



Technical Brief

Avoidance, Reduction and Safe Management of Health Care Waste

Allocation Period 2023-2025

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Introduction

Executive Summary

Around the world, health care waste (HCW) volume rose substantially during the COVID-19 pandemic. While the provision of high-quality health services (including for HIV, TB and malaria) improves health and well-being overall, HCW is an inevitable byproduct. If not managed properly, HCW can cause unintended harm to human health as well as significant environmental damage. Safe and sustainable HCW management (HCWM) should therefore be seen as an integral part of commodities purchasing and Global Fund-supported programs, and not as an add-on or afterthought. As such, Global Fund requests grant applicants to incorporate sustainable HCWM practices into their operations.

In 2021, globally, 1 in 3 health care facilities (HCFs) lacked basic waste management systems and the situation is heightened in the least developed countries¹. As all health products procured through the Global Fund end up as waste, the Global Fund encourages grant applicants to allocate at least 1% of funding to HCWM interventions. Such interventions should be closely aligned with the [Resilient and Sustainable Systems for Health \(RSSH\) Modular Framework](#) and be based on an informed national strategic approach that complies with applicable legislation, responds to the challenges brought about by the COVID-19 pandemic, minimizes environmental impact, and facilitates circular economy implementation. This should be driven by effective HCW policy and underpinned by reliable data and robust financial plans.

This Technical Brief sets out the types of HCW interventions that should be prioritized by grant applicants when developing funding requests. Grant applicants should ensure that the right technical in-country stakeholders (e.g., infection prevention and control (IPC) and water/ sanitation and hygiene (WASH) focal points) are actively engaged in the proposal, and that it is aligned with a national waste management strategy. Applicants should focus on both upstream and downstream interventions so that the full HCW value chain is considered. Accordingly, this Technical Brief provides guidance in sustainable HCWM from waste avoidance through sustainable green procurement to safe disposal using effective treatment technology selection. Detailed information is also included in a series of technical appendices.

Applicants – including country stakeholders, members of the Country Coordinating Mechanism (CCM), technical assistance providers and writing teams - are encouraged to review this document in parallel with the resources available for this allocation period, including the HIV, TB, malaria and RSSH Information Notes, and related technical briefs.

¹ WHO/UNICEF, 2022. Progress on WASH in health care facilities 2000-2021. World Health Organization, Geneva. <https://washdata.org/>

Background

Health care waste (HCW) is an inevitable by-product of providing health services, including for those HIV, TB and malaria services financed by Global Fund grants and in its response to the COVID-19 global pandemic. HCW can be potentially harmful to both the environment and human health. Not only does improperly managed HCW cause contamination, pollution and unnecessary carbon emissions; it is a waste of resources. It can also pose a danger to patients, health workers and the general public. Finally, improper HCW management (HCWM) can also directly contribute to some of the diseases that the Global Fund seeks to eliminate as public health threats, for example through contact with contaminated HCW.

Sustainable HCWM is, therefore, essential to reducing the impact of large-scale health interventions on human health and helping to safeguard against environmental effects. A good example of this is in extending health products' lifecycle so that waste is avoided or to prevent the use of incorrect waste disposal pathways (as illustrated in the case study below).

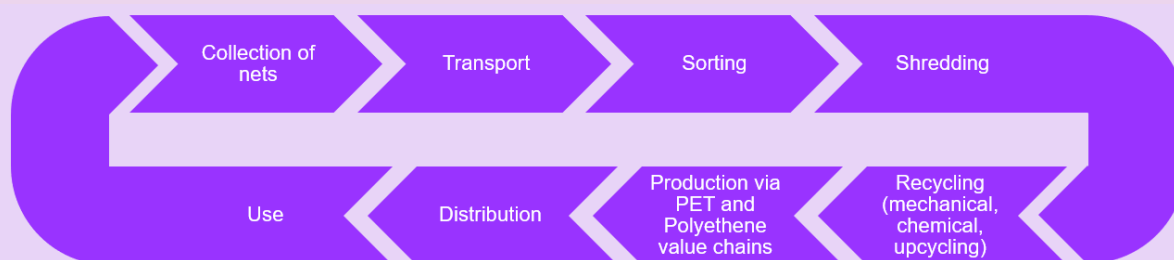
Definitions: Health care waste (HCW)

HCW includes all waste generated within health-care facilities, research centers and laboratories related to medical procedures. It includes waste originating from minor and scattered sources, including waste produced when health care is undertaken in the home (e.g., home dialysis, self-administration of insulin, recuperative care). It is sometimes also referred to as medical or biomedical waste.

Certain types of HCW are hazardous, meaning they display one or more of the following properties: explosive, oxidizing, highly flammable, flammable, irritant, harmful, acutely toxic, carcinogenic, corrosive, infectious, toxic for reproduction, mutagenic, sensitizing, ecotoxic, or capable of yielding another substance after disposal which possesses any of the characteristics listed above.

Management of end-of-life long-life insecticidal nets (LLINs)

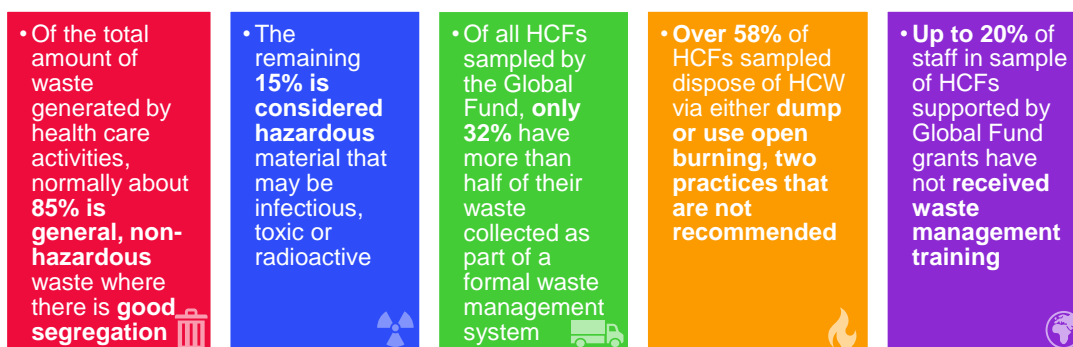
- 2.5 billion LLINs (typically made of PET or polyethylene) were distributed to countries affected by malaria between 2004 and 2022.
- After use, LLINs are mostly incinerated by communities, become environmental waste, or are repurposed to become carriers for crops, fishing equipment or pest protection for crops.
- Steps towards circularity include the prevention of afterlife uses for LLINs and, instead, redirecting them towards recycling routes in order to be re-used as LLINs.



- In order to achieve full circularity of LLINs in target areas, the following should be considered:
 - Educate households on the environmental consequences of LLINs, and the material value;
 - Use incentives to obtain end-of-life LLINs from households; and
 - Identify and strategize to overcome constraints on LLIN collections.

The Global Fund requires countries preparing funding requests to include interventions that take into consideration the environmental impacts of the grants, a key aspect of which is avoiding, reducing and safely managing HCW.

This Technical Brief sets out the types of HCW interventions that should be prioritized by grant applicants when developing funding requests and provides conceptual and technical guidance in sustainable HCWM. It should be noted that recipients of Global Fund HCW grants may be required to confirm or report against a set of HCW indicators, through Local Fund Agent (LFA) spot checks.



The Case for Investing in Safe and Sustainable Health Care Waste Management

Around the world, waste generation is rising. In 2020, the world was estimated to generate 2.24 billion tons of solid waste, the equivalent of 0.79 kilograms per person per day. With rapid population growth and urbanization, this is expected to increase by 73% to 3.88 billion tons in 2050².

Sustainable waste management broadly seeks to reduce the amount of natural resources that are consumed by reusing, recycling or recovering materials as many times as possible before they reach the end of their useful life. It also ensures that any waste generated is kept to a minimum and is disposed of in a manner that minimizes environmental harm. Measures to ensure the safe and environmentally sound management of HCW can prevent adverse health and environmental impacts including the unintended release of chemical or biological hazards, including drug-resistant microorganisms, into the environment, thus protecting the health of patients, health workers, and the community.

Health products procured locally or sourced through the Global Fund can account for a large proportion of total HCW and can lead to the generation of a range of HCW types. In recognition of this, Global Fund expenditure on HCWM has significantly increased over the last few years, from just US\$8.1 million in the Grant Cycle 6 (NFM3) to US\$61 million through the COVID-19 Response Mechanism (C19RM). However, Global Fund allocations for HCWM still represent just 0.3% of all funds awarded, with more than half of C19RM funding requests allocating less than 1% for HCWM.

The Global Fund encourages and actively supports greater investment in HCWM. There is a need to focus on both upstream (supply chain investments that indirectly contribute to sustainable HCWM through waste avoidance, see Procurement and Supply Chain Technical Brief³ for further details) and downstream (through system-level improvements, equipment and proper handling) interventions so that the full HCW value chain is considered. This can be addressed through the application of the guiding principles and conceptual and technical guidance, outlined in the following sections of this Technical Brief.

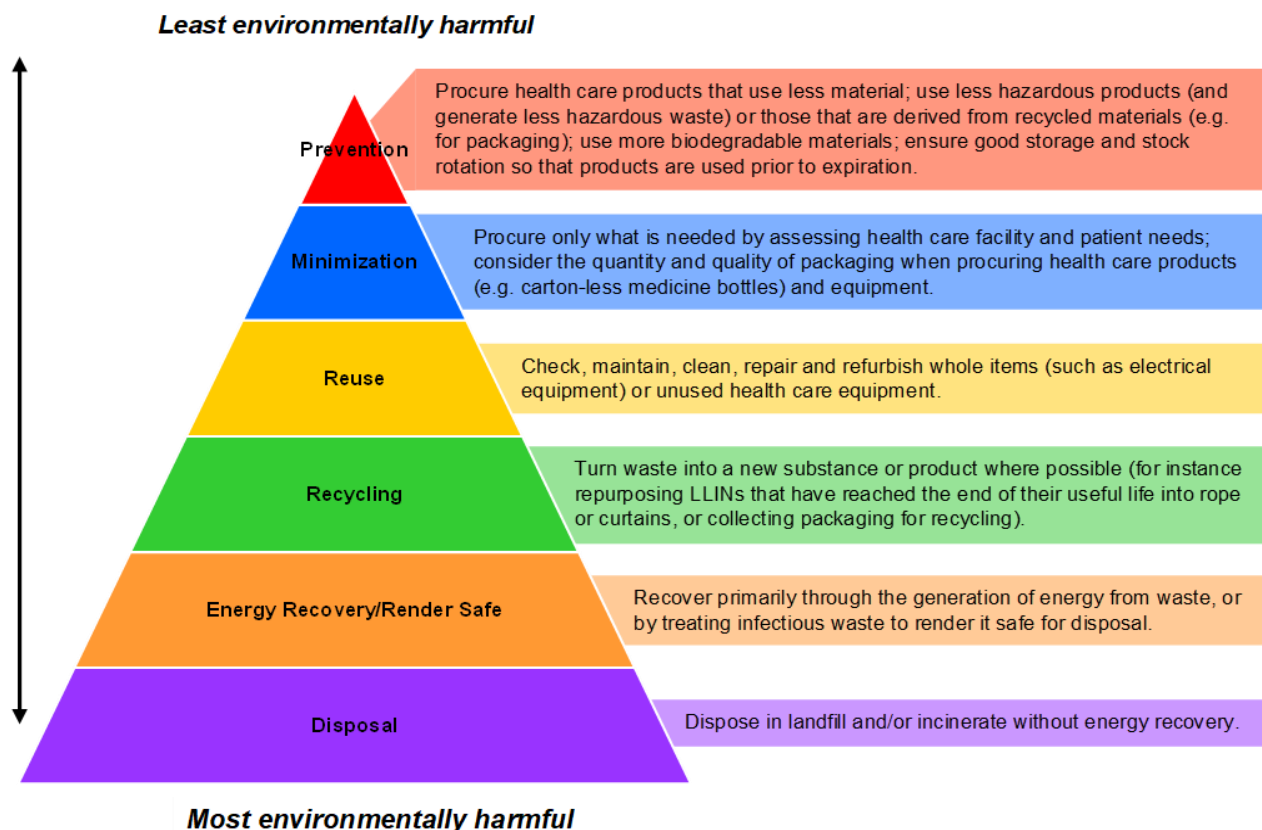
The Waste Hierarchy and Other Guiding Principles

Compliance with the waste management hierarchy ([Figure 1](#)) is essential, given the intrinsic environmental and health risks associated with managing and needing to control potentially hazardous substances and infectious wastes.

² [Solid Waste Management \(worldbank.org\)](https://www.worldbank.org)

³ Global Fund Procurement and Supply Chain Technical Brief, 2022. Available at https://www.theglobalfund.org/media/9234/core_supplychains_technicalbrief_en.pdf?u=63727328779000000

Figure 1: The Waste Management Hierarchy



Other guiding principles should also be considered, as illustrated in Figure 2.

