, fees or other direct user charges, which can be politically sensitive, and expensive for consumers. Stakeholders (donors or governments) also face risks should private partners fail to properly execute contracts or deliver adequate services. As such, a detailed procurement process should be followed including detailed risk management, robust contract and technical specifications, and analysis of value-for-money.<sup>49</sup>

Many types of PPP model exist, and the selection of the correct configuration is essential to achieving successful outcomes. Types of PPP contracts can be defined by how project phases or functions, i.e., design (engineering), construction, financing, and operations and maintenance, are bundled together and allocated. Usually a dedicated Special Purpose Vehicle (SPV) is set up as the contracting entity, which takes on defined assets and liabilities. For example, many waste management facilities are delivered under Design, Build, Operate (and Maintain) (DBO) contracts, whereby all these activities are contracted to an entity for a specific period (say 15-20 years). Under such contracts, entities are entitled to collect fees and/or subsidies for operation during that period, with payment usually linked to

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<sup>48</sup> <https://www.brookings.edu/research/usaid-public-private-partnerships-a-data-picture-and-review-of-business-engagement/>

<sup>49</sup> To achieve 'value for money', waste management solutions must be both financially affordable and able to deliver maximum efficiency for resources available.

performance. At the end of the period, the ‘ownership’ or right to operate the facility transfers back to the government, who may extend or re-tender the contract, or bring operation in-house.

Review of suitable PPP models should be based on international best practice and specific to the local project context. Review should include the evaluation against current national and regional laws, policies and institutional arrangements to identify any constraints to the project including any capacity to manage and monitor implementation, including advice on:

- Public sector procurement
- Resourcing, training and capacity building needs for the public sector
- Operational arrangements between public sector and advisers during procurement
- Contract management arrangements

The PPP review will develop the legal structure and transaction design, identifying the type of PPP contract to be used together with the investment plan and the type of public sector support required. By taking account of the legal PPP framework, relevant environment legislation and policies and technical solutions can be developed that are:

- **Flexible** – able to treat a range of waste quantities and types, and to contractually allow changes without requiring contract renegotiation.
- **Deliverable** – using proven technologies and processing to meet the output specification requirements. Contractually the contractor must be able to provide a clear and realistic project program and method statements providing assurance that the project can be delivered on time and to budget.
- **Value for money** – Key methods for doing this are by having a clear output specification and minimizing the amount of input specification, while ensuring that the key requirements of the Waste Strategy are met.
- **Meet environmental performance requirements** – Waste should be moved up the waste hierarchy (see Section 3.1.1) minimizing the environmental impact of waste management.

### 4.3 SOLICITATION OF CONTRACTORS AND CONTRACT MANAGEMENT

Proponents can solicit offers or quotations for services from contractors using sealed bid procedures (often referred to as "invitations for bids" or "invitations to tender") or using negotiated procedures ("requests for proposals" or "requests for quotations"). For large contracts, sealed bidding procedures are often preferred. The process must be transparent to reduce opportunities for corruption and ensure that the best value contractor is appointed to undertake works and services. Transparency can be achieved by issuing tender evaluation criteria at the start of procurement to make it clear what the criteria for selection will be. A two-envelope system where the commercial offer is only opened after bidders have passed the technical evaluation is also often adopted for public procurement projects. Bidders who do not pass the technical evaluation threshold will not proceed to the opening of the commercial offer.

Contract management, or contract administration, refers to the processes and procedures that public waste authorities and other project proponents implement to manage the negotiation, execution,

performance, modification and termination of contracts. Contract management arrangements should incorporate procedures that complement payment mechanisms, ensure that there is evidence submitted to support payments, and that payments are in accordance with the terms of the contract.

#### **4.4 OPERATIONS AND MAINTENANCE**

A services delivery plan should be developed as part of the operations and maintenance services. This plan states how the Contractor(s) will deliver the services against the contractual requirements that have been laid down under the contract, and should include the following:

- A Service Operational Plan (SOP) which is required for each waste management facility which provides for how the plants will be operated and maintained.
- The SOP will include for the operational capacity of the facility to ensure that the planned tonnage is met, and capacity is not exceeded.
- An Environmental Impact Control Plan to ensure that the waste facilities are being monitored to ensure there is no impact caused by noise, odor, litter, emissions, traffic and pests.
- A waste acceptance plan to ensure that waste complies with protocols and does not include waste material outside permitted waste acceptance criteria.
- A contingency plan to ensure that the waste site can be maintained correctly and that any waste diversion or storage arrangements are sufficient to ensure the service continues in accordance with the contract.
- A routine inspection and maintenance plan to ensure that all preventative maintenance and equipment services events are undertaken in accordance with the schedule to ensure the plants can operate effectively and without damage to the equipment.

#### **4.5 WASTE HANDLING AND DISPOSAL RATES, AND OTHER REVENUE STREAMS**

Waste handling or disposal rates may be charged through a payment mechanism which covers the infrastructure revenue, costs of capital, costs of operating and maintaining the waste management facilities and any variations on service provision and increases in the amount of waste being treated. The waste management costs are offset against revenue streams which may include the resale of recycled products removed from the waste stream such as glass, paper, metals and plastics, the sale of electricity generated from waste plants such as anaerobic digestors or energy from waste plants and potentially sale of organic waste material and bottom ash.

It is important to note that waste management usually represents a cost, and revenues usually contribute to reducing overall costs but that the services may not be financially viable for investors bases on revenue streams alone.

#### **4.6 ESTIMATING PROJECT COSTS AND STAFFING REQUIREMENTS**

Once a preferred technical model has been selected in the technical feasibility study, a cost model can be developed for the project or activity, including (as relevant) the design, construction and operation and maintenance costs. Capital costs/expenditures ('Capex') are initial outlays required for the

procurement and development of solid waste assets (e.g., infrastructure and equipment) or any other upfront fees and deposits. Capital outlays may be required for vehicles, waste containers, equipment and machinery at the transfer sites and treatment locations and supporting infrastructure. Disposal and treatment costs will be driven by the selection and design of the treatment technology chosen in the feasibility study.

Operational expenditures ('Opex') are based on the staffing and maintenance requirements to operate the waste management facilities, and potentially equipment replacement costs. Operational costs are a key consideration for authorities and investors, as the operational costs over the lifetime of a facilities or services usually far exceeds that of the initial capital costs. Authorities should build operational costs into financial models for each of stage of the waste management process, including waste collection costs, disposal costs, treatment costs and landfill aftercare costs, as well as related non-project costs such as waste prevention and education programs and recycling and waste diversion initiatives to determine long-term budgets.

Financial models estimate costs over the contract or strategy period and include many assumptions which cannot be known with certainty at the outset, such as macro-economic factors (e.g., inflation, revenues). Financial models should therefore include sensitivity analysis to develop risk management strategies and contingencies.

## **4.7 INSTITUTIONAL CAPACITY, POLICY AND REGULATORY CONSIDERATIONS**

### **4.7.1 STRENGTHENING OF INSTITUTIONS AND CAPACITY BUILDING**

When undertaking waste management projects, it is important to understand the institutional capacity and capabilities of public authorities and partners. In some cases, public authorities may lack experience or resources required for delivery of the project or program in question. Therefore, development proposals which include capacity building and training for public authorities, private waste management companies, NGOs or civil society organizations may be valuable for the success and sustainability of development projects and waste services provision more generally. Technical assistance and capacity building may also be required to ensure effective O&M of waste facilities and infrastructure. The ability to transfer knowledge and skills by carrying out training sessions will assist recipients of donor assistance to take ownership of projects or programs and facilitate the development of new projects and programs by application of newly developed capacity and skills.

### **4.7.2 POLICY AND REGULATORY CONSIDERATIONS**

The formulation of policies and strategies, and their translation into legislation and regulations are the backbone of effective solid waste governance. Waste management policy formation is driven by goals such as improving public health and sanitation, environmental protection, and recovery of resource value from discarded materials. Waste management goals should be identified and prioritized in consultation with local stakeholders. Once legislation has been enacted, a regulatory program must be developed, implemented and enforced by the relevant executive authorities. Regulations are ancillary or subordinate to laws but both laws and regulations are enforceable.

Laws and regulations can limit or prohibit actions such as informal dumping, open burning and hazardous wastes; provide specifications for technologies; and set out functional requirements (e.g. environmental pollution limits). Other non-regulatory instruments and policy measures can also be used to for implementing policies and strategies and improving compliance, such as social mobilization (e.g. education and awareness, participation), and economic instruments (i.e. incentives/disincentives).

Legislation should include purpose and scope; definitions; requirements, procedures and standards; enforcement; and administration. It is important to clearly establish the relevant authorities and responsibilities of different government institutions and provide resources for their implementation and enforcement. Political support, institutional capacity and financing are essential to successfully implement and enforce new waste legislation and regulations.

When developing solid waste projects, or implementing waste programs, host country policies, legislation and regulatory environment must be fully understood and complied with. There are likely to be a wide range of applicable laws, regulations, and policies relating to waste, land ownership, spatial planning, public health, environmental permitting, and many others.

## **5 ENVIRONMENTAL AND SOCIAL IMPACTS FROM SOLID WASTE MANAGEMENT**

### **5.1 ENVIRONMENTAL PLANNING AND MANAGEMENT PROCESS**

USAID’s mandatory environmental procedures, specified in Regulation 22 CFR 216 (“Reg. 216”) and related provisions of the USAID Automated Directives System (ADS), are applicable to USAID funded and managed projects and activities.

In summary, these procedures mandate (1) a pre-implementation EIA process, and (2) implementing and reporting on any environmental conditions (required mitigation measures) that result from this review. The pre-implementation environmental review is documented in a Request for Categorical Exclusion (RCE), Initial Environmental Examination (IEE) or an Environmental Assessment (EA). Each of these Reg. 216 documents must be approved by both the Mission Director and Bureau Environmental Officer (BEO).

In addition, USAID projects or activities are subject to compliance with the environmental planning and management regulations and guidelines specific to the territory in which they are operating. Environmental standards and guidelines associated with international financial institutions, such as multilateral or regional development banks (E.g., World Bank / International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability, and Asian Development Bank (ABD) Environmental Safeguards, and others), are often applicable.

### **5.2 IDENTIFYING, EVALUATING AND MANAGING ENVIRONMENTAL IMPACTS**

Environmental procedures, standards and guidelines from USAID and others require environmental and social impacts to be identified, evaluated and managed throughout their duration and at all stages of their lifecycle. Such impacts are effects associated with a project (in isolation or in combination with other projects), that may have environmental, social, health and safety, or economic significance to society.

After impacts have been identified and described, they are evaluated to determine their significance. Under US Code of Federal Regulations (CFR) Regulation 216,<sup>50</sup> this is done by the evaluating the impact's "context" (i.e., the physical, social and temporal context in which the effects will occur) and "intensity" (i.e., the severity or magnitude of the impact within the context). When evaluating impacts, a broad range of effect characteristics should be considered including, whether they are:

- negative or positive;
- direct, indirect or induced;
- permanent or temporary; and
- reversible or irreversible.

Whether impacts are cumulative (or produce effects in combination) with other activities or aspects, affect more than one jurisdiction (transboundary), or violate regulatory limits / legal statutes, must also be evaluated.