Figure 2: Summary of Sustainable Waste Management Principles



Source: Mott MacDonald

1. Prioritized Interventions to be Funded by the Global Fund

Global Fund will support waste management activities that help strengthen or are in alignment with national HCWM strategies and plans. A strong national HCWM strategy or plan should outline activities intended for the avoidance, reduction and management of HCW. Effective HCWM should be seen as an integral part of commodity purchasing and health care systems strengthening.

It is essential that investments are well coordinated and aligned with a national HCWM strategy or plan. Countries are usually the major investors in their own waste management systems, however both development partners and the private sector may also contribute. If no national strategy or plan exists, activities that will result in such a framework should be prioritized. Sub-national or facility level plans are also important. Wherever possible, proposed activities should be in alignment with a broader strategy/plan and should not be ad hoc. Likewise, activities should be in collaboration/engagement with national stakeholders, as most countries have existing programs or expertise in country.

It is critical that a national entity is empowered and has authority to oversee HCW. This entity should also engage the relevant sectors in health (e.g., infection prevention and control (IPC), and water, sanitation, and hygiene (WASH)). Sectors other than health must also be actively involved (as set out in Section 2.1.3). Most countries have standards for HCWM and many of these have a climate and environmental (as well as health) focus. The WHO/UNICEF country tracker for water, sanitation, hygiene and health care waste provides a snapshot of the status of national standards⁴. Understanding national standards and working, collaboratively with national actors to implement them, is an important action.

⁴ WHO/UNICEF. Available at <https://www.washinhcf.org/country-progress-tracker/>

When requesting funds for HCWM under the RSSH Modular Framework, applicants must demonstrate how investments will help in the development or implementation of a national plan, in accordance with one or more of the following objectives:



Avoid and minimize waste through the responsible (or “green”) procurement of health products, whilst supporting decarbonization of the HCW supply chain using reverse logistics and circular economy principles.



Improve all components of the national HCWM system through the development of operational plans or guidelines; training and supportive supervision of health workers; the monitoring, assessment, and improvement of these plans; and development of related policies (e.g., IPC, environmental cleaning).



Increase awareness and competency in sustainable HCWM through training and engagement across both public and private sectors throughout the supply chain, supported by the establishment of public-private and multi-agency partnerships.



Be in alignment with global HCW guidance and guidelines, and national and international environmental legislation and best practices, including demonstratable innovation in HCWM where practical.



Establishment of data gathering and measurement systems at national and sub-national level to ensure that robust system-level baseline data exists and is assessed on a recurring basis.



Address gaps in infrastructure and equipment for the collection, transport, treatment, and disposal of HCW in compliance with environmental and occupational health standards.



Demonstrate evidence of long-term financial planning, particularly where Global Fund financing is supported or complements investments by third parties, so that capital, operational and maintenance costs are adequately budgeted.

[Table 1](#), below, provides examples of the types of HCWM interventions and activities that can be implemented to help achieve these objectives. It is not an exhaustive list, is provided for illustrative purposes and is not provided in order of importance. Typical budgets required for each intervention example are also provided. It is essential that all HCWM interventions are robustly costed and well budgeted for (as described in Section 2.3). Where HCWM budgets are limited or constrained, grant applicants should be mindful of the waste hierarchy and consider those interventions that are most impactful or stimulate the most significant systematic improvement.

Table 1: Examples of HCWM Interventions and Typical Required Investment Allocation

INTERVENTION EXAMPLE	CONSIDERATIONS	TYPICAL BUDGET (\$)
<ul style="list-style-type: none"> • HCF staff and supply chain training/ upskilling/ supervision; • Identification or recruitment of person responsible for HCW; • HCF-level HCW policies/plans/ guidance; • HCF-level HCW handling equipment/ PPE/signage; • HCF and/or community-level engagement and awareness campaigns; • Procurement/tendering/specification costs for new HCW equipment /infrastructure; • HCW consumables and reagents; • HCF and/or community-level repair, reuse, recycling and take-back/ reverse logistics trials; • HCF and/or community-level waste audits/ composition studies; • HCF and/or community-level bin and container provision. 	<ul style="list-style-type: none"> • Demonstrate how such investments could be upscaled or support achievement of national targets/KPIs; • Demonstrate how public-private partnerships could be used to support implementation; • To be in line with national strategic plans and guidelines. 	<p>Up to 100,000</p>
<ul style="list-style-type: none"> • Development of national-level HCW policies/ plans/ regulations; • National-level waste composition studies and data tracking systems; • HCWM feasibility studies/scoping assessments/due diligence for new infrastructure/services/equipment; • Individual small scale (HCF-level) waste treatment units (autoclaves, microwaves, high temperature incinerators); • Individual HCW collection vehicles. 	<ul style="list-style-type: none"> • Plan/policy to be in place as a prerequisite to major capital investment or wide-scale systematic change; • Engage with national actors/stakeholders; • Demonstrate how long-term operation and maintenance costs are budgeted. 	<p>Up to 250,000</p>
<ul style="list-style-type: none"> • National-level reverse logistics planning/ schemes/ trials; • Multiple small-scale (HCF-level) waste treatment units; • Large scale (multiple HCFs) training/upskilling campaigns. 	<ul style="list-style-type: none"> • Identify how outcomes contribute to national policy objectives; • Consider separate provision for hazardous and non-hazardous wastes. 	<p>Up to 500,000</p>
<ul style="list-style-type: none"> • National-level engagement and awareness-raising campaigns • HCW collection vehicle fleet-level investment; • HCW storage yards and compounds; • Large-scale (multiple HCFs) HCW handling equipment/PPE/signage. 		<p>Up to 1,500,000</p>
<ul style="list-style-type: none"> • Sanitary engineered landfill development; • Non-hazardous waste sorting and recovery machinery/equipment; • Large-scale waste treatment/transfer/infrastructure hubs for regional centralized HCWM. 	<ul style="list-style-type: none"> • Pre-feasibility/ environmental impact assessment likely to be required; • Demonstrate how long-term operation and maintenance costs are budgeted; • Consider integration with wider solid waste management systems. 	<p>Over 1,500,000</p>

Considerations when developing national HCWM strategies or plans

1.1 Theme 1: Pandemic preparedness and resilience

Local, regional, and national issues such as supplier failures, natural disasters and pandemics can cause unexpected increases in HCW. Developing a clear and well-communicated business continuity plan (BCP) supports the understanding of measures that should be implemented in preparing for such scenarios. Figure 3 details the key principles of an effective BCP.

Figure 3: Key Principles of a BCP



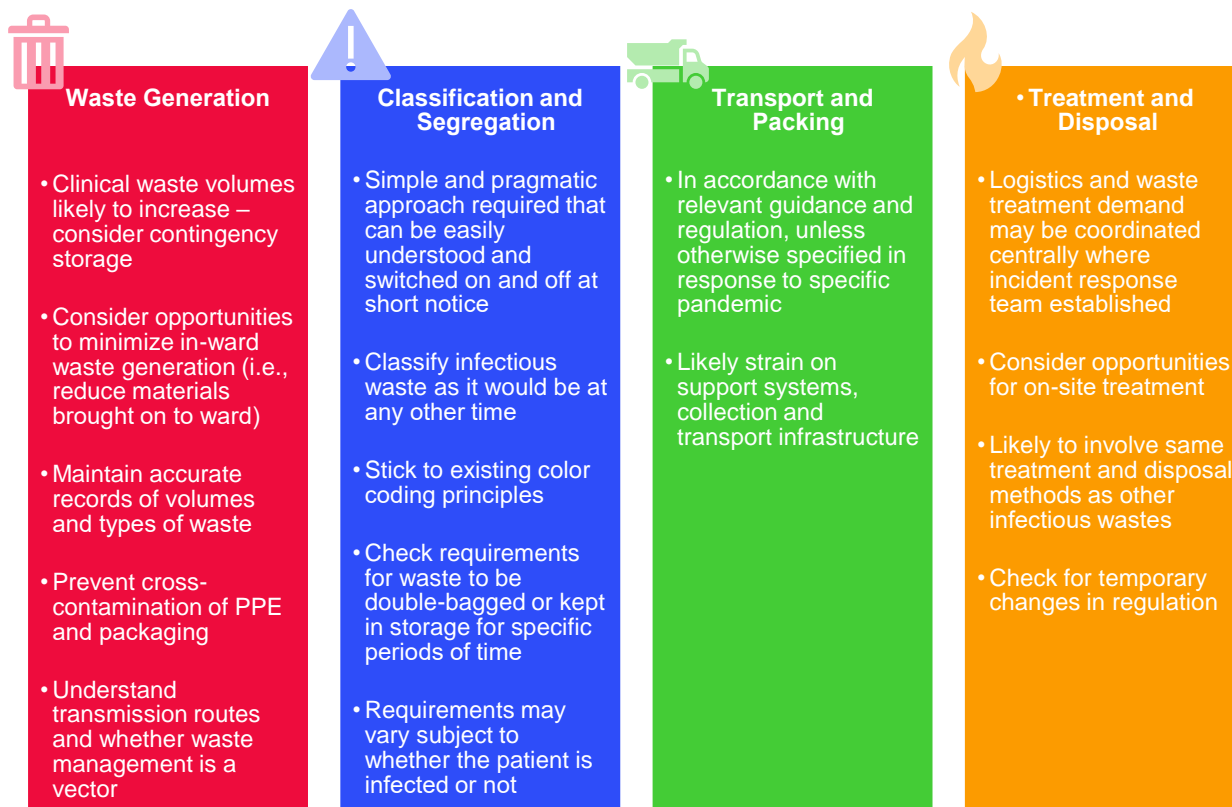
Source: Mott MacDonald

The COVID-19 pandemic has illustrated the need for health care organizations to be able to quickly adapt their HCWM arrangements in response to rapid increases in waste volumes and temporary changes in the way in which the HCW is managed. The following waste management challenges were typical:

- Large quantities of littered disposable masks;
- Excessive storage of personal protective equipment (PPE) and single-use diagnostic kits;
- Excessive storage of infectious waste, due to insufficient treatment capacity;
- Stockpile of full “sharps” boxes at vaccination sites;
- Significant wastage of expired single-use diagnostic kits due to over-purchasing.

It is important to consider the types of HCW that might be generated in such events, which may include packaging, PPE waste and diagnostic kits. Efforts should be made to minimize this and avoid cross-contamination. Other key principles in HCWM pandemic response are detailed in Figure 4, below.

Figure 4: Key Principles in HCWM Response to a Pandemic



Source: Mott MacDonald

Initiatives to Combat Increase in COVID-19 Waste, Fundación Clínica Infantil Club Noel, Colombia

The hospital undertook a number of activities to strengthen its waste management in response to COVID-19:

- Training to raise awareness among health care staff on biosafety, management of PPE and patient care;
- Development of protocols specific to COVID-19 waste;
- Agreement to manage COVID-19 waste as standard infectious waste with treatment through existing microwave and autoclave technologies;
- Introduction of sustainable procurement in favor of PPE that can be decontaminated or reprocessed for reuse.

Source: World Health Organization, 2022⁵

⁵ World Health Organisation, 2022. <https://www.who.int/publications/i/item/9789240039612>

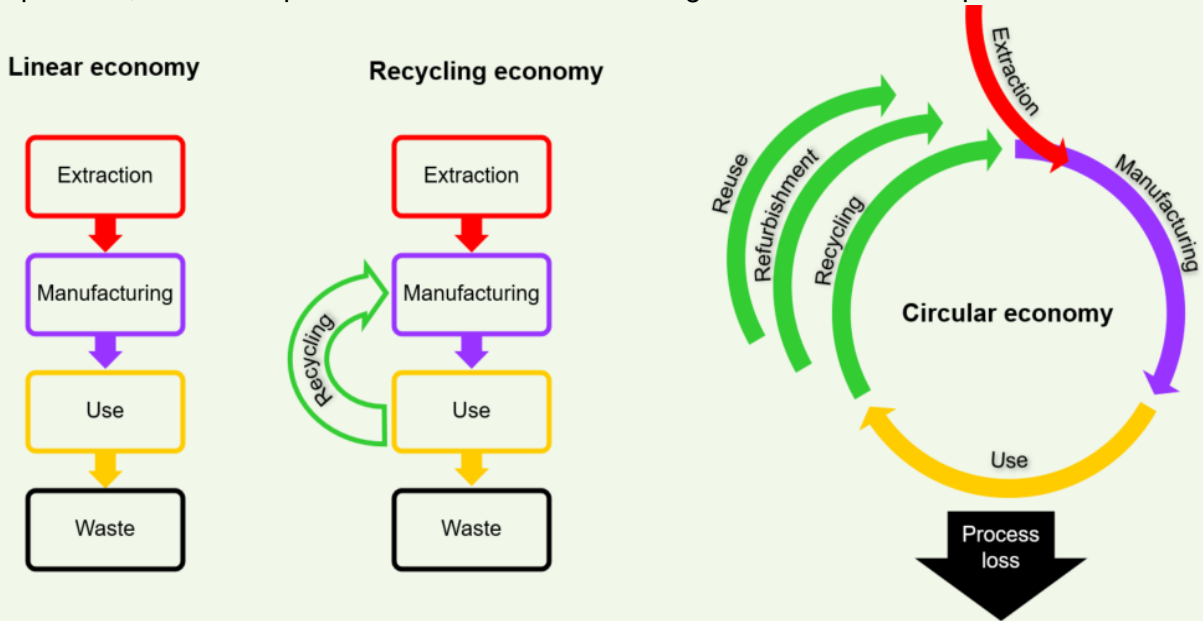
1.2 Theme 2: Applying the circular economy

What is the circular economy?

A circular economy aims to decouple economic activity from the consumption of finite resources and designs waste out of the system. It is based on three principles:

- “design out” waste and pollution
- keep products and materials in use
- regenerate natural systems

The “linear economy” and recycling economy” limit opportunities to use resources for as long as possible, which can place a burden on waste management at the end of product life.



A closed-loop recycling system is the process by which a material (such as glass and most metals) can be recycled indefinitely without a change in properties during the recycling process and can assist in the transition to a circular economy by minimising material loss. An open loop recycling system can also play a part in the transition, where products (such as plastics) are reprocessed into other products when the recycled material cannot be used in their original application, and hence their lifespan is limited by the number of times they can be recycled.

Source: Graphic adopted from IEMA⁶

Applying circular economy principles - where countries transform the way they consume and dispose of health care products - can also help ease pressure on the health sector by saving money. Given the scale of Global Fund investment in HCWM, it is essential that green procurement and supply chain management using circular principles be implemented. Table A1 in [Appendix A](#) outlines practical ways in which circular economy principles can be implemented.

⁶ IEMA - Circular Economy 101: An introduction to sustainable resource & waste management

1.3 Theme 3: Decarbonization and the impact on climate change

Adopting good practices helps to reduce the carbon footprint of the HCW value chain and thus its potential impact on climate change. Measures that avoid waste production, promote the reuse, repair and remanufacture of products (where safe and practical to do so) as described in the waste hierarchy ([Figure 1](#)) and enhance resource efficiency will inevitably support decarbonization.

Managing HCW in a safe, efficient, and compliant manner contributes towards reducing whole-life carbon emissions. Any failure to correctly segregate infectious waste from non-infectious waste can cause the entire waste stream to be over-managed or treated, for example by use of incineration over alternative treatment (e.g., autoclave, microwave, frictional heat) which are typically lower-carbon technologies.

Diverting waste from landfills also reduces carbon and harmful methane emissions. Similarly, by implementing circular principles (e.g., through sustainable procurement) that replace single-use products with reusable ones, there is a reduction in manufacture and transport demand and associated lifecycle emissions.

The implementation of on-site HCW treatment may allow HCFs to have more control over their own waste, in accordance with the proximity principle. Correct application of the proximity principle can improve on-site resilience and reduce transport emissions associated with haulage. Where practical, the use of approved bulk transport should be encouraged.

Sustainable HCWM is essential in reducing the contribution of HCFs to climate change, which in turn helps to minimize future spread of diseases such as malaria. For example, an increase in temperature, rainfall, and humidity may cause the numbers of malaria-carrying mosquitoes to multiply. Warmer temperatures will alter the growth cycle of the parasite in the mosquito enabling it to develop faster and increase rate of transmission⁷. Changes in temperature, precipitation, humidity and wind speed have been associated with TB transmission⁸. Extreme climate events also induce population displacement that has been associated with increased TB and HIV/AIDS transmission^{7,9}.

The autoclaving process typically generates 35% less carbon than high-temperature incineration (HTI). This makes it essential to correctly segregate HCW, so that wastes are not over-treated and thus avoiding unnecessary carbon production.

⁷ <https://www.un.org/en/chronicle/article/climate-change-and-malaria-complex-relationship#:~:text=An%20increase%20in%20temperature%2C%20rainfall,it%20was%20not%20reported%20earlier.>

⁸ Kharwadkar, Sahil, et al. "The impact of climate change on the risk factors for tuberculosis: A systematic review." *Environmental Research* 212 (2022): 113436.

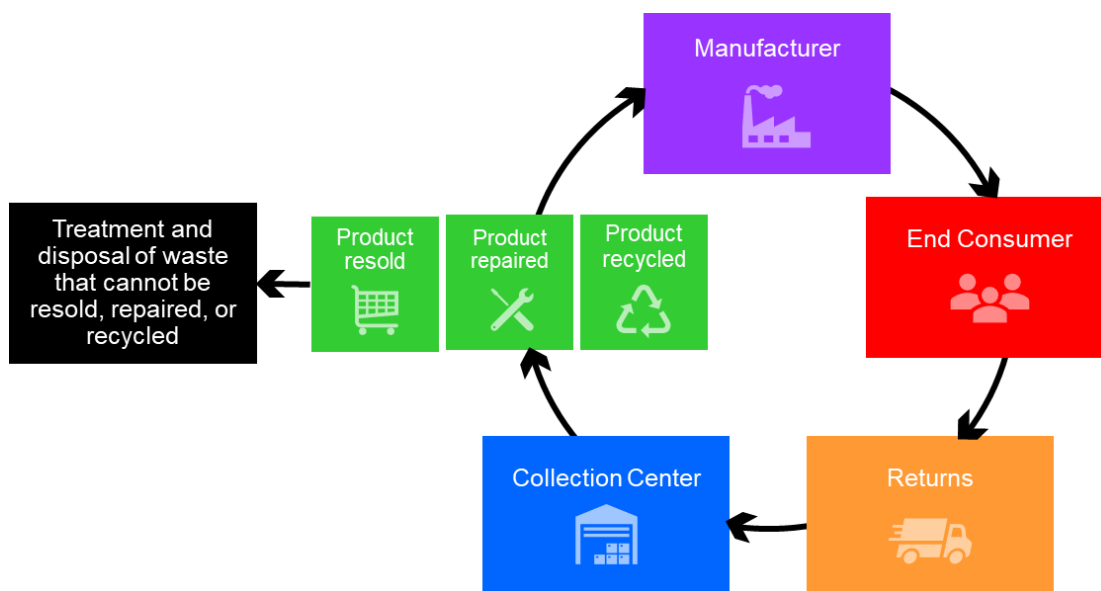
⁹ <https://www.un.org/en/chronicle/article/pattern-response-hiv-aids-and-climate-change-commentary>

Reverse logistics is a process by which products can be returned one step back in the supply chain or back to the original supplier to be recycled, repaired, or resold (

Some countries have successfully implemented reverse logistics at the community level. **Vaccinations are delivered in sharps containers and those containers, once filled with the used sharps, are returned to the collection point** by health care workers when picking up a new batch of vaccinations, enabling practical reuse of containers within the supply chain.

Figure 5). The focus is on returned goods and how to best reuse or dispose of them in a cost-effective way and thus reducing the transport burden and associated carbon impact. Well-designed supply chains are usually responsive and can handle some reverse logistics requirements.

Figure 5: Reverse Logistics Flow Diagram



Source: Mott MacDonald

1.4 Theme 4: Optimizing operational and institutional performance

Perhaps the most important aspect of HCWM planning is having an entity (with accountable and identified officers) that is responsible and empowered to oversee the implementation and quality of the program, at least at national and HCF levels (although sub-national focal persons likely will also be needed). At national, sub-national, and HCF levels, such HCWM individuals are often the IPC or WASH/HCF engineering focal persons. They should be supported and strengthened to oversee the program and engage stakeholders, including administration and finance, for the proper operationalization and improvement of the HCWM system.

One responsibility of the HCWM entity is the collection and use of data to improve performance. Without reliable baseline data, performance cannot be measured, and

improvement measures cannot be assessed for impact or effectiveness. Data collection and monitoring and evaluation may be aligned with national or facility quality improvement departments or goals. For further information on data collection, see Section 2.2.

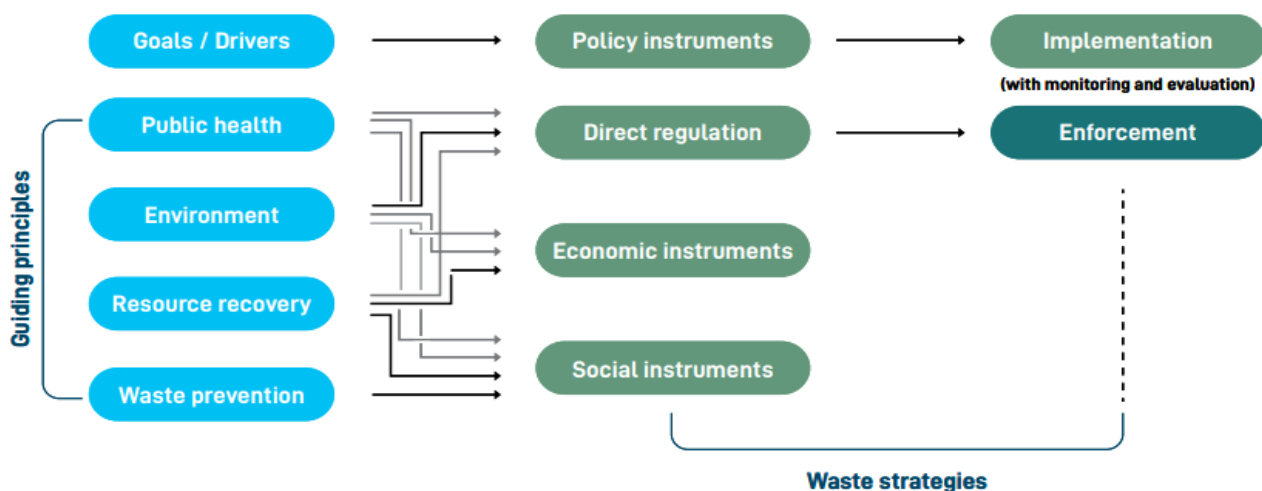
Optimization of HCWM can be either proactive (aimed at improving performance when there are no immediate issues or aimed at preventing or preparing for future issues) or reactive (in response to a known issue). Proactive measures generally involve establishing a baseline of current performance, using data, and establishing KPIs for targeted or systematic improvement. Reactive measures typically focus on an immediate issue (such as excess waste being generated during a disease outbreak).

Performance improvement measures relating to behavior should be targeted at specific staff, based on their role in the HCW system. For instance, if trying to improve waste segregation, resources should be focused on training the staff who generate waste at ward level (nurses, clinicians, and support staff), whereas improvement measures targeting safety or waste treatment should be aimed at waste handling and disposal staff. Mentorship and supportive supervision for all health workers are evidence-based methods to improve health worker behavior.

Performance can also be improved through investment in equipment, infrastructure and materials. For instance, adequate PPE and waste trollies to reduce cross-contamination or the occurrence of injury among waste-handling staff, or investment in on-site treatment technologies. Major investments (for example in waste treatment at large scale) should be carefully considered, and ideally prefaced by a feasibility study or business case to determine whether the equipment is affordable (both in terms of CAPEX, and ongoing expenditure), suitable for the facility and the wastes it generates, and operable (i.e., can consumables, suitably trained staff, utilities, maintenance, and replacement parts be supplied).

The International Solid Waste Association has developed a conceptual model for waste governance, institutional change and planning (see Figure 6 below), outlining the guiding principles of good waste management and how they can be driven, which is also discussed in Section 2.1.

Figure 6: Guiding Principles of Waste Management Intervention



Source: International Solid Waste Association

1.5 Theme 5: Legislative and regulatory compliance

1.5.1 Compliance

Compliance with international, national and local waste management legislation and regulation is imperative if the impact from HCW to the environment and human health is to be mitigated.

Most governments publish legislation online. Others may issue legislation in paper format, sometimes called gazettes. It may be possible to obtain copies of these documents from a government office or public library.

Applicants **should identify relevant national legislation** prior to the implementation of HCWM interventions and **maintain close dialogue with the regulator** to ensure that new waste management interventions are introduced in a way which is compliant with local legislation.

1.5.2 Relevant international conventions

A number of international conventions exist which have implications for HCW, as summarized in Table 2. Applicants should review the applicability of these conventions to waste management activities planned under Global Fund grants.

Table 2: Relevant International Conventions Which Have Implications for HCW

CONVENTION	YEAR	DESCRIPTION
Basel Convention ¹⁰	1989	Aims to protect human health and the environment against the adverse effects of the generation, management, transboundary movement, and disposal of hazardous and other wastes.
Aarhus Convention ¹¹	1998	Grants the public rights, and imposes obligations regarding access to information and public participation and access to environmental justice.
Bamako Convention ¹²	1998	Treaty of African nations prohibiting the import and controlling transboundary movements of hazardous waste.
Stockholm Convention ¹³	2001	Global treaty to protect human health and the environment from the effects of persistent organic pollutants (POPs), which are highly dangerous and long-lasting chemicals.
Rotterdam Convention ¹⁴	2004	Promotes shared responsibilities and cooperation among parties in international trade of certain hazardous chemicals to protect human health and environment from potential harm.
Minamata Convention ¹⁵	2013	Signatory countries to undertake measures to reduce the human and environmental impact of anthropogenic mercury.