Regulation 216 requires the consideration of environmental and social impacts associated with projects at all phases of implementation. A detailed description of methods for evaluating environmental impacts is provided in Automated Directives System Chapter 204 (ADS 204) and Regulation 216.<sup>51,52</sup>

### **5.3 CONSTRUCTION AND DECOMMISSIONING STAGE IMPACTS**

Impacts associated with the development (i.e., construction) and decommissioning of waste management facilities are similar to those associated with other types of industrial or public facilities. Detailed description, and examples, of impacts associated with construction are provided in the USAID Construction SEG.<sup>53</sup>

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<sup>50</sup> US Code of Federal Regulations (CFR), Title 22 - Foreign Relations, Part 216 – Agency Environmental Procedures (CFR 22 216) referred to as 'Reg 216'

<sup>51</sup> <https://www.usaid.gov/ads/policy/200/204>

<sup>52</sup> [https://www.usaid.gov/our\\_work/environment/compliance/22cfr216](https://www.usaid.gov/our_work/environment/compliance/22cfr216)

<sup>53</sup> <http://www.usaidgems.org/sectorguidelines.htm>

## 5.4 OPERATIONAL ENVIRONMENTAL IMPACTS

Examples of general environmental impacts associated with the execution of solid waste management activities and the operation of waste disposal facilities are described in Table 1, presented by category of impact. Impacts associated with specific projects and activities will be dependent on their specific features and circumstances. The impacts provided here are examples for informational purposes only, and do not represent an exhaustive list.

**TABLE 1: POTENTIAL OPERATIONAL ENVIRONMENTAL IMPACTS AND EFFECTS**

CATEGORY OF IMPACT	DESCRIPTION OF POTENTIAL IMPACTS AND EFFECTS
Air quality	<p>Pollution from waste management facilities and activities can adversely affect air quality. Typical releases and emissions include:</p> <ul style="list-style-type: none"> <li>• <b>Landfills and dumpsites</b> – landfill gas (methane, CO<sub>2</sub>, and a range of other potential contaminants, e.g., hydrogen sulfide, ammonia, NMOCs, at low concentrations); dust; volatilization of organics.</li> <li>• <b>Incinerators, and energy-from-waste</b> – emissions of NO<sub>x</sub>, SO<sub>x</sub>, CO<sub>2</sub>, carbon monoxide (CO), unburned hydrocarbons (HC), dioxins, furans, and particulates. NO<sub>x</sub> contributes to formation of smog and acid rain and affects tropospheric ozone.</li> <li>• <b>MRFs, transfer stations, and composting facilities</b> –generate dust and VOCs from daily operations. Enclosed facilities can contain these releases, but open sites are far more common in the developing world.</li> <li>• <b>Transportation</b> – Most waste vehicles use internal combustion engines and represent a mobile source of air pollution (including NO<sub>x</sub>, SO<sub>x</sub>, HC, CO, CO<sub>2</sub> and particulates).</li> </ul> <p>The significance of the impacts is dependent on many factors such as the source, intensity, duration, proximity to sensitive receivers, and climatic conditions, but can affect human health (see below) and ecology.</p>
Noise and vibration	<ul style="list-style-type: none"> <li>• Waste management operations can generate significant amounts of noise from (1) fixed equipment or process operations; (2) mobile equipment or process operations; and (3) waste transport.</li> <li>• Heavy mobile equipment (e.g., compactors, tipper trucks) can generate ground vibration, which can affect nearby people and structures.</li> <li>• Solid waste facilities may operate 24-hours every day, but are typically located in industrial areas, which are less sensitive to noise.</li> <li>• Facilities generate traffic, causing chronic low-level noise affecting communities located along roadways. Waste collections also generate significant noise in urban areas, usually early in the morning.</li> <li>• Noise impacts can affect human (see Table 2) and ecological health and well-being.</li> </ul>



**TABLE I: POTENTIAL OPERATIONAL ENVIRONMENTAL IMPACTS AND EFFECTS**

CATEGORY OF IMPACT	DESCRIPTION OF POTENTIAL IMPACTS AND EFFECTS
<p>Pollution of surface waters and groundwater</p>	<p>Waste management activities can have a range of impacts on the quality of fresh and marine surface water bodies and groundwater.</p> <ul style="list-style-type: none"> <li>• Waste management facilities such as landfills and transfer stations generate leachate and contaminated stormwater which can pollute soils, groundwater and surface waters if discharged to ground, stormwater drains or sewerage systems.</li> <li>• Pollutants (BOD, COD, ammonia, inorganic salts, etc.) in higher concentrations makes leachate a potential source of contamination for surface waters (and ground waters (see below)).</li> <li>• Stormwater runoff contaminated with pollutants, including hydrocarbons, heavy metals, litter and organics can enter waters or groundwater via drainage or sewerage systems, through infiltration or direct overflow leading to adverse effects on water quality.</li> <li>• Direct stormwater runoff may contain elevated levels of suspended sediments, which can increase turbidity of receiving waters, and nutrients.</li> <li>• Nutrient pollution from organics/leachate leads to excessive plant/algae growth (eutrophication), blocking light and absorbing oxygen in the water, which can kill aquatic animals.</li> <li>• Application of liquid by-products from anaerobic digestion to land can lead to nutrient pollution in waterbodies via run-off or groundwater connectivity.</li> <li>• Uncontrolled landfills or dumpsites containing toxic hazardous wastes risk contamination of surface and ground waters. Risks depend on quantity, concentration, leachability, and characteristics of source material(s), pathways and receptors.</li> <li>• Groundwater pollution is difficult and expensive to remediate. In some cases (e.g., contamination of an aquifer) such impacts may be long-term/irreversible.</li> <li>• Plastic waste can harm physical habitats and aquatic life, transport chemical pollutants, and interfere with human uses of river, marine and coastal environments (see Section 2.9).</li> <li>• Discharges to water from waste sites containing trace levels of heavy metals and other persistent compounds can build up in river and marine sediments over time. If disturbed, such sediments can become a source of pollution causing deterioration of water quality.</li> </ul>
<p>Soil/sediment and land contamination</p>	<p>Waste management is closely related to contaminated land management because existing and former waste sites may be a source of contamination and engineered waste sites manage wastes from remediation of contaminated land. There may be many existing or former waste sites within a developing country that are contaminated by hazardous materials, including industrial sites and dumpsites or semi-controlled landfills containing hazardous wastes. Such sites can pose a significant long-term risk to human</p>

**TABLE I: POTENTIAL OPERATIONAL ENVIRONMENTAL IMPACTS AND EFFECTS**

CATEGORY OF IMPACT	DESCRIPTION OF POTENTIAL IMPACTS AND EFFECTS
	<p>health and can disrupt ecosystem services and productive use of land. If wastes are also leachable, contaminants can be mobilized via water and groundwater pathways (see pollution of surface waters and groundwater above).</p> <ul style="list-style-type: none"> <li>• Contaminants in soils may be dispersed via windblown dust and particulates when ground is exposed or by volatilization to the atmosphere and pose a risk to people via direct contact or ingestion of contaminated food, particularly where such sites are not secured.</li> <li>• Attempts to remediate or contain contaminated sites may lead to mobilization of contaminants if not properly planned and implemented (e.g., breaking up of asbestos concrete creating respirable dust).</li> <li>• The legacy of hazardous wastes contamination can last many years, particularly in the case of heavy metals, persistent organic pollutants (POPs), and other non-biodegradable compounds.</li> </ul>
Ecology and biodiversity	<p>Pollution from waste management sites and activities can adversely affect wildlife, habitats and ecosystems on land, and in rivers, coastal areas, and the ocean. Understanding these impacts requires assessment of species present, their abundance, the ecological context, relevant processes and interactions, and the nature of adverse effects. Examples of adverse effects on wildlife include:</p> <ul style="list-style-type: none"> <li>• Contamination of marine and fresh water leading to toxic effects on aquatic species; e.g., nutrient rich discharges causing eutrophication or harmful algal blooms; and changes in water chemistry or pH leading to habitat degradation and fish kills.</li> <li>• Waste management activities and sites can also cause disturbance to wildlife, and attract scavenging animals such as vermin and birds, which can affect local native species (e.g., eating eggs, competing for food or directly predating).</li> <li>• Chronic and frequent noise interferes with animals’ abilities to detect sounds, and intermittent and unpredictable noise may be perceived as a threat. This can lead to adverse behavioral and physiological responses, affecting fitness, foraging, breeding, or mortality.</li> <li>• Accumulated waste and litter can damage sensitive habitats, which may be home to threatened and endangered species.</li> <li>• Plastic litter is consumed by organisms which mistake it for food at many trophic levels (from plankton to whales). Plastics can harm birds and aquatic animals by blocking their digestive system or toxicity.</li> <li>• Waste sites, particularly those containing hazardous wastes, can cause deterioration in ecosystem services (such as freshwater provision, ecological uses), and productive use of land (construction / agriculture).</li> </ul>

## 5.5 OPERATIONAL SOCIAL, CULTURAL AND ECONOMIC IMPACTS

Examples of social, cultural and economic impacts and effects associated with solid waste management activities and the operation of waste facilities are described in Table 2Table I, by category of impact. This list is illustrative and non-exhaustive.

**TABLE 2: POTENTIAL OPERATIONAL SOCIAL, CULTURAL AND ECONOMIC IMPACTS AND EFFECTS**

CATEGORY OF IMPACT	DESCRIPTION OF POTENTIAL IMPACTS AND EFFECTS
Social and Community	<ul style="list-style-type: none"> <li>Waste management activities and sites can lead to visual and amenity impacts when located in residential areas. Unsightly waste sites, litter, dust, noise and odor can affect the quality of life for nearby communities, as well as affecting land/property prices, and businesses.</li> <li>In the informal waste sector, workers may suffer from effects of extreme poverty, such as food insecurity, social exclusion, and lack of access to water, sanitation, healthcare. education, and housing.</li> <li>Workers' welfare and rights may not be prioritized by some employers and governments, with many working in poor conditions for very low income. Informal waste activities are often carried out by vulnerable populations, including children and the elderly, who may face increased risks of health problems or being victims of crime or exploitation.</li> <li>In some cases, activities in the waste management sector can be associated with incidences of corruption. Corrupt contracting practices, graft, and illegal trading and dumping of hazardous and other wastes are examples of opportunities for corrupt officials and criminals.</li> <li>Traffic impacts are a major consideration when implementing waste management activities. Traffic accidents involving waste vehicles can result in spillage of hazardous materials (e.g., clinical and industrial wastes, or contaminated soils).</li> </ul>
Economic	<ul style="list-style-type: none"> <li>While import of recyclable materials is an important generator of foreign currency, employment, and materials for industries the environmental and social costs may offset economic gains.</li> <li>Presence of dumpsites and litter can reduce value of land and property. The buildup of plastic debris on beaches can affect coastal areas' attractiveness to tourists.</li> <li>Projects and activities aimed at improving waste management may increase capital and operational expenditures for public authorities, businesses and taxpayers, and can divert funds from other programs.</li> </ul>
Public health and occupational health and safety	<p>Municipal waste management activities are carried out for the benefit of human health. However, in themselves they can be associated with a wide range of public health and occupational health and safety impacts. Examples are as follows:</p> <ul style="list-style-type: none"> <li>Hazardous gas emissions from landfills and dumps can lead to human health impacts through toxicity, fires and explosions. People can be exposed to landfill gas in the air in the proximity of the site, or gas can migrate through the ground where it can accumulate in confined spaces (e.g., basements, tunnels, pipes).</li> </ul>