¹⁰ <http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx>

¹¹ <https://unece.org/environment-policy/public-participation/aarhus-convention/text>

¹² <https://www.unep.org/bamako-convention>

¹³ <http://www.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx>

¹⁴ <http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx>

¹⁵ <http://www.mercuryconvention.org/Convention/Text/tabid/3426/language/en-US/Default.aspx>

1.5.3 National regulation

An effective national regulatory framework is an essential component of any resilient health system and a critical enabler as an assurance mechanism to health products¹⁶. National legislation should also define different types of waste and a scheme for waste type classification or refer to an internationally recognized definition. It is expected that the regulatory framework for HCW also include monitoring, enforcement, and health and safety, with specific regulation established in the areas of:

- Permitting and licensing;
- Waste reduction;
- Reduction of toxic substances;
- Procurement;
- End of waste criteria;
- Producer responsibility;
- Hazardous waste;
- Treatment and disposal technologies
- Waste transportation and shipment
- Worker health and safety;
- Circular economy;
- Climate change and decarbonization; and
- Landfill management;

When implementing HCWM interventions applicants should **identify the duty-of-care principles that have been enacted at country level**. This may require a record to be kept of HCW movements and that the data be reported centrally.

In the HCW sector, a range of more specific regulatory measures should also be considered. Examples of types of legislation that can be used to regulate HCW at the national level, along with relevant stakeholders and entry points, are described in [Appendix C](#).

1.5.4 Preventing illegal activities

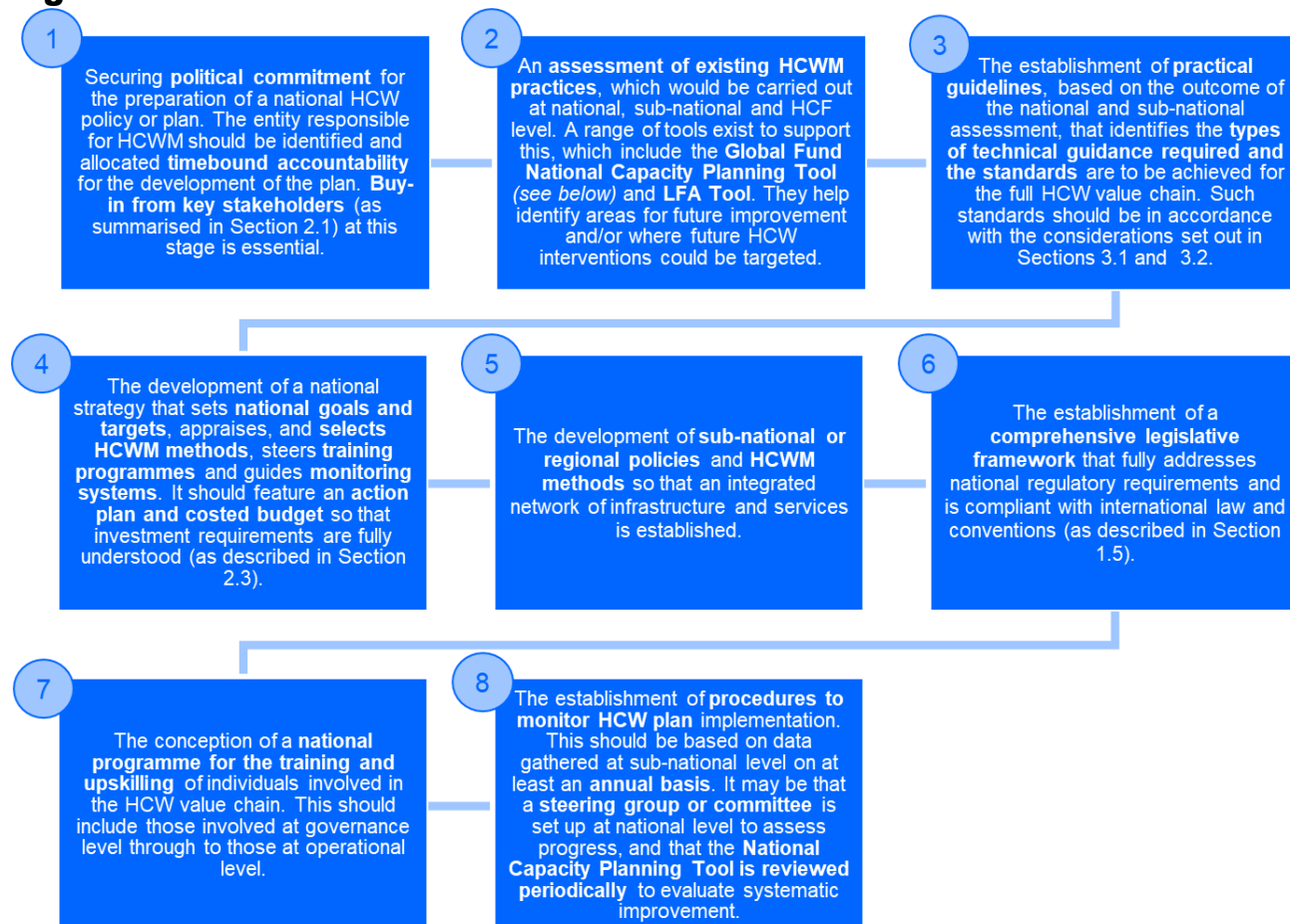
A sustainable waste management system can only be supported by a comprehensive and robust regulatory system that clearly establishes rules and responsibilities, carries out meaningful enforcement and implements measures to deter illegal waste activities. Illegal waste activities can range from littering and illegal dumping to uncontrolled waste processing or operations. In turn, these can lead to the release of uncontrolled emissions that harm the environment along with the spread of disease, and damage community health. Global Fund encourages interventions that help to reduce illegal dumping or open burning of HCW and supports controlled HCWM.

¹⁶ [Support to Effective Regulatory Systems for Procurement and Supply Management of Health Products, Global Fund, October 2019](#)

2. Investment Approach

The approach to HCWM investment should be considered in the context of national HCW planning. Applicants should follow a clear process based on an assessment of HCWM options and priorities, driven by robust data and policy. The process would typically involve the steps set out in Figure 7.

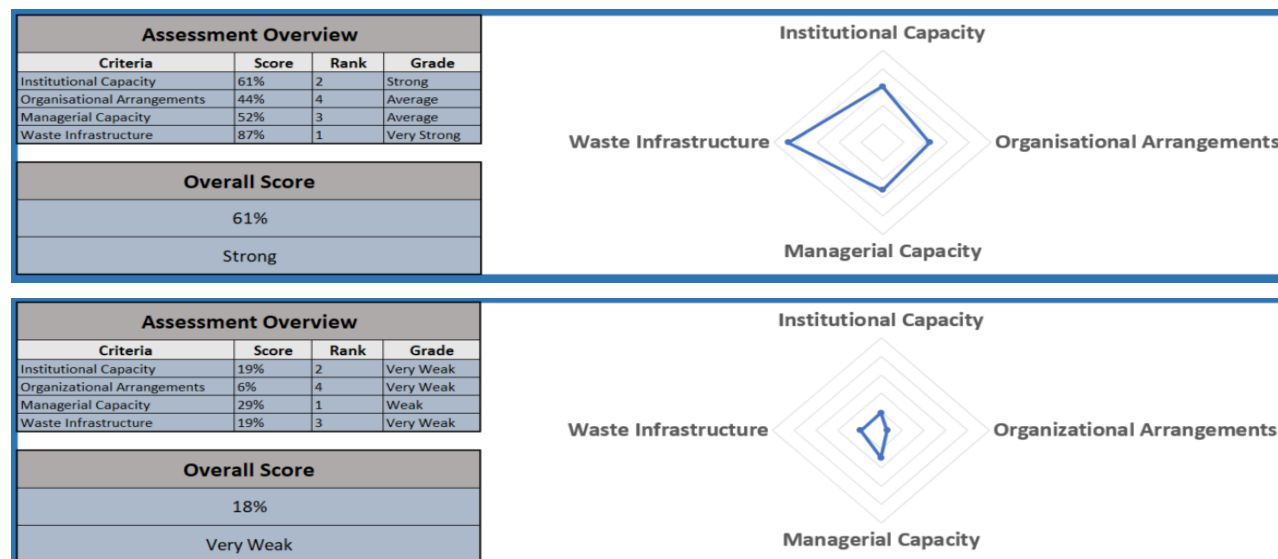
Figure 7: Process for HCWM Investment



Several tools have been published to help support national system development. This includes a series of rapid assessment tools developed by WHO, a HCW maturity model developed by Gavi and UNICEF (applicable specifically for immunization waste), and a toolkit developed by USAID to assess national supply chain capability. The Global Fund has also developed a National Capacity Planning Tool, which assesses the institutional, organization and managerial capacities for HCWM at country level. It involves a framework of evaluation criteria upon which such capacity can be assessed (as shown in Figure 8) and can be used to identify how existing practices compare with global standards, and points to the types of strategic actions that could be implemented to address system gaps¹⁷.

Applicants should decide which tool best suits their needs when performing Step 2 of the process outlined in Figure 7. The assessment of existing practices should also feature the gathering of baseline data (as set out in [Section 2.2](#)).

Figure 8: Examples of output from the National Capacity Assessment Tool



The sub-sections that follow provide further detail on key aspects of national HCW strategy or plan development. Detailed guidance can also be found in the [WHO Blue Book](#)¹⁸.

2.1 Strategic planning and policy development

2.1.1 Policy development

The establishment of national waste management policy is fundamental to the long-term development of sustainable waste management practices. This is typically set out in a National Waste Management Strategy or Waste Plan which spans a period of time sufficient to be able to facilitate, measure and evaluate policy objectives. This is normally a period of up to 30 years, but it may be as short as five years. Policy implementation is usually reviewed at one- to five-yearly intervals and monitored using an implementation plan.

¹⁸ Safe management of wastes from healthcare facilities, second edition, WHO, 2014.

Malawi: Nationwide assessment of health care waste management system (2020 – 2022)

- The Global Fund’s Office of the Inspector General (OIG) indicated a significant gap in waste management in the public and private health facilities in Malawi, with the recommendation to set up a waste management system and national policy.
- External consultants were appointed to undertake waste audits to collect primary data over a two-year period from 15 HCFs, including assessment of the training provided and the procurement policies.
- Stakeholder interviews assisted in responding to gap analysis and understanding of the legal framework in Malawi.
- The study recommended updates to the legal framework and measures for development of an integrated HCWM plan for the 15 HCFs.



Policy measures are expected to include specific targets to address gaps in the existing HCW system. These should be linked to reducing the environmental burden associated with waste management practices, and/or reducing the impact of waste management on society.

Examples of HCWM policy include:

- Establishing targets for the compliant treatment and disposal of HCW;
- Setting timescales for the implementation of HCW infrastructure development and service improvements at all HCFs;
- Introducing financial tools and incentives to help achieve these targets (such as subsidies or tax relief schemes where HCW is collected and treated compliantly);
- Setting budgets and investment requirements; and
- Introducing enforcement measures for non-compliant or illegal management of HCW.

Grant applicants are expected to ensure that a **national HCWM plan or policy is in place a pre-requisite to requests for major capital investment** for HCW infrastructure and services to ensure such requests align with national long-term objectives.

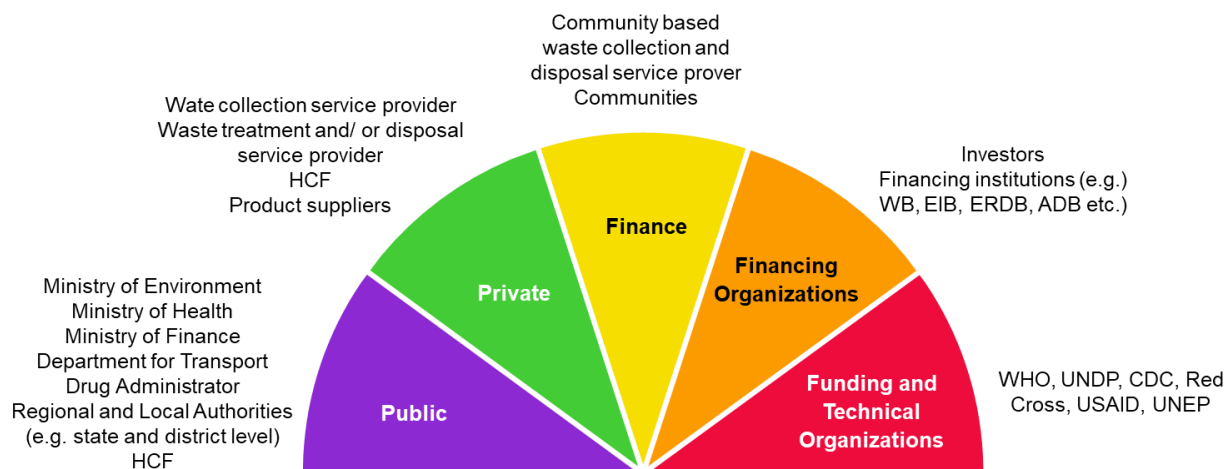
2.1.2 Identifying gaps and needs

When developing waste management plans at a national level, it is important to first assess the existing level of services in country, identify any gaps and determine the capacity to handle future requirements. This requires an examination of current practices, the degree to which legislation exists and is successfully implemented, and the human and infrastructural resources available to handle and treat waste. The Global Fund’s National Capacity Planning Tool is a good way to help do this.

2.1.3 Engaging key stakeholders

The key stakeholders who should be engaged during the HCW intervention planning process are summarized below in [Figure 9](#).

Figure 9: Key HCW Stakeholders



In addition to the country-level stakeholders, applicants should also consider the role of international regulators in HCWM system development, including those who regulate the production of health care products and the assessment of environmental risk. Established regulatory entities in developed nations are fairly consistent in requiring health product producers to report on specific waste management and environmental standards, but this is not the case in other parts of the world. The European Medicines Agency (EMA) has produced guidelines on the approach to environmental risk assessment¹⁹ in authorizing pharmaceutical products.

2.2 Data, auditing and measurement

Waste auditing and composition studies are fundamental in establishing the need for waste management interventions. They help to determine how much waste is generated, where it comes from, and the types being produced. This can then be used to inform future HCW planning and decision-making. Applicants should encourage waste audit and composition study interventions at the HCF level to help support the gathering of baseline data and HCW system development. Detailed guidance on assessing HCF waste generation is included in the [WHO Blue Book](#)²⁰. Applicants should prioritize the establishment of data-gathering and measurement systems at the national and sub-national levels to ensure that robust system-level baseline data exists and is frequently monitored, as set out in Section 2.2.1.

Applicants may wish to establish HCW coverage at the HCF level by carrying out a HCF assessment in accordance with the Water and Sanitation for Health Facility Improvement Tool (WASH FIT) developed by WHO and UNICEF. The tool can be used to assess a HCF in accordance with national and global standards to identify the basis for making improvements. Data gathered helps to identify service level based on whether waste is

¹⁹ [Guideline on the Environmental Risk Assessment of Medicinal Products for Human Use \(europa.eu\)](#) updated 2015

²⁰ [Safe management of wastes from healthcare facilities, second edition, WHO, 2014](#)

safely segregated (for example, into at least three clearly labelled bins) and safely treated and disposed of (using methods such as incineration, autoclaving, and burial in a lined, protected pit).

2.2.1 Measurement

Capacity planning at the national level should be supported by robust data. Types of data that should be collected include:

- Total waste generated;
- Waste composition;
- Waste generated per bed/patient;
- Waste treatment/disposal;
- Financial/expenditure data; and
- Incidents and injuries associated with waste handling.

This data would typically be collected through periodic waste audits (recommended at least twice per year, if possible). In some circumstances it may be collected on a continuous basis, through weighbridge data or other automated measurement systems. Information on staff knowledge and awareness and other qualitative data can also be collected through studies or surveys.

2.2.2 Uses of data

It is important that the entity or authority responsible for data gathering and measurement at the national level is clearly identified in the regulations. Data reporting and monitoring requirements should also be set out within a national HCWM strategy or plan.

Data can be used internally to:

- Confirm and demonstrate legal compliance;
- Track performance (environmental and financial) and identify improvement measures;
- Help plan and inform future operations and developments;
- Allow for projection of future waste needs (by extrapolating from current per bed/per patient waste generation) and help determine requirements for storage, transportation, and treatment requirements; and
- Demonstrate progress to funders, investors, and other stakeholders.

Data can also be extremely useful to other stakeholders:

- Funders/investors can use it to help prepare investments and identify the need for additional funding;
- Local and national governments can use it to plan for future infrastructure requirements (sanitary landfills with hazardous waste cells and municipal treatment infrastructure, including incinerators);
- Other funding recipients and health care suppliers can use it to estimate their own needs, and to benchmark performance;

- The wider community can use it to understand the risks they may face, and support interventions when needed (including by pressuring local and national governments to provide support);
- Academics and educators can use the data to examine trends, develop models, and teach students who will go on to enter the health care sector.

Where possible, data should be shared with stakeholders or published, to facilitate cooperation and partnering, and to improve transparency.

Bongani Regional Hospital, South Africa

In 2016, Bongani Regional Hospital set a goal to promote the use of a web-based HCW data management system as a tool to develop a strategy for hospital waste minimization. The electronic tool is a simple Excel model which monitors HCWM. The tool was successfully implemented and saved approximately US\$23,000 between November 2016 and August 2017, due to a reduction of losses stemming from improper segregation at the ward level.



Source: Global Green and Health Hospitals (2017)²¹

2.3 Costing and budgeting for waste management

HCWM in low- and middle-income countries is typically under-funded and insufficient to meet long-term needs or to support sustainable or resilient service provision. Effective waste management is expensive, often comprising 20-50% of municipal budgets²². It is therefore essential that HCW plans and interventions are comprehensively costed, with adequate budget provision at national scale. To support this, the Global Fund encourages grant applicants to allocate at least 1% of funding to HCWM.

WHO has developed a costing tool²³ for low- and middle-income countries to help estimate costs related to HCWM at the HCF, sub-national and national levels. The tool uses assumed capital and operational costs for equipment, consumables and staff, based on a set of price assumptions. It is useful in helping to determine HCWM budgets at the local and national levels but should be used for indicative purposes only, given that many of the pricing assumptions will be subject to local and/or macroeconomic conditions.

Developing a robust long-term financial plan is essential in supporting national HCW plan implementation. Typically local governments cover approximately 50% of investment costs for waste systems with the remainder coming from subsidies or the private sector²⁴. HCWM budgets should feature the following minimum components:

²¹ Online Data Management, Bongani, South Africa, Global Green and Health Hospitals (2017)

²² [Solid Waste Management \(worldbank.org\)](https://www.worldbank.org)

²³ [Expanded Costing Analysis Tool, WHO, 2020](https://www.who.int)

²⁴ [Trends in Solid Waste Management \(worldbank.org\)](https://www.worldbank.org)

- Capital investments (e.g., the cost of purchasing waste management equipment and treatment infrastructure);
- Operational expenditure including costs associated with:
 - Staffing;
 - Maintenance (lifecycle, planned and reactive);
 - Training;
 - Disposal (e.g., of residues); and
 - Consumables.
- Revenue (e.g., from the sale of recyclables and/or waste-derived products); and
- Loan or disbursement repayments (i.e., where funds have been borrowed from lending organizations to support capital investments).

Applicants should **identify other investment and cost recovery opportunities** to support HCWM system sustainability in the long-term (i.e., non-Global Fund financing) which might include matched funding from the private sector or support from other partners. This may also include payments for waste management services by waste generators from the public and private sector, where major HCW producers make larger financial contributions to the cost of HCWM services (i.e., in accordance with the “**producer responsibility**” principle).

2.4 Waste management intervention good practise

A number of training resources exist, including the waste module and fact sheet in the WHO/UNICEF WASH FIT Version 2.0²⁵, as well as a broader set of WHO health care waste training slides, which can be used to identify and steer best practice interventions. An example of good practice in HCWM intervention planning is provided below. It is considered good practice as it broadly follows the principles and themes outlined in this Technical Brief and has been subject to prior country-level assessment (e.g., concept paper, options appraisal, proposal and justification).

Incineration in Dar Es Salaam, Tanzania

The Aga Khan Medical Service has doubled in size since opening in 1964, and hence volumes of medical waste have increased beyond the capacity of existing waste management systems. In parallel, existing incinerators had reached the end of their operational life.

The Medical Service commissioned a dual-chamber incinerator and an additional venturi wet scrubber, allowing the disposal of a wider range of medical waste types, while still maintaining clean emissions. Following the success of this upgrade, the Medical Service is currently procuring further incineration capacity to offer services to three districts situated within 100 miles of the site to widen better practices in the process.



²⁵ WHO/UNICEF, 2022. WASH FIT Portal. <https://www.washinhc.org/wash-fit/>.

Treatment of Infectious Waste, Jamaica

The Jamaican Ministry of Health and Wellness (MOHW) developed a waste management strategy in 2021 which identified the national infrastructure and the capacity required for a more resilient and sustainable HCWM system. Global Fund C19RM funding has been awarded to support procurement of alternative treatment technology (microwave) to process infectious HCW in line with the wider national strategy.

Jamaican policy discourages incineration and incentivises non-burn technologies, which heavily influenced initial funding discussions and the type of treatment technology that was proposed. There was significant discussion on the suitability of the proposed technology for high-hazard HCW (cytotoxic, cytostatic, pharmaceutical, chemical). For further details on treatment technology selection, see Section 3.7.

To decide the treatment technology which should be adopted, a gap analysis and business case appraisal was developed. This included an assessment of the current infrastructure and waste-generation data, in addition to a detailed options appraisal to identify the most appropriate HCW treatment solution.

A general trend of poor segregation at the ward level was highlighted. This will need to be addressed in order to prevent unsuitable wastes being processed through the new equipment, which could result in operational downtime due to blockages or equipment failure.

A solution for treatment of high hazard HCW still needs to be identified, as the microwave treatment technology procured with C19RM funding is not suitable to treat all HCW streams.

Source: AKDN²⁶, Addfield²⁷

²⁶ ADKN, 2022, [Environment and Climate - AKDN \(the.akdn\)](#)

²⁷ Addfield, 2022, [Hospital Medical Waste Solution in Tanzania Case Study \(addfield.com\)](#)

3. Waste Management Best Practice

This section provides a summary of the key conceptual and technical considerations to take into account when formulating national HCW guidelines. They encourage best practice in both upstream and downstream HCWM and are integral to effective HCWM plan implementation. Further guidance on the steps that should be followed when producing national HCW plans is included in Section 2. Complementary guidance on specific approaches for the management of waste from a range of Global Fund-supported health products is included in [Appendix B](#).

3.1 Conceptual Considerations

3.1.1 Green procurement

Green procurement (also known as sustainable procurement) is the purchasing of products and services that deliver environmental and social value and is fundamental in applying the circular economy and waste hierarchy. It may involve agreeing contractual measures with suppliers to deliver environmental benefits such as waste prevention, packaging reduction and take-back of end-of-life products for reprocessing (reverse logistics).

Carry out **trials and pilot schemes** to assess whether:

- The product is fit for purpose.
- There are additional waste management requirements (storage and collection provisions).

Liaise with suppliers to assess alternatives to existing packaging practices.

Check the environmental credentials of manufacturers and suppliers.

Ensure there are **provisions, services, and training to retain resources**.

When procuring a service or product, ask the following questions:

- Is the current product or service fit for purpose?
- What can be done to eliminate waste or the use of single-use items? Does the new provision impact waste management requirements?
- Can suppliers reduce packaging or implement Circular Economy principles?
- Does the manufacturer/supplier note any recognized accreditations or schemes? Can these be verified?
- Are there provisions, services and training to upskill and retain colleagues?
- Are there good examples of similar products or services being procured sustainably?

Procurement plays a pivotal role in working towards reducing waste and helps control the first step of the waste hierarchy (prevention). Considerations should be made to reducing product demand, reviewing options to reduce consumption, and identifying opportunities for remanufacture, redistribution, or refurbishment. Examples of such measures are provided below.

Those responsible for the procurement of health care products should seek to engage with responsible producers or suppliers (and purchase products) that minimize environmental harm, promote resource efficiency and encourage greater circularity in the use of products. Developments in sustainable packaging and improvements in the use of products and services should be followed up so as to identify opportunities to apply the key principles of sustainable waste management. Global Fund is in the process of developing a sustainable procurement framework to help improve environmental standards in the supply chain.

3.1.2 Avoidance, reduction and minimization

Unfortunately, some amount of waste generation is unavoidable. Wherever a waste stream cannot be eliminated completely, it should be minimized as much as possible.

Many of the most effective measures to eliminate or minimize waste streams in health care require effective supply chain engagement. These include reducing product packaging/shipping waste and modifying the design of health care products to use less material or to be easier to dispose of.

Assessing health product demand and use is fundamental in reducing over-supply and/or reducing the impact of product expiry, thus minimizing the potential for waste generation.

This is particularly important for health products with an explicit expiry date or short useful life (e.g., antiretrovirals and artemisinin combination therapies (ACT) drugs which could lead to the production of excessive quantities of pharmaceutical and packaging waste types).

Applicants should **ensure that a considered and methodical approach is taken towards health product forecasting** prior to the point of procurement and in consideration of the types of HCW likely to be produced.

Methods for eliminating waste may include:

- Switching from analogue to digital X-ray systems to eliminate the stream of hazardous fixer, developer, and film;
- Switching from single-use items (such as paper cups or disposable thermometer covers) to reusable equivalents (glass or ceramic cups, or washable thermometer probes);
- Avoiding unnecessary tests, procedures, and other actions that generate waste; and
- A procurement policy which explicitly precludes purchasing products that contain toxic materials such as mercury, PVC or glutaraldehyde; and setting progressive targets for those which cannot yet be eliminated.

Single Use Plastic Ban, Rwanda

Since 2004, Rwanda has been developing national bans to reduce the consumption and manufacturing of single-use plastic due to the environmental challenges posed by such items.