**TABLE 2: POTENTIAL OPERATIONAL SOCIAL, CULTURAL AND ECONOMIC IMPACTS AND EFFECTS**

CATEGORY OF IMPACT	DESCRIPTION OF POTENTIAL IMPACTS AND EFFECTS
	<ul style="list-style-type: none"> <li>• Landfill gas contains methane which is a highly combustible gas, which presents a risk of fire, explosion, or low-level toxicity. Landfill gas can also contain small amounts of hydrogen sulfide, nitrogen dioxide<sup>54</sup>, ammonia, and VOCs<sup>55</sup>, which can be harmful to human health.</li> <li>• Whether waste emissions pose a health hazard depends on the chemical concentrations to which people are being exposed and the duration of the exposure. Many exposures involve chemicals at low or trace levels, as well as mixtures of chemicals.</li> <li>• Particulates and toxic fumes from fires may be released in smoke. The toxicity of fumes and smoke depends on the source material. Tires, batteries and hazardous chemicals, as well as consumer products, such as plastics, pesticides, paints, solvents, or cleaners can lead to toxic releases when burned.</li> <li>• Production of dioxins and furans (potential carcinogens) are also a documented risk factor from burning waste, including at municipal incinerators. People working at, or living adjacent to, landfills and dumpsites with fires can be directly exposed to toxic fumes.</li> <li>• Most fires at landfills are small surface fires, but under certain conditions, they can escalate into a major incident with impacts over a large area. Fires at waste dumps and landfills can also burn underground in the absence of oxygen and without flames. Such fires may not be apparent at the surface, are extremely difficult to combat, and can burn for days or even weeks. Subsurface fires can also cause collapse of slopes.</li> <li>• Landfills and other waste management facilities that contain hazardous materials can represent a hazard to workers, pickers and nearby populations. Pathways could include physical contact by unprotected workers, inhalation of fugitive dust and fumes, and ingestion of contaminated water or food.</li> <li>• Informal work at waste sites can be dangerous, and proper health and safety precautions are often absent. In such conditions, workers may be at risk of injuries, diseases, and psychological trauma. Major occupational hazards for workers include being struck by vehicles and plant, burns, being buried under collapsing waste piles, infections and chronic respiratory diseases.</li> <li>• Odor from decomposing wastes (e.g., sulfides and ammonia) and presence of volatile chemicals can cause a nuisance for nearby communities. Odor often prompts complaints, and people may also have concerns about health effects. Temporary storage and transportation of wastes can also lead to odor impacts, especially in hot climates.</li> </ul>

<sup>54</sup> <https://www.epa.gov/no2-pollution/basic-information-about-no2#Effects>

<sup>55</sup> Many VOCs are Hazardous Air Pollutants (HAPs).

**TABLE 2: POTENTIAL OPERATIONAL SOCIAL, CULTURAL AND ECONOMIC IMPACTS AND EFFECTS**

CATEGORY OF IMPACT	DESCRIPTION OF POTENTIAL IMPACTS AND EFFECTS
	<ul style="list-style-type: none"> <li>• Regular exposure to elevated noise levels can cause annoyance and lead to physical and psychological health consequences including hypertension, heart disease, and sleep disturbance. Unprotected workers in waste facilities with elevated noise can face hearing impairment. Noise is a common complaint from populations near waste facilities in residential areas, and on collection and transportation routes.</li> <li>• Contamination (of surface and groundwater) by leachate and other pollutants from waste sites can enter potable water supplies. The risks associated with contamination of water sources is elevated if a landfill or dumpsite contains hazardous wastes. If ingested, pathogens and toxins can cause significant health problems. The likelihood of this occurring is increased in the developing world, as many people rely of informal or untreated water sources.</li> <li>• Landfills, dumpsites and open transfer stations in the proximity of airport are a safety hazard. Birds attracted to these sites can threaten aircraft.</li> </ul>
Natural disasters and emergencies	<ul style="list-style-type: none"> <li>• Incidences of landfills and dumpsites collapsing are well documented. Such incidents have led to injury and fatality of workers, as well as people occupying homes in adjacent (usually informal) settlements. Following collapse there is the added risk of the material catching fire. Earthquakes can also cause landfill / dumpsite collapse.</li> <li>• The risk of flooding can be exaggerated due to the presence of waste accumulated in drainage systems. Flooding can also mobilize waste from dumpsites and facilities leading to materials which are harmful to human health or the environment over a wide area.</li> <li>• The presence of waste and debris following flooding and storms can also hamper rescue and recovery activities.</li> </ul>

## 6 IMPACT MITIGATION, ENHANCEMENT AND MONITORING

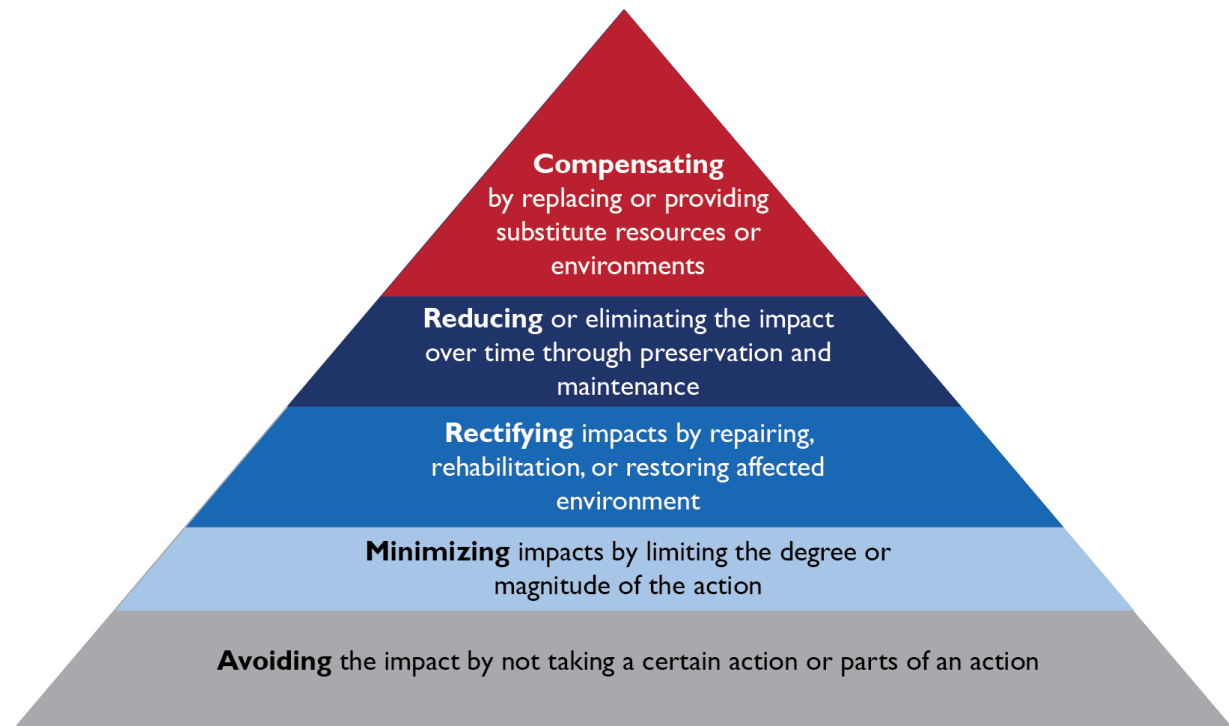
### 6.1 MITIGATION AND IMPLEMENTATION HIERARCHY

Where impacts are identified, it is necessary to work through possible mitigation and enhancement measures to manage impacts. Mitigation is the identification and application of measures to avoid, minimize, or remedy impacts. These may be defined as part of a formal EIA process and can be implemented at all stages of the project cycle. However, the earlier impacts are considered, the more likely they can be avoided. Mitigation is defined (under 40 CFR 1508.20, related to the US National Environmental Policy Act (NEPA)) as any activity that includes the following:

- Avoiding the impact altogether by not taking a certain action or parts of an action
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action
- Compensating for the impact by replacing or providing substitute resources or environments

Those responsible for designing or implementing projects or activities should prioritize mitigation measures in line with the “mitigation hierarchy”, as illustrated in Figure 12.

FIGURE 12. MITIGATION HIERARCHY



## **6.2 GOOD MANAGEMENT PRACTICES IN PLANNING AND DESIGN**

USAID-funded projects and related interventions or activities should be designed to maintain or improve environmental, health, or sociopolitical systems, as well as minimize negative impacts. Projects should be designed to meet good international industry practices goals and should follow the steps outlined in Reg. 216.56.

Environmental Mitigation and Monitoring Plans (EMMPs) are now required for most USAID-funded projects.

## **6.3 OPERATIONAL STAGE MITIGATION AND MONITORING**

It is essential that project managers engage environmental and social specialists to assist in identifying opportunities to avoid and minimize impacts. In countries where project infrastructure for supporting good environmental and social management is lacking, it is important that mission leaders take a proactive role in determining local solutions that achieve the best practices set out in the SEGs and nationally or internationally accepted standards.

The mitigation tables below serve as a reference on possible operational impacts and associated measures that can be planned for and implemented throughout the life-cycle of a project or activity, the objectives of these measures, and the indicators which may be used to monitor impacts. They are general references and the specific characteristics of each project context should be considered before applying them.

These mitigation and monitoring tables are organized by environmental or social component (e.g., air quality, social). For implementation, a column identifying the person or entity responsible for implementation within an organization should be included in the EMMP.

For environmental and social mitigation measures relating to the Construction Stage, please refer to the Construction SEG.

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<sup>56</sup> 22 CFR 216.

**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

CATEGORY	MITIGATION / ENHANCEMENT EXAMPLES	MONITORING EXAMPLES
Air quality	<p>Emissions from landfills are typically controlled by installing a gas collection system and combusting the collected gas (e.g., flares or gas engines). Gas collection systems are not 100% efficient in collecting landfill gas, so emissions of CH<sub>4</sub> and non-methane organic carbon still occur.</p> <p>Emissions from open burning of waste should be managed through prevention of fires. Stockpiling of large volumes of flammable materials (e.g., recyclables, wood, paper and plastic bales and tires) should be avoided or carefully managed, and open burning should be especially prevented where hazardous materials are present or nearby. Landfill gas collection systems are effective at reducing the risk of fires at landfill sites. However, overdrawn of landfill gas can also risk causing a fire.</p> <p>Effective fire control measures are required where there is a risk of fire, including development of fire prevention and response plans, communication with emergency responders (where available), training of operator staff, and provision of firefighting equipment. Equipment may include fire suppression systems (water hoses and retardants) or stockpiles of sand/dirt to cover fires. Sub-surface fires at landfills are more difficult to manage and may require specialist firefighting equipment.</p> <p>Pollution prevention systems (PPS) should be installed where exhausts (e.g., chimneys from incinerators and gas engines, generators or ventilation) may cause releases to air which exceed statutory limits or cause ambient air quality standards to be exceeded. Examples of PPS technologies are filters, catalysts, scrubbers, condensers and pressure swing adsorption. Operational control measures, such as reducing outputs or shutting off equipment when limits are reached may also be employed.</p> <p>Reduce dust generation at exposed areas, working areas and stockpiles at waste sites (e.g., landfills, transfer stations):</p> <ul style="list-style-type: none"> <li>• Cover exposed areas of ground and stockpiles to prevent windborne dust – areas can be covered temporarily with tarp, mulch, or gravel, the earth compacted, grassed/vegetated or paved. Vehicles carrying waste should also be covered;</li> <li>• Stockpiles, landfill working face and haul roads can be dampened with fixed water sprayers, hoses, or water bowser trucks. Spraying should be carried out such that areas are not over- or under-watered and that it is applied evenly. Spraying may be effective during the loading or tipping of dusty materials, and during excavation or levelling works;</li> <li>• Natural or artificial wind breaks can be used to prevent erosion of stockpiles and exposed areas, or around dust generating activities;</li> </ul>	<p>Emissions of CH<sub>4</sub> and NMOCs at site boundary or sensitive receptors.</p> <p>Thermal monitoring to identify subsurface fires at landfills.</p> <p>Continuous monitoring of emissions from incinerators (using Centralized Emissions Monitoring System (CEMS)).</p> <p>Dust monitoring (e.g., Total Particulate Matter (TPM), Particulate Matter &lt;10 microns diameter (PM<sub>10</sub>), and Respirable Suspended Particulates (RSP) – PM<sub>2.5</sub>).</p> <p>Direct monitoring of odor at boundary/sensitive receptors or recording of complaints.</p>