In 2019, the ban was extended to include all plastic bags and single-use plastics, making it illegal to import, produce, use or sell plastics. Exceptions are granted in industries such as hospitality and agriculture. Penalties can be as high as US\$10,000 or a year of imprisonment. Outcomes of the ban include an increase in the popularity of compostable plastics and significant growth in the local plastics recycling industry.



Source: Gaia (2021)²⁸, Hakuzimana (2021)²⁹

3.2 Technical Considerations

The following sections provide a summary of best practice in the classification, storage, treatment, and disposal of HCW in accordance with WHO principles. Applicants should always refer to published [WHO guidance](#)^{30, 31}, which sets out management steps and treatment options for typical HCW categories, when formulating national HCW guidelines.

3.2.1 Classification

A full list of typical HCW categories is set out in [WHO guidance](#). Specific examples of how wastes from health products may be categorized is provided in [Appendix B](#) of this brief.

HCW classification systems, legal requirements, terminology, and color-coding/labelling requirements vary significantly from country to country. Applicants should check local legislation to ensure that they are complying with the applicable standards and laws.

3.2.2 Source segregation

Proper segregation of HCW at (or near) the point of production is one of the most essential factors in safe, sustainable waste management. It is recommended that at minimum, bins should be provided in all locations where HCW may be generated to segregate at least the following categories:

- Sharps bins
 - For used needles and syringes
 - For glass vials and ampules
- Non-sharps infectious waste
 - For use with infectious waste (such as cultures and swabs from infected patients)

²⁸ Gaia (2021), Rwanda: A global leader in plastic pollution reduction [online]. Available at: [Rwanda: A Global Leader in Plastic Pollution Reduction](#). Accessed August 2022.

²⁹ [Break Free from Plastics: Environmental Perspectives and Evidence from Rwanda](#)

³⁰ Safe management of wastes from healthcare facilities, second edition, WHO, 2014. Available at [9789241548564_eng.pdf;jsessionid=C1B385C9260580F4BDB618E01231C721 \(who.int\)](#). Accessed October 2022.

³¹ World Health Organisation (WHO) (2019). Overview of technologies for the treatment of infectious and sharp waste from health care facilities [online] Available at: [Overview of technologies for the treatment of infectious and sharp waste from health care facilities \(who.int\)](#). Accessed July 2022.

- High-risk pharmaceutical waste (such as expired Efavirenz/Emtricitabine/Tenofovir)
- Low-risk pharmaceutical waste (such as expired Amikacin solution); and
- General waste bins (for MSW and recyclable waste)

At more established HCFs, and in better-resourced/non-emergency situations, additional levels of segregation can be implemented in accordance with best practice to correctly manage a wider range of waste streams and improve environmental performance:

- Separate bins for non-hazardous recyclable waste and general waste;
- Cytotoxic/cytostatic waste bins for hazardous wastes stemming from chemotherapy, oncology, and other medical practices;
- Anatomical/pathological waste bins for amputated body parts, afterbirth/childbirth wastes, and other solid anatomical wastes; and
- Radiological/radioactive wastes that cannot be decayed on-site.

Waste bins should be based on the types of waste generated (e.g., there is no reason to place cytotoxic waste bins if there is no cytotoxic material being used on-site), and the end treatment method (wastes being disposed of together, for instance using HTI, can be placed in the same bin). It is not necessary to place bins for specific waste types in areas where this type of waste will not be generated.

Source segregation is one of the most important aspects of HCWM. If a hazardous material is incorrectly placed into a general waste bin, the full contents of the bin must be treated as hazardous, requiring a higher level of treatment (and consequently higher costs and greater environmental impact).

Paropakar Maternity and Women's Hospital, Nepal

Until 2015, waste was collected in unstandardized waste bins, and only 5% were labelled. This meant that health care staff were subject to infection or injury.

Two new features have since been introduced in each ward:

- A general waste collection area for staff and visitors with standardized, colour-coded and clearly labelled bins for different sorts of waste
- A tailored medication trolley designed for segregation of waste at source, which includes separate bins for infectious waste and a needle cutter.

As a result of this change, high-risk waste has been reduced from 84% to 25%.

Behavioral and attitudinal change will be critical to ensuring sustainability of the HCWM system.



Source: Global Green and Healthy Hospitals, 2017³²

³² Paropakar Maternity and Women's Hospital Waste Management. Global Green and Healthy Hospitals, 2017.

3.2.3 Storage

All HCW storage areas must have enough capacity to hold the waste generated until it can be disposed of properly. This capacity will be determined by the waste generation rate of individual HCFs as well as the frequency of collection and disposal (see Section 2.2 for further details on gathering this data).

Waste storage requirements at existing facilities can be estimated using data from a waste audit (as discussed in Section 2.2). The amount of space required will also depend on the availability of waste management infrastructure (on-site or off-site).

Storage areas must be large enough so they do not overflow, and separate spaces must be provided for different types of waste. At minimum, an enclosed, lockable area must be provided for the storage of hazardous wastes (including infectious and chemically hazardous wastes) separate from all non-hazardous wastes. Controlled drugs, radiological material, and other more specialized waste streams may have additional storage requirements under local law. It is preferable to have spare capacity in order to cope with excess waste from unplanned events (see Section 1.1), or limit waste collections/treatment.

All HCW storage areas should have appropriate signage and be dry and secure from unauthorized persons, pests and disease vectors. Staff must be trained to use storage areas for them to be effective. More information is given in the [WHO Blue Book](#).

Holy Trinity Children's Hospital, Argentina

In 2013, the hospital implemented a waste management strategy as part of an overarching objective for Green and Healthy Hospitals. Measures were established to minimise the risks generated by inadequate waste management.

These included improved segregation and characterization of waste, achieved through additional identification on containers and bins and an increased quantity of such receptacles throughout the hospital.

Staff training on proper waste management from HCF was introduced. In addition, information leaflets on pathogenic and non-pathogenic residues were placed throughout the hospital.



Source: Global Green and Healthy Hospitals, 2017³³

3.2.4 Transfer and transport

The method used to transport HCW should be appropriate to the individual circumstances of HCFs and compliant with national transport regulations. Non-hazardous and hazardous waste should not be moved together. Separate vehicles are required for each, and hazardous waste transportation should be in line with international legislation, conventions and shipment requirements (see Section 1.5).

³³ Good Waste Management Practices in Healthcare Establishments. Global Green and Healthy Hospitals, 2017.

If it is well segregated, up to 85% of all waste generated at a HCF could be classified as non-hazardous. Therefore, it may be necessary to schedule more collections for non-hazardous waste than hazardous.

3.2.5 Treatment and disposal

When planning waste management interventions, applicants should consider the most suitable form of waste treatment and disposal, which will be dependent on the types of HCW generated, an adequate level of source segregation, national regulation and local conditions (environmental, social, economic).

3.2.5.1 Waste treatment technology options and selection

HCW with hazardous properties requires treatment with an appropriate technology prior to disposal in order to render it safe to handle/transport, and to minimize environmental and direct human harm. Treatment technologies typically use heat or chemicals to destroy pathogens and render waste safe. Chemically contaminated, pharmaceutical, and cytotoxic wastes typically have stricter treatment requirements (specifically High Temperature Incineration (HTI)) in order to render it safe for subsequent disposal.

The following guidance for laboratory management of uncontaminated spent and expired GeneXpert Cartridges should be adhered to:

Waste cartridges containing guanidinium thiocyanate (e.g., COVID-19)

- To be classified as chemical waste.
- No additional packaging or disinfection procedures are necessary.
- Disposal through HTI is recommended.

Waste cartridges not containing guanidinium thiocyanate (e.g., TB)

- To be classified as municipal solid waste (MSW).
- No additional packaging or disinfection procedures are necessary.
- Disposal with other MSW is recommended.

Source: African Society for Laboratory Medicine, 2020³⁴

Table D1 in [Appendix D](#) provides a comprehensive overview of the following established and emerging HCW treatment technologies. Those which are more widely utilized are listed first.

- HTI;
- Autoclaving;
- Microwaving;
- Frictional Heat;
- Chemical Disinfection (sodium hypochlorite); and
- Pyrolysis.

³⁴ African Society of Laboratory Medicine (2020). Available at https://aslm.org/wp-content/uploads/2020/06/1592472076-COVID-19_template_PPT_GEN_PUB_Laboratory-Biosafety-Review-ASLM-Final-Clean-DB-21May20.pdf?x20776

A series of parameters such as the types of HCW suitable for treatment, track record, environmental footprint, operational aspects and indicative cost information should be considered when selecting the treatment solution. The key criteria are summarized in Table 3. It may be that a single treatment is selected or that countries opt for a combination of treatment solutions.

Table 3: Comparison of HCW Treatment Technologies

COMPARATIVE CRITERIA		HIGH TEMPERATURE INCINERATION (HTI)		AUTOCLAVE	MICROWAVE DISINFECTION		FRICTIONAL HEAT	CHEMICAL DISINFECTION (sodium hypochlorite)	PYROLYSIS
		Without abatement	With abatement		BATCH	CONTINUOUS			
Suitable Healthcare Waste Types	Infectious	✓	✓	✓	✓	✓	✓	✓	✓
	Pathological	✓	✓	✗	✓	✓	✓	✓	✓
	Sharps	✓	✓	✓	✓	✓	✓	✓	✓
	Chemical	✓	✓	✗	✗	✗	✗	✗	✗
	Pharmaceutical	✓	✓	✗	✗	✗	✗	✗	✗
	Cytotoxic & Cytostatic	✗	✓	✗	✗	✗	✗	✗	✗
	Radiological	✗	✗	✗	✗	✗	✗	✗	✗
Track record of technology		●●●●●	●●●●●	●●●●●	●●●●	●●●●	●●	●●	●
Ease of construction		●●	●●	●●●●	●●●●	●●●	●●●	*	●
Ease of commissioning		●●●	●●	●●●●	●●●●	●●●●	●●●●	*	●
Ease of operation		●●	●●	●●●●	●●●●	●●●	●●●	*	*
Types of waste suitable for treatment		●●●●●	●●●●●	●●●	●●●	●●●	●●●	●●●	●●●
Indicative CAPEX**		●●	●●●	●	●●●	●●●●	*	*	●●●
Indicative OPEX		●●●●	●●●●●	●●	●	●●	●	●●●	●●●●●
Environmental footprint		●●●●●	●●●●	●	●	●●	●●	●●●	*
Indicative physical/land footprint		●	●●●●●	●●●●	●	●●	●●●	*	*
Licensing and regulatory implications		●●●	●●●●	●●●	●●●	●●●	●●●	●●●	●●●
Reliability of equipment		●●●●●	●●●●	●●●●	●●●●	●●●	●●●	*	●●●
Continuous or batch process		C	C	B	B	C	B	*	*
Modular or bespoke		M	B	M	M	M	M	B	B
Level of automation		Low	Low	High	Medium	Medium	Medium	High	High
Lead time on technology		●●	●●●	●●	●●	●●	*	*	●●●●

* Technology insufficiently established to assess criteria.

**Costs associated with processing equipment only and do not include civil or structural engineering associated with treatment building.

Note: Scale from low (●) to high (●●●●●)

3.2.5.2 Pre-treatment

Shredding of solid health care waste before or during disinfection using microwave, chemical and autoclave technology is typical and is used to enhance the efficiency of the sterilization process. Shredding is important to³⁵:

- Increase the surface area of the waste, eliminating voids in the waste load;
- Render any anatomical waste unrecognizable to avoid adverse visual impact on disposal; and
- Reduce the volume of waste (shredding of waste before sterilization and compaction can reduce the original waste volume by 60-90%, depending on the type of equipment used).

³⁵ World Health Organisation (WHO) (2014). Safe management of wastes from health-care activities [online] Available at: https://apps.who.int/iris/bitstream/handle/10665/85349/9789241548564_eng.pdf;jsessionid=... Accessed July 2022.

The following considerations should be made when integrating shredding into the treatment process:

- Should be undertaken in an enclosed system in order to avoid the release of pathogens/bioaerosols and to protect staff from moving machinery.
- The presence of an excessive proportion of sharps or glass in the feedstock may cause accelerated deterioration of the shredder and/or blockages in the process.
- If shredding is to be incorporated in the treatment process, good segregation of feedstock material is required to prevent inappropriate and bulky waste items from entering the shredding unit. Without good segregation there is a high risk of blockages and damage inside the shredding unit which is costly to repair.

Further information on HCW treatment technologies can be found in the [UNEP Compendium of Technologies for Treatment/Destruction of Healthcare Waste](#)³⁶ and in the [WHO guidance](#) on technologies for the treatment of infectious and sharp waste from HCFs³⁷.

Khayelitsha District Hospital (KDH), South Africa

After the commissioning of the Hospital in 2011, the number of patients and services provided increased at a rapid rate and led to an issue of storage space for HCW and the associated hygiene risks.

KDH was the first public hospital in the Western Cape (South Africa) to employ the new technology of frictional heat to treat infectious waste on site.