**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

	<ul style="list-style-type: none"> <li>• Dust generating activities should be limited during high wind conditions; and</li> <li>• Designate and implement speed restrictions for vehicles on unpaved roads or areas. Reducing speed from 45 to 35 mph can reduce dust emissions up to 22 percent.<sup>57</sup></li> </ul> <p>Odor complaints can be reduced / prevented by enclosing waste facilities and vehicles. Facilities can be operated at negative pressure using extractive fans and exhaust systems. The air in the exhaust systems can be treated by various methods including biofilters, scrubbers and UV light. Scented additives are sometimes used to mask odor, but preventative measures should be prioritized.</p>	
<p>Noise and vibration</p>	<p>Noise mitigation techniques which may be used during operation of plant and equipment at waste facilities include:</p> <ul style="list-style-type: none"> <li>• Locate noisy equipment and activities away from sensitive receivers, and avoid clustering of noisy plant / processes in one area;</li> <li>• Screen noise using permanent or temporary barriers, or existing structures / natural features;</li> <li>• Carrying out noisy activities (e.g., unloading, compaction) within enclosed areas;</li> <li>• Select quiet plant and processes wherever feasible;</li> <li>• Maintain plant and equipment in good working condition;</li> <li>• Turn off machinery when not in use;</li> <li>• Train staff to raise their awareness of noise impacts and management.</li> </ul> <p>Noise mitigation techniques used for mobile plant/vehicles at waste facilities and during transportation may include:</p> <ul style="list-style-type: none"> <li>• Implement speed restrictions to keep vehicle speeds as low as practical in facilities and during waste transportation;</li> <li>• Minimize vehicle movements (e.g., practice backloading);</li> <li>• Reduce vehicle movements and noise during night-time and early mornings;</li> <li>• Route deliveries away from urban areas where practicable;</li> <li>• Use quiet and well-maintained vehicles;</li> <li>• Appropriate surfacing of access roads and operational areas can also reduce noise;</li> <li>• Train drivers on operational noise control measures (e.g., vehicle speeds, controlled acceleration, use of horn, correct access/egress to sites, and limiting idling/revving of engines).</li> </ul>	<p>Noise level checks on equipment and background.</p> <p>Offsite Traffic Noise: Noise emission checks on vehicles.</p> <p>Vibration monitoring.</p>

<sup>57</sup> Washington State Department of Ecology <http://www.yakimacounty.us/DocumentCenter/View/2521/Appendix-A-Dust-Suppression-Ecology-PDF?bidId=>

**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

	<p>Where noise is generated 24 hours, the activity should be inaudible at the nearest residential sensitive receptor during night-time hours.</p>	
<p>Pollution of surface waters and groundwater</p>	<p>Water and groundwater pollution impacts caused by runoff from waste sites can be controlled, managed or mitigated by implementing the following measures:</p> <ul style="list-style-type: none"> <li>• Prevent run-on (from upland areas) from flowing onto site and contacting waste, and ensure the site is adequately protected from flooding;</li> <li>• Control runoff so that it is diverted from active waste management areas and does not create pools or saturated soil conditions;</li> <li>• Erosion and sedimentation control measures, such as minimizing activities during heavy rain, reducing, compacting, covering or vegetating areas of exposed soil);</li> <li>• Provide and regularly maintain stormwater drainage system, including sediment control (e.g., silt traps). Treatment may be required in contaminated and/or sensitive locations;</li> <li>• Install containment (e.g., bunding, drip-trays) in high-risk areas (e.g., operational areas, fixed equipment, storage areas);</li> <li>• Locate and manage waste stockpiles to reduce runoff impacts;</li> <li>• Regularly clean waste sites and provide cleaning and wheel wash facilities for vehicles at site access/egress; suspended solids should be removed from used washing water prior to disposal;</li> <li>• Prevent, control and clean up litter to prevent it entering nearby waters;</li> <li>• Emergency plans should be developed to deal with accidental spillages and leakages. Leaks and spills should be contained and cleaned up immediately. Train staff to clean-up leaks and spills and provide clean-up equipment;</li> <li>• Maintain equipment to prevent leaks. Maintenance of vehicles and equipment should take place on a covered hard-standing;</li> <li>• Use of green infrastructure such as bioswales, green roofs, and water harvesting; and</li> <li>• Use of fire suppression equipment which is designed to minimize impacts to ground and water from run-off.</li> </ul> <p>Avoid discharging wastewater into waters where it exceeds discharge standards or causes receiving waters to exceed (or further exceed) ambient water quality standards or objectives. Where permissible, sites can be connected to the sanitary sewer system, or for small quantities effluents may be transported by tankers to municipal sewage treatment plants, (although this is expensive and causes additional logistical impacts). If necessary, on-site treatment systems can be used to bring effluents to the appropriate quality for discharge (to waters or sewer). Primary treatment usually includes removal of sediments by filtration or settlement (often using flocculants and decanters), and grease traps. Secondary (or tertiary) treatments, such as biological treatment or reverse osmosis may be required for some effluents (e.g., anaerobic digestion</p>	<p>Monitoring of (post treatment) discharges (including stormwater and effluent) for COCs.</p> <p>Monitoring of receiving, or hydrologically connected, waters via sampling and testing or real-time monitoring (e.g., buoy measuring conductivity, turbidity).</p> <p>Visual monitoring of litter.</p> <p>Groundwater monitoring – installation of piezometers / monitoring wells. In-situ monitoring equipment with data-loggers, field monitoring and sampling and laboratory testing.</p>

**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

	<p>liquors, landfill leachate). Complex on-site effluent treatment systems can be expensive and difficult to supply and maintain. Alternatives include use of evaporation ponds, and recycling of leachates within landfill cells or processes (e.g., anaerobic digestion or composting).</p> <p>Leachate contamination of waters and groundwater from landfills can be prevented or minimized through containment (e.g., impermeable lining systems and capping), capture (i.e., leachate collection systems) and treatment (e.g., effluent treatment technologies or evaporation ponds). Hazardous materials should not be placed within unlined landfills and should be managed appropriately when stored on-site.</p> <p>Carry out regular inspections and install leakage detection systems on underground storage tanks, above ground storage, and pipelines which represent a potential source of groundwater pollution.</p> <p>Where groundwater contamination is present, impacts can be reduced through well extraction in the affected area and appropriate treatment prior to discharge or reinjection. Hydraulic barriers can be installed to divert groundwater flows around sources or contamination.</p> <p>Disposal to waters may be a management option for inert wastes, under some circumstances. However, this activity should be highly regulated and controlled, and must not take place in ecologically sensitive areas. Silt curtains can be used to limit turbidity from disturbance of sediments to the immediate area. Booms can be used to capture floating litter.</p> <p>Sanitary latrines should be provided to prevent impacts from human waste, including for informal workers. These should be connected to the municipal sewage network or regularly emptied by a licensed contractor for appropriate disposal.</p> <p>Where impacts to waters have occurred, it may be necessary to remediate the affected waters, or provide compensation or enhancements on site, or in other areas.</p>	
<p>Soil/sediment quality, and land contamination</p>	<p>Contamination of soil and sediments can be prevented, controlled or mitigated by implementing the pollution prevention and control measures (described in ‘pollution of surface waters and groundwater’ section above).</p> <p>At landfills and dumpsites, incoming waste materials should be screened so that hazardous materials can be identified and appropriately managed. Hazardous wastes should not be disposed of in an unlined or uncontrolled landfill or dumpsite.</p> <p>Illegal dumping of wastes and hazardous wastes should be prevented through appropriate policies and policing to avoid contamination of sites. Adopt a cradle to grave waste management system, which includes good handling practices in storage, collection, transportation, recycling and disposal. Hazardous waste may</p>	<p>Automatic leak detection systems for pipes and underground tanks.</p> <p>Carry out leachability testing of potentially contaminated soil/sediments to determine disposal risk.</p>

**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

	<p>require testing for toxicity, leachability and other properties prior to disposal in an appropriate facility (e.g., high-temperature incineration or double-lined landfill).</p> <p>Where contaminated land, soil or sediment exists, and this represents a risk to human health and/or the environment, it may be necessary to implement control or remediation measures. Such measures may include containment of the contamination (e.g., capping, lining or hydrological barrier), removal of the source of contamination or contaminated materials (e.g., hazardous wastes in a dumpsite), stabilization of materials (e.g., cement mixing) or in-situ remediation (e.g., biological, chemical or thermal treatment).</p> <p>Where soils are contaminated it is likely that groundwater is also contaminated. Remediation may therefore include pumped extraction and treatment of groundwater. When removing or remediating materials, it is important that precautions are made to avoid further disturbance and dispersal of contaminants.</p> <p>Contaminated sediments are usually removed or stabilized in-situ. Removal may be done by capital or environmental dredging techniques, or by installing a cofferdam and excavating the materials 'in the dry'.</p> <p>If it is not practical to remediate contamination at existing (operational or closed) waste sites, affected areas should be controlled such that human health risks are minimized (e.g., close and secure areas of the site, provide PPE, or move affected communities).</p>	
<p>Natural resources</p>	<p>Sustainable practices in solid waste management play a key role in reducing natural resource use. Measures include:</p> <ul style="list-style-type: none"> <li>• Building awareness and implementing systems to reduce, reuse, and recycle in line with the waste management hierarchy.</li> <li>• Foster secondary markets/demand from local businesses to use recovered material and publicize prices for recoverable materials.</li> <li>• Incentivize sustainable material use, recycling, reprocessing and energy from waste.</li> <li>• Facilitate separation at disposal sites (e.g., integrate MRF at landfills).</li> <li>• Promote composting and anaerobic digestion maximize landfill capacity and reduce pollution.</li> </ul>	<p>Keep accurate and comprehensive records for materials recovery, recycling, and disposal.</p> <p>Waste audits, characterization and generation studies.</p>
<p>Ecology and biodiversity</p>	<p>Indirect impacts to ecology and habitat, such as sedimentation resulting from erosion, deterioration of water quality and disturbance from noise, should be mitigated through implementation of measures described above.</p> <p>Vermin, scavenging animals and birds, frequently found at waste sites, should be controlled (e.g., bird/bat deterrents/ deflectors/ hazing, adequate fencing, covering of exposed wastes, avoiding feeding animals, or keeping domestic pets, and good housekeeping).</p>	<p>Ecological monitoring includes:</p> <ul style="list-style-type: none"> <li>• Ongoing surveys (transects, cameras, traps/netting, visual/auditory), or incidental recording of, for example, fish, birds, bats, reptiles, and mammals;</li> <li>• Monitoring of habitat condition against baseline (transects/aerial photography/GIS)</li> </ul>

**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

	<p>Waste management staff should be given environmental training which includes ecological awareness. Mitigation plans should be in place for staff should they encounter threatened or endangered wildlife (e.g., nesting, in burrows, or trapped on the site) to avoid harm to the animal. Temporary suspension of activities may be necessary should threatened or endangered wildlife be encountered. Activities at waste sites may need to be modified at certain times of year, where threatened or endangered wildlife are present (e.g., breeding, staging, migration, hibernation seasons). Staff may also be trained to identify and manage potential invasive plant species.</p> <p>In sensitive areas for wildlife, and where it represents a risk, hunting and fishing bans could be considered. Vehicles should also yield right-of-way to wildlife.</p> <p>Where water is abstracted from rivers for use at waste management sites, ensure intake pipes are screened to prevent fish take.</p>	<ul style="list-style-type: none"> <li>• Visual surveys for presence of invasive species.</li> </ul> <p>It may be necessary to carry out monitoring/surveys seasonally depending on affected species/habitats.</p>
<p>Social and Community</p>	<p>In residential areas, waste management sites should be operated, and activities carried out, with minimal impacts to the amenity of nearby communities. Visual amenity impacts can be mitigated by screening (e.g., tree planting, solid fencing/walls), sensitive design of buildings, community art, or architectural features. Measures to mitigate odor, dust, and noise can be implemented as outlined above (See ‘air quality’, ‘noise’). Potential disease vectors (e.g., rodents, insects, birds) and other pests can be prevented through covering waste (e.g., applying daily cover in landfills, covering stored tires); frequent waste collections; minimal storage of organic wastes; enclosing facilities; eliminating standing water; adequate water supplies and sanitation; and improving cleanliness of site, containers and equipment (e.g., washing out drains, scrubbing tanks, and cleaning stored recyclables), and controlled through safe use of pesticides, traps and other measures.</p> <p>Traffic impacts associated with solid waste management sites and activities should be minimized through implementation of measures set out in a traffic management plan. In some cases, plans should be developed based on a detailed Traffic Impact Assessment (TIA), which may include modelling of impacts to roads and junctions. Mitigation measures may include:</p> <ul style="list-style-type: none"> <li>• Reducing the amount of traffic by reducing generation at source, consolidation of collection services, reducing frequency of collection (i.e., for dry recyclables), efficient routing, backhauling and selection of vehicle type (e.g., compactor RCV, containerized transport);</li> <li>• Timing of vehicle movements outside peak traffic hours;</li> <li>• Improving site access/egress, roads and junctions, and providing truck lanes and off-street parking for vehicles; and</li> <li>• Provision of waste transfer or materials recovery facilities.</li> </ul>	<p>See above litter, noise, odor and air quality monitoring.</p> <p>Traffic monitoring – via direct observation surveys, GPS tracking, and complaints monitoring.</p> <p>Worker welfare monitoring can be carried out via qualitative interviews, anonymous reporting, grievance mechanism, and independent audits.</p>

**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

	<p>Worker welfare impacts can be mitigated through the adoption and implementation of specific policies and practices which aim to improve labor conditions. Policies may include minimum standards for worker accommodation, safe transportation, rights (e.g., right to form unions), human resource standards (e.g., sick pay and vacation entitlements), reasonable working hours, minimum wages, free health and safety training and PPE, and provision of adequate welfare facilities (ablutions, canteen, first aid). Labor agents should be regulated to prevent payment of fees leading to bonded labor conditions or withholding of documents or wages. It should be noted that the right to form unions is legally restricted in some jurisdictions. Minimum standards should be in line with local labor laws.</p> <p>The informal sector can be a significant resource for implementing socially sustainable waste projects, and the rights and livelihoods of existing workers should be protected. The right approach to providing inclusivity for informal sector will be contextual but could include formalizing waste picking at landfills by creating cooperatives with proper sorting facilities and improved working conditions. Such measures can improve material recovery rates for minimal investment and deliver considerable improvements in quality of life for workers.</p> <p>Policies and procedures should be in place to prevent corruption, for example using open competitive tendering and prequalification when letting operational contracts. GPS tracking of vehicles, robust waste manifest and record collection systems can also help to prevent illegal waste dumping.</p>	
<p>Public health and occupational health and safety</p>	<p>Mitigation measures to protect workers and the public from physical hazards during the operation of waste sites involves safety reviews of planned activities and the implementation of best management practice safety measures.</p> <p>Fire prevention and control is a major consideration at waste sites. Explosion of flammable gas is also a critical risk. Measures to avoid, control or mitigate fire and gas risks include:</p> <ul style="list-style-type: none"> <li>• Fire life-safety systems and equipment, including fire-escape provisions;</li> <li>• Fire detection, alarm and suppression/extinguishing systems;</li> <li>• Safe storage of wastes/materials, including capacity and timing of storage, bunkering/containment and safe spacing, location of hazardous and highly flammable materials;</li> <li>• Remove sources of ignition, including naked flames;</li> <li>• Prevention of arson/vandalism, removal of informal waste pickers, and no open burning for waste operations;</li> <li>• Fire suppression/extinguishing/fighting systems, connection to mains water supply;</li> <li>• Regular maintenance and cleaning program, good housekeeping practices;</li> <li>• Provision of 'hot works' and 'hot loads' areas;</li> </ul>	<p>Regular health and safety inspections, audits and incident records. Record training, issuance of PPE (and enforcement of PPE use) and any non-compliance with HSE policies by workers. Carry out management review at least annually.</p> <p>Fire and life safety monitoring, and where necessary gas detection systems.</p> <p>Monitoring of slope stability can be carried out using surveys and using continuous monitoring equipment.</p> <p>Monitor driving standards/violations via GPS tracking of vehicles (where feasible) and/or complaints.</p>

**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

<ul style="list-style-type: none"> <li>• Ensure adjacent community property is protected (e.g., fire breaks, non-flammable materials, relocation of at risk communities (only if no alternative, and following due process); and</li> <li>• Training and awareness of staff, fire prevention and control planning, and close communication with local fire department/civil defense.</li> </ul> <p>Good management practices should be employed to minimize risks to human health from contact, ingestion and inhalation of hazardous materials present at waste sites, including:</p> <ul style="list-style-type: none"> <li>• Screening of materials entering landfills and segregation, or rejection of hazardous materials identified;</li> <li>• Appropriate storage of hazardous materials including dedicated storage area (hard-standing, bunding/drip trays, ventilation, access control, signage), provision of material data sheets and compliance with safety regulations and standards;</li> <li>• Provision of clean up and containment materials and equipment, training of staff in their use, and preparation of emergency plans; and</li> <li>• Licensing, registration and regulation of hazardous waste collectors/service providers.</li> </ul> <p>Plant and machinery at waste sites should be in good condition, regularly maintained, and operated in accordance with manufacturers' instructions.</p> <p>Vehicle collisions are a major source of accidents at waste sites, and during waste collections and transportation. Risks to workers, road users and pedestrians should be minimized using appropriate safety measures and best practices, including:</p> <ul style="list-style-type: none"> <li>• Enhanced driver training, policies and awareness (e.g., speed, use of mobile phones, seatbelt use, safe reversing, and drugs/alcohol zero tolerance);</li> <li>• Provision of safety equipment on vehicles, including emergency shut off, audible reversing alert, LED and strobe lights, reflective tape, logos, and decals, GPS, and back-up cameras; and</li> <li>• Regular inspection and maintenance of vehicles.</li> </ul> <p>PPE is essential safety equipment. PPE includes clothing and equipment, such as safety boots, hard hat, safety glasses, ear defenders, gloves, respirator, high-visibility clothing, kneepads, overalls, and if required HAZMAT suit. Selection of appropriate PPE for workers and visitors at a waste site must be based on risk assessment of the site and activities.</p> <p>Limiting access for waste site pickers, will minimize the health and safety risks associated these activities (e.g., being struck by vehicles at landfill working face etc.). However, this is associated with many unwanted social and political implications. Formalizing waste reclaiming/picking activities at waste sites will allow</p>
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**TABLE 3. REFERENCE GUIDE FOR OPERATIONAL MITIGATION MEASURES AND MONITORING**

	<p>workers to be equipped with appropriate PPE, trained and provided with safe, sanitary and secure working conditions.</p> <p>The stability of landfills and stockpiles should be ensured to minimize the risks associated with collapse. Measures include reducing gradients, reinforcing slopes (e.g., gabions, concrete cap, vegetation, soil nails), erosion control and drainage methods, as well as relocating at-risk workers or communities (e.g., waste pickers, and (informal) settlements at the toe of slopes).</p> <p>Long-term impacts to the public from exposure to contaminated media (i.e., soil, water, plants, and animals) would be mitigated through the use of access controls (e.g., fences, warning signs, and personnel to limit public access to contaminated areas) and engineered barriers designed to reduce the migration of contaminants to the accessible environment. In places where fencing would not be practical (e.g., along a public stream) signs could be used to warn against ingestion of contaminated water, plants, and animals.</p>	
<p>Natural disasters and emergencies</p>	<p>Waste sites and programs should prepare detailed emergency response and contingency planning to effectively respond to emergency incidents and events, such as flooding, typhoon/hurricanes, earthquakes, fires, landslides, disease outbreak, and security issues.</p> <p>Flood prevention and control measures at waste sites include:</p> <ul style="list-style-type: none"> <li>• Development of a flood prevention strategy</li> <li>• Structural measures (defense structures)</li> <li>• Flood forecasting and warning measures and emergency preparedness and response planning</li> <li>• Clearing litter and debris from storm drains</li> <li>• Good housekeeping and proper storage of materials</li> </ul> <p>Following an emergency event such as a flooding or typhoon/hurricane public authorities and waste facilities may be required to quickly and effectively manage the resulting debris from infrastructure and the public realm. Such debris can prevent rescue operations, lead to disease outbreaks by encouraging vectors, divert resources, and slow down an area’s recovery. Emergency plans for debris management should include provisions for labor, equipment, facility capacity and operations.</p>	<p>Regional and local earthquake and flooding early warning systems (where present), and weather reports may be monitored as part of emergency planning and management at facilities.</p>



## 7 PLANNING FOR A CHANGING CLIMATE

Climate change is a cross-cutting issue that can undermine development progress and increase risk and insecurity in developing countries. The effects of global climate change are likely to be numerous and far-reaching, including sea level rise, seasonal shifts and variability in temperature and precipitation, and increased frequency, intensity, and duration of extreme events (including droughts, floods, high winds, and tropical storms). In the long term, sea level rise could lead to permanent loss of low-lying and coastal land areas or increased need for coastal engineering and management to prevent their inundation.

USAID is committed to address both the causes of climate change and its impact on the broader development of its partner countries. USAID's 2012 Climate Change and Development Strategy laid out three clear objectives:

1. To accelerate the transition to low-emission development through investments in clean energy and sustainable landscapes;
2. To increase the resilience of people, places and livelihoods through investments in adaptation; and
3. To strengthen development outcomes by integrating climate change across USAID programs, learning, policy dialogues and operations.