The Department of Transport and Public Works (DTPW) came on board and agreed to run a pilot project at KDH with the intention to adopt new treatment technology in the future. By treating HCW on site, the hospital was able to reduce the volume of waste sent to landfill by 70% and save approximately R 900,000 for the 2018/2019 fiscal year. KDH will procure a second system in the future.



Source: Global Green and Healthy Hospitals, 2019³⁸

3.2.5.3 Treatment outputs and end-of-waste criteria

Consideration should be given to the range of outputs and by-products likely to be generated by each technology, and to the manner in which such by-products should subsequently be disposed of. This is a function of whether the output is hazardous or non-hazardous. For example, frictional heat, autoclaving and microwave treatment produce a dry, non-hazardous floc at a range of particle sizes. HTI produces a number of outputs including Incinerator Bottom Ash (IBA) which can be treated to extract metals, with the remaining fraction suitable for reuse in aggregate. The process also produces hazardous fly ash and Abatement Pollution Control (APC) residue, which must be treated. Chemical treatment with sodium hypochlorite causes toxic compounds in wastewater to form by reacting with acids to produce hazardous chlorine gas.

³⁶ United Nations Environment Programme (UNEP), (2012). Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/8628/IETC_Compndium_Technologies_Treatment_Destruction_Healthcare_Waste.pdf?sequence=3&isAllowed=y. Accessed October 2022.

³⁷ Overview of technologies for the treatment of infectious and sharp waste from health care facilities, WHO, 2019

³⁸ On-Site Treatment of Infectious Waste Khayelitsha District Hospital (KDH): Global Green and Healthy Hospitals, 2019.

End-of-waste is a status given to waste materials which are no longer considered waste (i.e., if it becomes a useful or saleable product). This concept is defined under EU law, but parallel systems and legislation exist in non-EU countries. Grant applicants should establish whether there is end-of-waste status and dispose or recover treatment outputs in accordance with such criteria. Specific considerations for each treatment technology are outlined in [Appendix D](#).

Western Regional Hospital (WRH), Nepal

In 2008, WRH was either burning its HCW or disposing of it in the municipal stream and was subject to public criticism and strikes. Because of this, the hospital requested technical assistance to establish a safe, non-burn HCWM system.

Alongside the installation of an autoclave, a model waste segregation and handling system was applied throughout the hospital and a waste treatment and storage center was established.

The project was particularly successful due to stakeholder engagement and hospital staff have reported fewer needle-stick injuries.



Source: Global Green and Health Hospitals, 2014³⁹

3.2.5.4 Off-site treatment

Off-site treatment and disposal involves the transfer of HCW to a private contractor, government entity, or the informal sector, and is subject to the availability of third-party operated HCW treatment and/or disposal infrastructure. It is important to make sure the organization transporting the waste off-site is treating and disposing of it properly, to avoid environmental contamination, damage to human health and potential legal liability. This may include checking that the organization is certified and has the appropriate equipment to transport HCW.

3.2.5.5 Disposal of residues

After treatment and once rendered safe, non-hazardous waste normally requires disposal in an engineered sanitary landfill. A properly engineered sanitary landfill should feature leachate management systems, boreholes (for inspection of leachate), gas management measures (to deal with the gasses created by decomposing organic waste), barrier systems (to prevent hazardous materials leaching into soil and groundwater), and security/management systems (to prevent the local populace from entering the site and potentially injuring themselves or damaging equipment).

Hazardous wastes that have not been rendered safe through treatment require disposal in a specialized hazardous waste cell within a landfill. Ash (and any anti-pollution residues) from HTI must also be disposed of in a hazardous cell (although incineration significantly reduces the volume of waste which requires disposal, lowering transport and disposal costs).

³⁹ Implementation of Safe Health Care Waste Management System Western Regional Hospital (WRH) Pokhara, Nepal Global Green and Healthy Hospitals, 2014.

List of Abbreviations

ACT	Artemisinin Combination Therapies
AD	Anaerobic Digestion
ADB	Asian Development Bank
ALT	Alanine Aminotransferase
APC	Air Pollution Control
AST	Aspartate Aminotransferase
AT	Alternative Treatment
BCP	Business Continuity Plan
CAPEX	Capital Expenditure
C19RM	COVID-19 Response Mechanism
CDC	Centre for Disease Control
DTPW	Department of Transport and Public Works
DQA	Data Quality Assessments
EBRD	European Bank for Reconstruction and Development
EMA	European Medicines Agency
EIB	European Investment Bank
EU	European Union
GTC	Guanidinium Thiocyanate
HCF	Health Care Facility
HCW	Health Care Waste / Healthcare Waste
HCWM	Health Care Waste Management
HTI	High Temperature Incineration
IBA	Incinerator Bottom Ash
IETC	International Environmental Technology Centre
IT	Information Technology
IV	Intravenous
KDH	Khayelitsha District Hospital
KPI	Key Performance Indicator
LFA	Local Fund Agent
LLIN	Long-Lasting Insecticidal Nets
MOHW	Ministry of Health and Wellness
MSW	Municipal Solid Waste
NSI	Needle Stick Injury
OPEX	Operational Expenditure

POPs	Persistent Organic Pollutants
PPE	Personal Protective Equipment
PPP	Public Private Partnership
PR	Principal Recipient
RSSH	Resilient and Sustainable Systems for Health
SOP	Standard Operating Procedure
TB	Tuberculosis
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WASH FIT	Water and Sanitation for Health Facility Improvement Tool
WB	World Bank
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organization
WRH	Western Regional Hospital

Appendix A

Table A1: Circular Economy Implementation

PRINCIPLE	ACTION	CIRCULAR INTERVENTION
“Designing out” waste and emissions	Procure products or devices designed with consideration to circularity	Incorporate disassembly into design, opportunity for upgradability, products manufactured with reduced use of materials (e.g., glues, unnecessary accessories and details), durable, at end-of-life the product can be reused, remanufactured or recycled by the service provider.
	Reduce consumables	Limit the use of single-use materials to patients and staff that require them for health and safety purposes, liaise with suppliers to assess alternatives to single-use or difficult-to-recycle packaging.
	Digitalization	Replace need for materials by using a digital alternative or online service, such as replace need for film for x-rays by converting to digital imagery and store reference document/textbooks online.
	Substitute harmful substances	Purchase safer alternative products with no or less hazardous substances; request details of specifications and use of harmful or potentially harmful substances in products from suppliers and enquire into alternatives.
Keep products and materials in use	Maintain product	Implement planned prevention measures for larger equipment, training on simple repairs, correct storage of products; procure specialist external services to maintain equipment.
	Reuse products	Prioritize reusable equipment over single-use, where appropriate leasing or hiring equipment; provide a clear designated location for the collection of products and equipment suitable for reuse; procure products with reusable packaging (request suppliers take back the packaging).
	Redistribute equipment and products	Identify products that will be suitable for redistribution once no longer required at the facility; establish networks with redistribution organizations to remove products; establish storage and collection areas to prepare for removal.
	Refurbish	Purchase remanufactured devices, identify products that will be suitable for remanufacture/refurbishment to retain use of the product at the facility (where feasible) or externally, establish networks with remanufacturing organizations, establish storage and collection areas to prepare for removal.
	Recycle	Purchase materials that are recyclable and composed of recycled/re-used content. Inventory locations of recyclable packaging and products to ensure sufficient bin provisions and correct waste segregation. Some clinical wastes are suitable for recycling following treatment to be rendered safe at specialist waste management facilities to separate different material types (plastics, metals etc).
	Recover calorific value of waste through incineration/anaerobic digestion	Unavoidable and non-recyclable waste to be diverted from landfill where feasible through Energy from Waste, which is the processing of wastes for the generation of energy and/or other resources (water, heat, material, nutrients). It is critical that there be effective segregation of non-hazardous general waste and co-treatment with non-hazardous wastes from other sources (e.g., municipal, commercial). Energy recovery can also include the anaerobic digestion (AD) of food waste which generates biogas to produce heat and electricity and produce solid and liquid digestate (fertiliser).
Regenerate natural systems	Recover energy from biologically based products (e.g., wood, paper, cellulose fibres) that can no longer be reused or recycled	Implement measures to reuse and recycle biologically based products where possible before consideration for diversion from landfill e.g., Energy from Waste.

Appendix B

Table B1: Waste Categories and Management Approaches

HEALTH CARE WASTE CATEGORY	ASSOCIATED DISEASE	HEALTH PRODUCT DESCRIPTION	WASTE MANAGEMENT APPROACHES
Infectious waste	All	Waste contaminated with blood and other bodily fluids (e.g., from discarded diagnostic samples), cultures and stocks of infectious agents from laboratory work (e.g., waste from autopsies and infected animals from laboratories), or waste from patients with infections (e.g., swabs, bandages and disposable medical devices)	<p>Infectious waste can be incinerated, or can be treated using:</p> <ul style="list-style-type: none"> • Thermal; • Chemical; • Biological; and/or • Irradiative techniques <p>Treated wastes can then be disposed of in an approved, engineered landfill.</p> <p>Autoclaving is the most widely practiced method of infectious waste treatment (where it is available). Other thermal waste treatment options include microwaving, electrothermal disinfection, frictional heating, and dry heating.</p> <p>Chemical disinfectants are widely used, but usually result in the emission of persistent pollutants.</p> <p>Biological and irradiative methods are not widely commercially available, or commonly used.</p>
	All	Used surgical and face masks	Can be treated with low-temperature thermal methods, including autoclaving, microwaving, and friction heating, before final disposal. Masks should not be reused unless they are purposely designed for re-use (e.g., reusable medical or FFP2 masks). Reusable masks should be decontaminated according to manufacturer instructions.
	All	Used gloves	Latex/nitrile gloves should never be reused. Gloves used in patient treatment areas should be disposed of with other infectious waste. Gloves used in labs which may have come into contact with hazardous chemicals should be treated as chemical waste.
	All	Contaminated cleaning supplies	Can be treated with low-temperature thermal methods, including autoclaving, microwaving, and friction heating, before final disposal.
	HIV/AIDS	Condoms and tampons	These are distributed for off-premises use and will likely end up mixed with MSW in household/public bins. This is not considered a significant danger due to the low infection risk.
	TB	Liquid media with supplements (including BD Bactec MGIT tubes and supplement kits, BD Bactec PZA tubes and kits, and BD Taxo test strips)	Can be treated with low-temperature thermal methods (including autoclaving, microwaving, and friction heating) before final disposal. Chemical treatment can also be suitable.
	TB	Consumables for LPA testing	Can be treated with low-temperature thermal methods (including autoclaving, microwaving, and friction heating) before final disposal. Chemical treatment can also be suitable.
	TB	Sputum containers, slides for microscopy, applicators, and filter paper	Infectious items can be treated with low-temperature thermal methods. Some items may be safe for reuse (see manufacturer recommendations and local legislation).

HEALTH CARE WASTE CATEGORY	ASSOCIATED DISEASE	HEALTH PRODUCT DESCRIPTION	WASTE MANAGEMENT APPROACHES
	Malaria/HIV/AIDS	Rapid diagnostic tests, microscopy supplies	Infectious items can be treated with low-temperature thermal or chemical methods. Some microscopy supplies may be safe for reuse (see manufacturer recommendations and local legislation).
	COVID-19	Lateral flow tests	Typically classified as non-hazardous chemical waste/offensive waste. Considered appropriate for EfW/low-temperature incineration. Tests distributed for home use are generally safe for disposal through the municipal waste stream. Check local legislation and guidelines before disposal.
Infectious/ Chemical	All	Pipettes and lab tubes, bottles, vials, beakers, and viral load kits, diagnostic products	Infectious items can be treated with low-temperature thermal methods. Chemically contaminated items may be safe to rinse (for small amounts of low-hazard chemical contamination) and reused.
Infectious/ Chemical	Malaria	Protective clothing	Should not be reused beyond manufacturer's recommendation and should be removed from service when it becomes unsafe to use (obvious holes, or other significant wear). Protective clothing should be incinerated at HTI when it is ready for disposal.
Pathological waste		Human tissues, organs or fluids, and body parts	Wastes of this type must be either buried or incinerated. Lab cultured pathological wastes should be autoclaved in the lab before disposal. Pathological wastes are often disposed of using the same channels as dead bodies (either incinerated, or buried), and in a health care setting are often handled by the same contractor/department responsible for those. Local culture also has an impact on disposal. In some areas of the world, certain pathological waste (such as placentas) must be treated in a culturally appropriate fashion (for instance, placentas being taken home by the mother for home-burial). Some pathological wastes have been biodigested using anaerobic digestion (AD) technology.
	TB	Biochemical tests for patients on 2nd line treatment, including serum creatinine, serum potassium, thyroid-stimulating hormone, aspartate aminotransferase (AST), alanine aminotransferase (ALT)	If possible, these wastes should be treated in the lab (with low-temperature thermal or chemical methods), before final disposal (sanitary landfill, or HTI before landfilling).
Sharps waste	All	Syringes, needles, disposable scalpels and blades	Sharps waste is one of the most dangerous streams to handle due to the high risk of needle stick injuries (NSIs), which can spread serious diseases. This waste stream requires the use of secure, rigid, and impenetrable storage bins (ideally color-coded, with a secure one-way needle deposition system). Staff handling sharps waste should be equipped with NSI preventative PPE.
	All	Needles for clinical use	Sharps bins are essential for the adequate management of sharps waste. Needle-destruction devices are recommended to minimize the amount of sharps waste that must be handled. Needles should never be reused. Suitable methods for sharps waste treatment include low-heat thermal processes, chemical methods, and high-temperature incineration. In resource-poor situations, sharps can be disposed of in a purpose-built sharps pit.
	HIV/AIDS	Needles for off-site use	These are distributed by some programs to reduce the risk of infection through contaminated needles. Often managed through needle exchange programs.