By ensuring that projects are resilient against, and reduce vulnerability to, the effects of climate change, and identifying cost-effective ways to reducing their contribution to climate change, USAID can increase the sustainability its investments and improve the likelihood of their long-term success. To plan for a changing climate, field operatives should identify and assess potential climate change risks, relevant to their projects, programs and operations, and develop ways to manage such risks, through avoidance or adaptation. USAID provides guidance for climate risk management in ADS Reference 201: Climate Risk Management for USAID Projects and Activities.

### 7.1 CLIMATE CHANGE RISK MANAGEMENT

Climate Risk Management (CRM) is the process of assessing, addressing and adaptively managing climate risks at all stages in the program cycle. With a few exceptions, USAID Project and Activity Design Teams are required to identify and assess relevant climate risks, implement measures to mitigate unacceptable risks, and monitor and evaluate the effectiveness of adopted measures, in accordance with Mandatory Reference for ADS Chapter 201.<sup>58</sup>

The CRM processes and results, including identified climate risks, risk ratings, how risks are addressed, opportunities and any further analysis needed, should be documented in Project Appraisal Documents (PADs) and Environmental Compliance Analyses (e.g., the Initial Environmental Examination (IEE)). It is also important to monitor and evaluate the application of climate change mitigation during implementation, and to apply learning throughout the Program Cycle.

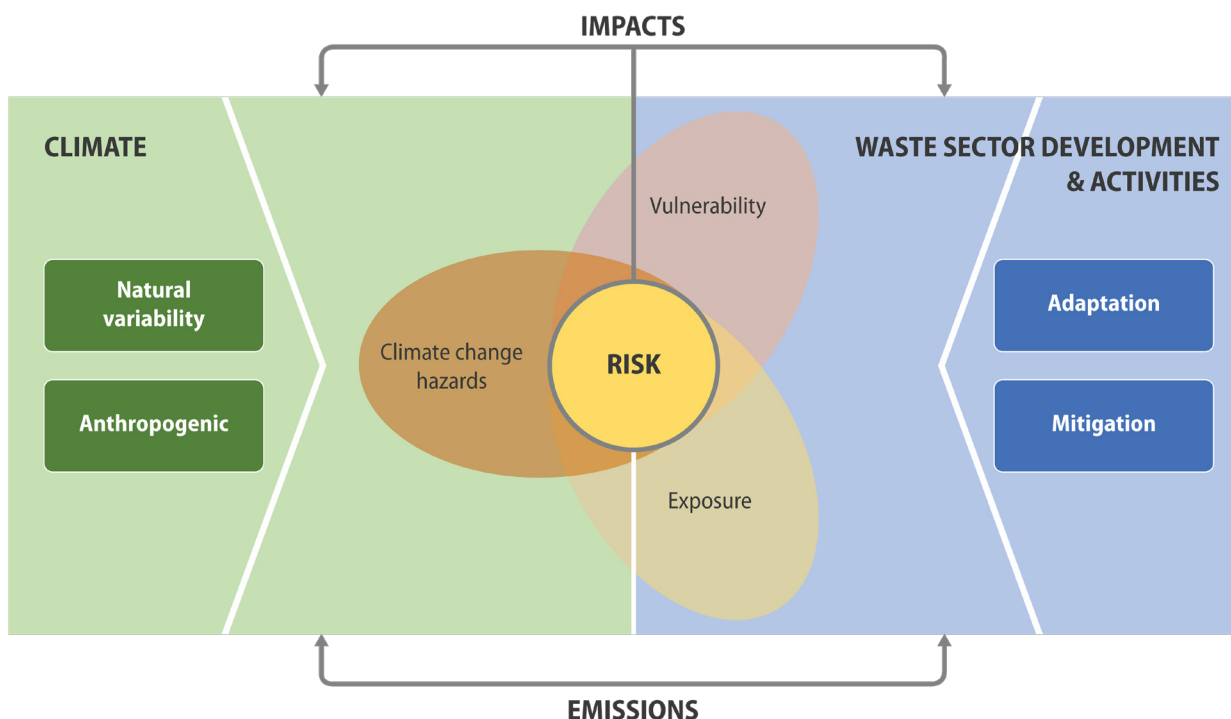
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<sup>58</sup> Climate Risk Management for USAID Projects and Activities: A Mandatory Reference for ADS Chapter 201. [https://www.usaid.gov/sites/default/files/documents/1868/201mal\\_042817.pdf](https://www.usaid.gov/sites/default/files/documents/1868/201mal_042817.pdf)

### 7.1.1 ASSESS CLIMATE CHANGE RISKS

Assessing climate change risks associated with a project or activity involves: 1) forecasting potential climate change trends and predicting the related hazards; 2) evaluating the project or activity's level of exposure to impacts from that hazard, and its vulnerability (i.e., ability to cope with impacts) to determine the potential severity of impacts; and 3) evaluating the likelihood that impacts will occur.<sup>59</sup> The potential effects from the project or activity itself on the vulnerability of communities and physical assets to climate change impacts and adaptability should also be considered. The interaction between these factors is illustrated in Figure 13.

FIGURE 13. CLIMATE CHANGE RISKS MODEL



Source: After IPCC (2012) [https://www.ipcc.ch/pdf/special-reports/srex/SREX\\_Full\\_Report.pdf](https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf)

USAID internally screens for all potential risks associated with activities that include construction investments during the planning and activity design phase. However, detailed risk assessment and the processes for integrating climate change considerations into construction projects are part of the engineering design phase, and this responsibility is thereby outsourced to the Designer of Record (DOR).

Project officers and engineer teams should work together to investigate the likely extent of variability and extreme weather events, drawing from available historical records, current trends, and future projections. The timeframe of projects should reflect the type of investment being made. Planned actions associated with the project or activity should then be evaluated against the predicted trends to

<sup>59</sup> Climate risk = severity of potential climate change impact x predicted likelihood that it will occur.

identify potential climate change risks. Procedural aspects of identifying climate change impacts associated with a project or activity are set out in US Reg 216.

Tools are increasingly available to help decision-makers and project designers pragmatically assess potential climate risks in the face of uncertainty by first screening for climate vulnerabilities through use of a “decision tree.” Further or deeper analysis is performed only as needed, allowing decision-makers to allocate scarce project resources proportional to project needs.<sup>60</sup>

Climate change risks and impacts will be distinctive to the specific location, timing and project or activity characteristics. Examples of potential risks which could be associated with solid waste management sites and operations are listed in Table 4, and are discussed in the paragraphs below.

TABLE 4. POTENTIAL CLIMATE CHANGE RISKS IN THE SOLID WASTE MANAGEMENT SECTOR	
POTENTIAL CHANGE	POTENTIAL INCREASED RISK
Increase in annual average and maximum climatic temperatures. Increased incidence of drought.	<ul style="list-style-type: none"> <li>• Fires at landfills, waste storage areas and dumpsites</li> <li>• Altered chemical composition of contaminants below the surface, and changes in evaporation rates affecting land disposal</li> <li>• Proliferation of disease vectors (insects, vermin) at waste storage areas and disposal sites</li> <li>• Reduced storage times for organic wastes</li> <li>• Odor around storage areas and facilities</li> <li>• Mobilization of dust and volatile organics, leading to deterioration in air quality</li> <li>• Thawing permafrost or soils disrupting drainage and surface water flow around landfill sites</li> </ul>
Increase in mean sea level	<ul style="list-style-type: none"> <li>• Flooding of waste management sites and facilities</li> <li>• Rising water-table can affect the hydrology around landfills, causing contamination of groundwater, aquifers waterways and water supplies</li> <li>• Impacts on coastal docking and transfer facilities</li> <li>• Permanent inundation of collection, processing, and disposal infrastructure</li> </ul>
Increased average rainfall and more frequent/intense wind/rainfall events (including hurricanes, typhoons)	<ul style="list-style-type: none"> <li>• Saturated soils and decreased stability of slopes and landfill linings at waste management sites</li> <li>• Flooding of waste sites leading to groundwater, soil and surface water contamination, and mobilization of hazardous materials</li> <li>• Disruptions in the removal and transportation of solid waste</li> <li>• Damage to waste containment facilities or structures</li> <li>• Increased requirement to manage debris following storms or flooding</li> </ul>
Increased incidence and intensity of storm surges	<ul style="list-style-type: none"> <li>• Inundation of waste sites releasing contaminants to waterways, land and occupied areas</li> <li>• Potential for pools of standing contaminated water that promote water and vector-borne diseases</li> <li>• Floating waste may wash up with storm surges</li> </ul>

Source: World Bank (2018) Adapted from Zimmerman and Faris (2010)<sup>61</sup>

<sup>60</sup> Ray, Patrick A., and Casey M. Brown. 2015. Confronting Climate Uncertainty in Water Resources Planning and Project Design: The Decision Tree Framework. Washington, DC: World Bank.

<sup>61</sup> <http://www-esd.worldbank.org/citiesccadaptation/solidwaste.html>

Once risks and potential impacts have been identified and described, they should be evaluated to determine their overall significance, which involves predicting the severity of the impacts and the likelihood that they will occur.

The key determinants of impact severity are exposure and vulnerability. Waste management facilities, particularly landfills and dumpsites, can be vulnerable to flooding or rising groundwater, potentially spreading contaminants from untreated wastes into soils, groundwater and surface waters, or undermining their structural integrity. Increased temperatures and drought can lead to higher frequency of fires at waste sites, and increased incidence of odor, vermin/vectors and dust may require higher collection frequency and greater implementation of waste management controls.

In many developing countries, solid waste management systems can be inadequate, leading to the accumulation of waste in areas affecting water runoff or flood control, such as drains, sewers, channels, and waterways.<sup>62</sup> These conditions can lead to increased vulnerability to flooding, from intense precipitation, storm surges, and even moderate rainfall. Such impacts can be pronounced in urban areas, especially in informal settlements which lack formal infrastructure or are on marginal lands (e.g., hillsides, marshland, or floodplains), due to exposure to contaminated water and water/vector-borne diseases, landslides, and damage to property and livelihoods caused by flooding.

Vulnerability to climate change impacts can be compounded in some developing countries, due to limited ability to provide a planned and coordinated debris clean-up and management following storms and flooding. Much of the debris left behind after storms and flooding represents a danger to human health and safety, is a barrier to rescue and relief operations, and post-disaster recovery.

The magnitude, timing, geographic variability and reversibility of climate change effects cannot be predicted with certainty. However, it is widely accepted that without significant reductions in global GHG emissions, global warming is likely to continue, and that extreme climate events would also likely increase in frequency and severity.<sup>63</sup> From a risk management perspective, depending on the project, the precautionary approach may be appropriate when faced with such uncertainty, as users, businesses, and governments in developing countries may not be able to absorb the full cost of the damages, or risk the loss of services, should impacts be realized.

### 7.1.2 ADDRESS CLIMATE CHANGE RISKS

USAID design teams considering including construction activities in new projects should be aware of potential impacts from climate change and ensure that procurement documents, agreements and/or contracts include requirements to conduct appropriate architectural and engineering design and risk management procedures that include climate change considerations.

Significant identified risks associated with projects and activities should be addressed through mitigation or adaptation. In this context, mitigation refers to the reducing or avoiding climate change impacts from projects or activities (e.g., landfill site causing increased damage to communities when flooded), and adaptation means reducing the impacts to the project from unavoidable climate change effects (e.g.,

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<sup>62</sup> Zimmerman and Faris 2010

<sup>63</sup> US Global Change Research Program 2018

reducing exposure to flooding at a landfill site, and/or reducing the likely effects on the operation of the facility). The overall objective is to create projects or activities that are resilient to the effects of climate change. Climate resilience is the capacity of a system to absorb the stresses imposed by climate change, respond to them, and evolve into more sustainable and robust systems. Embedding climate resilience in the design of waste management projects and activities will contribute to minimizing future losses and damages (and associated costs) of extreme climate events and help them to rebound swiftly.

Siting and design of waste facilities near the sea should account for potential changes in daily sea levels, sea level rise, and storm surges, and appropriate locations should be selected based on these considerations. The same principle applies to construction near floodplains, rivers, and wetlands. Siting decisions should be informed by accurate data on geology, groundwater, surface water, flooding hazards, and proximity to vulnerable populations. Adapting design, operation, and maintenance of solid waste management sites to climate change effects, involves ensuring that structures and systems can withstand increased variability and duration of extreme temperature, wind, and precipitation, to protect occupants and maintain uninterrupted provision of services.

Reducing the amount of solid waste stored in landfills is one of the easiest ways to reduce their vulnerability. Establishing waste sorting and recycling facilities can create local jobs and perhaps provide work for trash pickers whose livelihoods were compromised by a more robust municipal waste collection system. Recycling also reduces resource use and the amount of waste that must be managed in a landfill.

Solid waste-related flooding can be mitigated through the improvement of solid waste management practices, such as carrying out regular collection of solid waste from streets, drains, and waterways. This can be taken as a low-cost measure in advance of an anticipated storm. In municipal solid waste collection systems, accumulation of waste and informal disposal should be minimized, and adequate collection and storage/containment systems should be in place to reduce spread of contamination and litter from flooding.<sup>64</sup> However, many governments and municipal authorities in developing countries face a variety of challenges in implementing effective solid waste management systems, including financing minimal solid waste operations.

The ability of waste management sites to provide continued services during extreme climate events, is also a key factor in establishing resilient projects and activities. Adaptation includes integrating, where economically feasible, back-up systems to provide services (e.g., power, water, and communications) in the event of sudden or intermittent failures due to weather events. Debris management following these events is also important to protect human health, comply with regulations, conserve disposal capacity, reduce injuries, and prevent or minimize environmental impacts.

General examples of climate change adaptation measures are provided in Table 5. Specific characteristics of each project or activity should be considered on a case by case basis.

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<sup>64</sup> UN-HABITAT 2011

**TABLE 5. POTENTIAL CLIMATE CHANGE RISKS IN THE SOLID WASTE MANAGEMENT SECTOR**

PROGRAM CYCLE	ACCOMMODATE/MANAGE	PROTECT/HARDEN	RETREAT/RELOCATE
Design	<ul style="list-style-type: none"> <li>• Properly site landfills away from floodplains, wetlands, or areas with high water tables</li> <li>• Site landfills away from drinking water supplies</li> <li>• Develop sites large enough to accommodate projected population growth and corresponding waste generation</li> <li>• Design sites with sorting, recycling, and composting facilities to reduce waste storage needs</li> </ul>	<ul style="list-style-type: none"> <li>• Update design standards to elevate and strengthen containment walls to accommodate future sea level rise and high winds</li> <li>• Design water catchment systems that can keep pace with projected rainfall patterns</li> <li>• Update equipment design standards to increase efficiency and reduce maintenance costs in changing climate, particularly for complex, HVAC-dependent equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Plan for secure landfill closure and/or relocation</li> <li>• Plan for extreme event evacuation</li> </ul>
Implement / Manage	<ul style="list-style-type: none"> <li>• Increase financial and technical resources for more frequent maintenance and repairs</li> <li>• Train waste sorters and educate the public about separating recyclable and compostable material from other waste</li> <li>• Maintain collection vehicles to minimize disruptions due to mechanical failures</li> </ul>	<ul style="list-style-type: none"> <li>• Prevent erosion of landfill slopes, covers, and roads into and around landfills</li> <li>• Maintain storm water catchment systems to ensure proper function</li> </ul>	<ul style="list-style-type: none"> <li>• Cover threatened landfills</li> <li>• develop new sites in more secure locations</li> </ul>

USAID 2012 Solid Waste Management Addressing Climate Change Impacts on Infrastructure: Preparing for Change. [https://www.climatelinks.org/sites/default/files/asset/document/Infrastructure\\_SolidWasteManagement.pdf](https://www.climatelinks.org/sites/default/files/asset/document/Infrastructure_SolidWasteManagement.pdf)

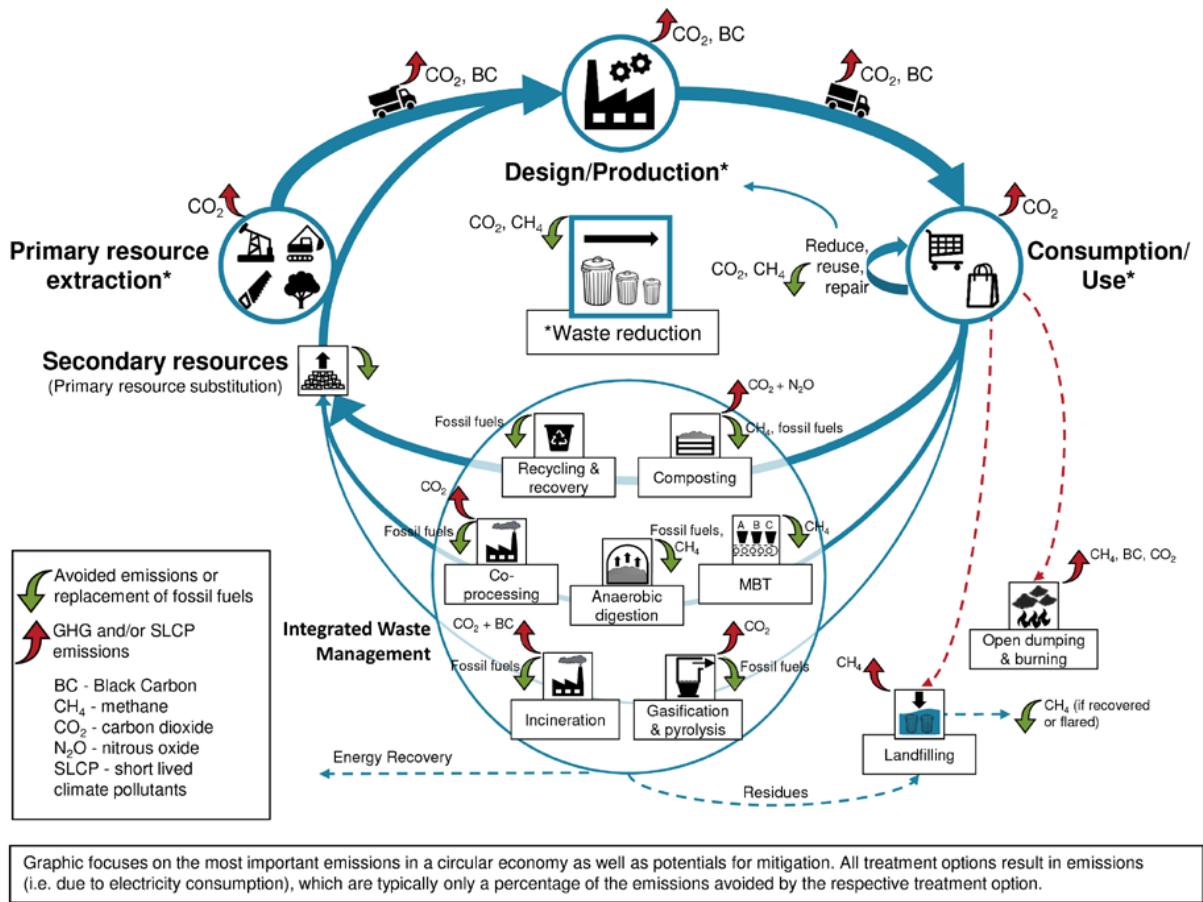
## 7.2 REDUCING GREENHOUSE GAS EMISSIONS IN SOLID WASTE MANAGEMENT

The goal of USAID’s work in climate change mitigation is to reduce GHG emissions and demonstrate that it is possible for countries to grow their economies in a sustainable, low-emission way.

The waste management sector is a major source of GHG emissions, most significantly through the release of methane as organic waste breaks down in landfills and dumpsites,<sup>65</sup> but also through transportation of wastes, emissions from incineration/open burning and inefficient use of resources (see Figure 14).

<sup>65</sup> Landfills are the third largest source of anthropogenic methane (CH<sub>4</sub>) emissions, accounting for approximately 11% of estimated global methane emissions.

FIGURE 14. RELATIONSHIP BETWEEN MATERIAL LIFECYCLE AND CLIMATE CHANGE



Source: Duetsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (2017)

<https://www.giz.de/de/downloads/giz2017-en-ndc-waste-management.pdf>

Population growth, urbanization and changing consumption patterns, means the total amount of municipal solid waste being generated will nearly double worldwide by 2050, increasing pressure on cities to manage this growing economic, environmental, and social challenge.<sup>66</sup> Reducing GHG emissions through well-managed waste systems, and energy and resource recovery, will contribute to mitigating climate change risks and could also have significant health, environmental, and economic co-benefits.

The two main approaches to reducing methane emissions from landfills are (1) capturing methane generated in landfills and either flaring or preferably using it to produce energy (electricity and heat); and (2) reducing the quantity of landfilled waste through source reduction, recycling, composting and/or anaerobic digestion of organic wastes.

Examples of measures to reduce GHG emissions in solid waste management are outlined in Table 6.

<sup>66</sup> World Bank 2018. What a Waste 2.0. And UNFCCC 2015. Available at: <https://unfccc.int/news/mitigating-slcp-from-the-municipal-solid-waste-sector>

**TABLE 6. EXAMPLES OF GHG REDUCTION IN SOLID WASTE MANAGEMENT**

CATEGORY	MEASURE TO REDUCE GHG EMISSIONS
Waste reduction / energy efficiency	<ul style="list-style-type: none"> <li>• Design energy efficient waste management facilities</li> <li>• Prevent food waste by reducing spoilage, oversupply and over-consumption</li> <li>• Encourage reuse of materials, reduce in consumption and encourage sustainable consumer practices via education and awareness programs</li> <li>• Restrict plastic bags and single-use plastics</li> </ul>
Material recovery	<ul style="list-style-type: none"> <li>• Recover soil improvement materials by composting organic waste</li> <li>• Recover recyclable materials through separate collections and recovery facilities</li> <li>• Process recyclable materials locally (where strict environmental controls can be enforced)</li> <li>• Encourage manufacturers to use of materials which are recyclables, or have recycled content</li> </ul>
Energy recovery	<ul style="list-style-type: none"> <li>• Energy recovery from incineration (with strict pollution control technology)</li> <li>• Create refuse derived fuels for local energy needs</li> <li>• Generate biogas through anaerobic digestion or landfill gas capture</li> <li>• Utilize biogas for electricity / heat generation, transport fuel, gas network injection</li> <li>• Where energy generation at landfills is uneconomic, carry out flaring of landfill gasses to prevent methane release</li> <li>• Promote advanced energy generation technologies in energy from waste projects, such as fuel cells (where local capacity makes this feasible to install, operate and maintain – including availability of spare parts)</li> </ul>
Disposal	<ul style="list-style-type: none"> <li>• Landfill gas collection and energy use (heat and power), or flaring (less preferred if energy generation viable)</li> <li>• Reduce / eliminate landfilling of organics</li> <li>• Carbon negative after-uses for closed landfills (e.g., tree planting, solar panels).</li> </ul>
Transportation	<ul style="list-style-type: none"> <li>• Use sustainable transport modes, such as barges and rail, electric vehicles, and run RCVs on green fuels</li> <li>• Efficient collection systems. Use transfer stations, match services supply to demand, discourage double handling and encourage backhauling</li> <li>• Proximity principle – manage waste at source location. Do not export large quantities of waste and recyclables.</li> </ul>

Consideration should be given to reducing GHG emissions when planning, designing and implementing solid waste management projects and activities. However, decisions on adopting specific measures should be based on sound financial principles, and subject to cost-benefit analysis, evaluated on a case by case basis.



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# 10 GLOSSARY OF TERMS

TERM	DEFINITION
<b>ADAPTIVE MANAGEMENT</b>	An intentional way for USAID to make planning decisions and adjustments during implementation in response to additional information or changes in context.
<b>AREA OF INFLUENCE</b>	The area over which the impacts of a project are likely to be felt, including all its related or associated (where applicable) facilities, such as transmission line corridors, access roads, accommodation facilities (where required), as well as any reasonably foreseen unplanned developments induced by a project or cumulative impacts.
<b>BASELINE DATA</b>	Data that describes existing physical, biological, socioeconomic, health, labor, and cultural heritage conditions, or any other variable considered relevant before project development.



TERM	DEFINITION
<b>BIODIVERSITY</b>	Variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems.
<b>CHANCE FINDS</b>	Archaeological or cultural sites and artifacts, including such items as ceramics, tools, buildings, and burials, previously unrecognized in baseline studies that are discovered during exploration activities.
<b>CLIMATE CHANGE ADAPTATION</b>	Refers to a system or a community's ability to adapt to climate change effects that are already occurring or can be expected to occur soon. The goal of climate change adaptation is to reduce communities' vulnerability to the harmful effects of climate change. To do this, a community must become more resilient, able to rapidly recover after a catastrophe. <sup>67</sup> Climate change adaptation could also refer to finding ways to take advantage of any potential benefits associated with climate change, such as longer growing seasons and increased crop yields in some regions and reduced heating bills in others.
<b>CLIMATE CHANGE MITIGATION</b>	Refers to preventing or reducing emissions of carbon and other greenhouse gases (GHGs), thereby reducing negative impacts of climate change in the future. Even if emissions of all GHGs end today, global warming and climate change will continue to affect future generations.
<b>CONSTRUCTION</b>	Construction, alteration, or repair of buildings, structures. Includes excavation and demolition activities.
<b>CLIMATE RESILIENCE</b>	The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to and recover rapidly from disruptions.
<b>CLIMATE RISK ASSESSMENT</b>	The systematic process of evaluating the potential climate-related risks that may be involved in a strategy, project or activity. This includes both screening and analysis.
<b>CONSULTATION</b>	Consultation is a two-way process of dialogue between the project implementer and its stakeholders. Stakeholder consultation is about initiating and sustaining constructive external relationships over time.
<b>CRITICAL HABITAT</b>	Either modified or natural habitats supporting high biodiversity value, such as habitat required for the survival of threatened or endangered species.
<b>CUMULATIVE IMPACTS</b>	Incremental impact of a project action when added to impacts of past, present, and reasonable near-future impacts. Cumulative impacts are contextual and encompass a broad spectrum of impacts at different spatial and temporal scales.
<b>DIRECT AREA OF IMPACT</b>	Considers the physical footprint of the projects such as the right of way, construction sites, work staging area, and area affected during operational works (e.g., traffic patterns).
<b>DIRECT IMPACT</b>	Impacts caused directly by a project action, at the same time and in the same place that the action is occurring.
<b>ECOSYSTEM</b>	The interacting system of a biological community and its non-living environmental surroundings.
<b>EMISSION</b>	Pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or watercraft exhausts.
<b>ENVIRONMENTAL IMPACT STATEMENT (EIS)</b>	A detailed study of the reasonably foreseeable positive and negative environmental impacts of a proposed USAID action and its reasonable alternatives on the United

<sup>67</sup> Cambridge Centre for Risk Studies. 2015. WORLD CITIES RISK 2015-2025. Available at <http://cambridgeriskframework.com/wcr>

TERM	DEFINITION
	States, the global environment, or areas outside the jurisdiction of any nation. (Chapter 204).
<b>ENVIRONMENTAL IMPACT ASSESSMENT (EIA)</b>	A forward-looking instrument that proactively advises decision-makers on what might happen if a proposed action is implemented. Impacts are changes that have environmental, political, economic, or social significance to society. Impacts may be positive or negative and may affect the environment, communities, human health and well-being, desired sustainability objectives, or a combination of these.
<b>ENVIRONMENTAL AND SOCIAL MANAGEMENT SYSTEM (ESMS)</b>	Part of a project's overall management system that includes the organizational structure, responsibilities, practices, and resources necessary for implementing the project-specific management program developed through the environmental and social assessment of the project.
<b>ENVIRONMENTAL IMPACTS</b>	Impacts on the natural environment including air, water, ecosystems, flora and fauna, and other naturally occurring phenomena.
<b>GOOD INTERNATIONAL INDUSTRY PRACTICE</b>	Exercise of professional skill, diligence, prudence, and foresight that would reasonably be expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally or regionally. The outcome of such exercise should be that the project employs the most appropriate technologies in the project-specific circumstances.
<b>GREENHOUSE GASES</b>	Includes the following six gases or class of gases: carbon dioxide (CO <sub>2</sub> ), nitrous oxide (N <sub>2</sub> O), methane (CH <sub>4</sub> ), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF <sub>6</sub> ).
<b>GRIEVANCE MECHANISM</b>	Procedure developed by project implementer to receive and facilitate resolution of affected communities' concerns and grievances about the project's environmental and social performance.
<b>HABITAT</b>	Terrestrial, freshwater, or marine geographical unit or airway that supports assemblages of living organisms and their interactions with the non-living environment.
<b>HAZARDOUS WASTE</b>	Byproducts of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Substances classified as hazardous wastes possess at least one of four characteristics – ignitability, corrosivity, reactivity, or toxicity – or appear on special lists.
<b>INDIGENOUS PEOPLES</b>	Defined by the World Bank E&S Framework as a distinct social and cultural group possessing the following characteristics in varying degrees: (1) Self-identification as members of a distinct indigenous social and cultural group and recognition of this identity by others; (2) collective attachment to geographically distinct habitats, ancestral territories, or areas of seasonal use or occupation, as well as to the natural resources in these areas; (3) customary cultural, economic, social, or political institutions that are distinct or separate from those of the mainstream society or culture; and (4) a distinct language or dialect, often different from the official language or languages of the country or region in which they reside.
<b>INDIRECT AREA OF INFLUENCE</b>	Includes area which may experience project-related changes resulting from activities not under the direct control of the project.
<b>INDIRECT IMPACT</b>	Impacts from project activities that may occur at different times or at some distance from the project. Also known as secondary or even third-level impacts.
<b>INDUCED IMPACT</b>	Secondary impacts that do not bear a direct relationship with the project itself.
<b>INITIAL ENVIRONMENTAL EXAMINATION (IEE)</b>	The first review of the reasonably foreseeable effects of a proposed action on the environment. Its function is to provide a brief statement of the factual basis for a Threshold Decision as to whether an Environmental Assessment or an Environmental Impact Statement will be required.

TERM	DEFINITION
<b>LAND ACQUISITION</b>	All methods of obtaining land for project purposes, which may include outright purchase, expropriation of property, and acquisition of access rights such as easements or rights of way.
<b>LIVELIHOOD</b>	Full range of means that individuals, families, and communities utilize to make a living, such as working for wages; participating in agriculture, fishing, foraging, or other natural resource-based livelihoods; petty trade; and bartering.
<b>MAGNITUDE</b>	The assessment of magnitude is undertaken in two steps. First, the potential impacts associated with a project are categorized as beneficial or adverse. Second, the beneficial or adverse impacts are categorized as major, moderate, minor, or negligible based on consideration of a number of parameters.
<b>MUNICIPAL SOLID WASTE</b>	Waste material (i) generated by a household (including a single or multifamily residence); (ii) generated by a commercial, industrial, or institutional entity, that is essentially the same as normal household waste; is collected and disposed of with other MSW and contains hazardous substances not greater than that generated by a typical household.
<b>NATURAL HABITAT</b>	Land and water areas where the biological communities are formed largely by native plant and animal species, and where human activity has not essentially modified the area's primary ecological functions.
<b>NO NET LOSS</b>	No net loss is a principal that aims to balance losses of biodiversity in one area with gains in biodiversity conservation in other areas.
<b>OCCUPATIONAL HEALTH AND SAFETY</b>	The range of endeavors aimed at protecting workers from injury or illness associated with exposure to hazards in the workplace or while working.
<b>PARTICIPATORY APPROACH</b>	An approach that recognizes that affected communities should be involved in the determination and identification of ecosystems that may be affected by a project and the management measures that should be implemented to manage predicted impacts.
<b>PRECAUTIONARY APPROACH</b>	The precautionary approach argues that in the event of scientific uncertainty, the worst reasonable case assumptions should be adopted to predict an impact of an action, to ensure that the impact is not underestimated.
<b>PROJECT-AFFECTED PEOPLE OR COMMUNITIES</b>	Individuals, workers, groups, or local communities which are or could be affected by the project, directly or indirectly, including through cumulative impacts.
<b>RENEWABLE ENERGY</b>	Energy sources derived from solar power, hydro, wind, certain types of geothermal resources, and biomass.
<b>SENSITIVITY</b>	The sensitivity of a receptor is determined based on the review of the population (including proximity/numbers/vulnerability), biological features of the site and the surrounding area, soil, agricultural suitability, geology and geomorphology, proximity of aquifers and watercourses, existing air quality, presence of any archaeological features, etc.
<b>SIGNIFICANCE</b>	Significance of impact accounts for the interaction between the magnitude and sensitivity criteria.
<b>SOCIAL IMPACTS</b>	Impacts on health and well-being determinants such as lifestyle, personal circumstances, genetics, biophysical environment, social influences, economic conditions, and availability and access to services and facilities.
<b>SOLID WASTE</b>	Material with low liquid content, sometimes hazardous. Includes municipal garbage, industrial and commercial waste, sewage sludge, wastes resulting from agricultural and animal husbandry operations and other connected activities, demolition wastes, and mining residues.

TERM	DEFINITION
<b>STAKEHOLDERS</b>	Stakeholders are persons or groups who are directly or indirectly affected by a project, as well as those who may have interests in a project or the ability to influence its outcome, either positively or negatively.
<b>TRANSBOUNDARY IMPACT</b>	Impact that transcends national boundaries.
<b>VOLATILIZATION</b>	Process when compounds, particularly organic compounds, change from a liquid or a solid into a vapor.
<b>VULNERABLE PEOPLE</b>	Individuals and groups that may be directly and differentially or disproportionately affected by project activities because of their disadvantaged or vulnerable status (based on race, color, sex, language, religion, political or other opinion, national or social origin, property, birth, or other status).