HEALTH CARE WASTE CATEGORY	ASSOCIATED DISEASE	HEALTH PRODUCT DESCRIPTION	WASTE MANAGEMENT APPROACHES
Chemical waste	All	Solvents and reagents used for laboratory preparations, disinfectants, sterilisants and heavy metals contained in medical devices (e.g., mercury in broken thermometers) and batteries	<p>The health care implications of chemical waste depend on its nature. Less-hazardous chemical wastes may be diluted and disposed of using sewage/wastewater drains in countries where there is adequate infrastructure (if allowed by local legislation). Larger quantities and more hazardous chemical wastes will require more advanced treatment. Where possible, chemical wastes should be returned to the supplier, or passed on to a licensed contractor or suitable government body for disposal.</p> <p>Hazardous chemical wastes of different composition should be stored separately to avoid unwanted chemical reactions;</p> <p>Hazardous chemical waste should not be discharged into sewerage systems;</p> <p>Large amounts of chemical waste should not be buried, because they may leak from their containers, overwhelm the natural attenuation process provided by the surrounding waste and soils, and contaminate water sources.</p> <p>Large amounts of chemical disinfectants should not be encapsulated, because they are corrosive to concrete and sometimes produce flammable gases.</p>
	All	Laboratory cleaning supplies	Wastes will depend on nature of supplies/cleaning. Recognized standards for lab cleaning exist, such as ASTM D5245 - 19 ⁴⁰ .
	TB	Consumables for LPA testing	Small quantities of less-hazardous chemical waste can be diluted and disposed of via the wastewater system (if a robust wastewater treatment system exists in the region/country), subject to local guidelines and regulations. Larger quantities and more hazardous substances should be collected for handoff to a specialist contractor or government entity.
	TB	GeneXpert cartridges	<p>Some GeneXpert cartridges (e.g., HIV, COVID-19 and other viruses) contain guanidinium thiocyanate (GTC), a hazardous chemical.</p> <p>Spent, expired, or unneeded cartridges containing GTC should be classified as chemical waste, and disposal through HTI is recommended.</p> <p>For uncontaminated spent, expired, or unneeded GeneXpert cartridges not containing GTC (e.g., for TB), disposal with MSW is recommended.</p> <p>Contact the manufacturer for further support.</p>
	TB / HIV	Molecular/genetic analyzer wastes	<p>For sample wastes, see “<i>Sputum containers, slides for microscopy, applicators, and filter paper</i>”, above. These devices typically contain a waste chamber for the collection of excess reagents. These containers should be emptied according to the user manual, with the contents typically classified as chemical waste (suitable for HTI).</p> <p>Wastes generated and procedures for emptying/disposing of waste can vary significantly between models. Check the user manual, and/or contact the manufacturer for model-specific guidance.</p>
	TB/HIV	Lab reagents	Small quantities of less-hazardous chemical waste can be diluted and disposed of via the wastewater system (if a robust wastewater treatment system exists that does not drain or leach into the watercourse).

⁴⁰ <https://www.astm.org/Standards/D5245.htm>

HEALTH CARE WASTE CATEGORY	ASSOCIATED DISEASE	HEALTH PRODUCT DESCRIPTION	WASTE MANAGEMENT APPROACHES
			Larger quantities and more hazardous substances should be collected for handoff to a specialist contractor or government entity.
	TB	Immersion oil, carbon fuchsine, methylene blue, phenol detached crystals, and sodium hypochlorite.	Small quantities of less-hazardous chemical waste can be diluted and disposed of via the wastewater system (if a robust wastewater treatment system exists in the region/country). Larger quantities and more hazardous substances should be collected for handoff to a specialist contractor or government entity.
	TB	X-ray fixer	Contains hazardous levels of silver. Should be handled with extreme care. Recovery of this silver is difficult, and not widely practiced. This waste can be eliminated through the use of digital X-ray systems.
	Malaria	Pyrethroids	Small quantities of less-hazardous chemical waste can be diluted and disposed of via the wastewater system (if a robust wastewater treatment system exists in the region/country). Larger quantities and more hazardous substances should be collected for handoff to a specialist contractor or government entity.
	Malaria	Insecticide spray pumps	Typically treated using soak-pits.
Chemical/ Recyclable waste	TB	X-ray film	Contains high levels of silver. Can potentially be hazardous to handle, but the concentration is usually not high enough to be dangerous without long-term exposure. Can be recycled profitably due to high precious metal content.
Chemical/ Infectious	TB	Lab reagents from culturing and drug susceptibility testing	Small quantities of less-hazardous chemical waste can be diluted and disposed of via the wastewater system (if a robust wastewater treatment system exists in the region/country). Larger quantities and more hazardous substances should be collected for handoff to a specialist contractor or government entity.
Chemical/ Recyclable waste	Malaria	Long-lasting insecticidal nets (LLINs)	<p>WHO advises that LLINs (even those with holes) continue to be used past expiry unless a replacement is available, as they remain effective to some degree.</p> <p>These nets are made of high-strength plastic (typically PET or polyethylene). This makes it possible to recycle them in countries with the necessary infrastructure.</p> <p>LLINs can be repurposed to become carriers for crops, fishing equipment or pest protection for agricultural land.</p> <p>However reuse in applications where there is a risk of human contact (such as clothing or washing equipment) should be avoided.</p> <p>Educate on the environmental consequences of LLINs, and the material value to encourage uptake in repurposing and take-back schemes.</p> <p>Introduce community-level take-back schemes, to redirect waste LLINs to appropriate recycling routes.</p> <p>Use incentives to obtain end-of-life LLINs from households.</p> <p>HTI is recommended for final disposal (i.e., >1100°C).</p>
Pharmaceutical waste	All/general	Expired, unused and contaminated drugs and vaccines	<p>As with chemical waste, the properties of pharmaceutical waste can vary significantly.</p> <p>Ideally hospitals should avoid allowing pharmaceutical products to expire, by using “just-in-time” procurement. Where expired drugs are unavoidable, HCF managers should aim to establish take-back systems with their suppliers.</p> <p>When this cannot be achieved, they should be passed on to specialist contractors, or government entities, as with chemical waste.</p>

HEALTH CARE WASTE CATEGORY	ASSOCIATED DISEASE	HEALTH PRODUCT DESCRIPTION	WASTE MANAGEMENT APPROACHES
			Cheap and easily obtained chemicals can neutralize specific drugs, particularly chemotherapeutic agents. Many are listed in the Annexes of the WHO Guidelines on the Safe Management of Wastes from Healthcare Facilities. These are particularly useful for small amounts of liquid residues, for example in IV sets.
	TB	First- and second-line anti-TB medications	To be returned to manufacturer for disposal if possible. If return is impossible, specialist disposal contractors can be sought. At minimum this waste stream should be disposed of in an HTI (unless otherwise specified in manufacturers' disposal instructions)
	Malaria	Expired/unused malaria medications	To be returned to manufacturer for disposal if possible. If return is impossible, specialist disposal contractors can be sought. At minimum this waste stream should be disposed of in an HTI (unless otherwise specified in manufacturers' disposal instructions)
Cytotoxic waste	All	Waste containing substances with genotoxic properties (i.e., highly hazardous substances that are mutagenic, teratogenic or carcinogenic), such as cytotoxic drugs used in cancer treatment and their metabolites	<p>Cytotoxic waste is highly hazardous and should never be landfilled or discharged into the sewerage system. Disposal options include:</p> <ul style="list-style-type: none"> • Return to the original supplier; • Incineration at high temperatures; • Chemical degradation in accordance with manufacturers' instructions. <p>Full destruction of all cytotoxic substances may require incineration temperatures up to 1200 °C and a minimum gas residence time of two seconds in the second chamber. The incinerator should be equipped with gas-cleaning equipment. Incineration at lower temperatures may release hazardous cytotoxic vapours into the atmosphere.</p> <p>Incineration in most municipal mass-burn incinerators (i.e., <1100°C), in single-chamber incinerators or by open-air burning, is inappropriate for the disposal of cytotoxic waste.</p>
Radioactive waste	TB	Products contaminated by radionuclides, including radioactive diagnostic material or radiotherapeutic materials	<p>The treatment and disposal of radioactive waste is generally under the jurisdiction of a nuclear regulatory agency. Facilities producing radioactive waste should have a radioactive waste management plan in place and should have arrangements approved by the local nuclear body if possible.</p> <p>Three disposal methods are possible for low-level radioactive waste:</p> <ul style="list-style-type: none"> • "Decay in storage", which is the safe storage of waste until its radiation levels are indistinguishable from background radiation; a general rule is to store the waste for at least 10 times the half-life of the longest-lived radionuclide in the waste; • Return to supplier; • Long-term storage at an authorized radioactive waste disposal site. <p>Long-lived radionuclides, sealed sources, and spent sources (such as end-of-life x-ray equipment) should be returned to the supplier when possible.</p>
Waste Electrical and Electronic Equipment (WEEE)/Radioactive waste	TB	Mobile digital x-ray equipment	If possible, should be returned to manufacturer for refurbishment, or specialist deconstruction and recycling.

HEALTH CARE WASTE CATEGORY	ASSOCIATED DISEASE	HEALTH PRODUCT DESCRIPTION	WASTE MANAGEMENT APPROACHES
Non-Health Care Waste Categories			
Municipal Solid Waste	All	General waste of the type produced by households. Often consists of food scraps (where not processed as a separate waste stream), non-recyclable plastics, packaging, non-infectious textiles, and small amounts of inorganic materials, such as stone.	Generally handled by a local government authority. In areas where government authorities are unable to provide adequate general waste management, a general waste contractor may be appointed to collect and dispose of MSW. Typically, MSW may be incinerated, landfilled, or sent to a materials recovery facility to have any recyclable content sorted from it.
	All	Uncontaminated cleaning supplies	Can be disposed of in main bins with other MSW
Recyclable waste	All	Items such as non-infectious/non-chemically contaminated glass, plastics, and metals.	In many places collected by a local government authority, or general waste contractor. May potentially be sold for a profit in some areas (where there is a market for recyclable materials).
Paper/ cardboard waste	All	Non-contaminated paper and cardboard. Recyclable in most areas.	In many places collected by a local government authority, or general waste contractor. May potentially be sold for a profit in some areas (where there is a market for recyclable materials).
	All	Stationary/printed materials	Commonly recycled at municipal scale. Should be kept separate from non-recyclable wastes to avoid cross-contamination.
WEEE	All	All electronics and electrical equipment (except for radioactive items such as x-ray machinery).	Electronics can be hazardous to the environment and should be returned to the manufacturer for disposal/recycling where possible (as in the case of certain medical/laboratory electronics) or handed off to a designated government agency or specialist contractor. Much of the world lacks access to environmentally friendly and safe WEEE disposal. WEEE specialist recyclers do exist in some countries, however. If feasible, WEEE should be exported to such a specialist. Simpler/non-laboratory WEEE can be repaired and/or donated (for instance in the case of outdated IT equipment).
	All	IT equipment	Can often be repaired, or have components replaced. Items damaged beyond potential reuse should be stored and handed off to a government-backed WEEE recycling program or specialist recycler if possible.
	TB	Coagulators, centrifuges, and audiometry equipment	If possible, should be returned to manufacturer for refurbishment, or specialist deconstruction and recycling.
WEEE/ Recyclable waste	TB	Microscopes	If possible, should be returned to manufacturer for refurbishment, or specialist deconstruction and recycling. Simple microscopes should be safe to sell for scrap/local recycling.
WEEE/Bulky waste	TB	Bio-safety cabinets, refrigerators	If possible, should be returned to manufacturer for refurbishment, or specialist deconstruction and recycling.
WEEE/Infectious waste	TB	Autoclaves	If possible, should be returned to manufacturer for refurbishment, or specialist deconstruction and recycling.
WEEE/ Radioactive waste	TB	Mobile digital x-ray equipment	If possible, should be returned to manufacturer for refurbishment, or specialist deconstruction and recycling.
Bulky waste	All	Large items of furniture and WEEE (except for radioactive items such as x-ray machinery)	May potentially be repairable or recyclable. Depends on the nature of the item. Bulky waste items are typically too large to be stored in bins, so should be kept uncontained in a secure area where possible.

Appendix C

Table C1: Typical Legislation Used to Regulate the Health Care Waste Sector

TYPES OF LEGISLATION	TYPICAL REQUIREMENTS	RELEVANT STAKEHOLDER/ENTRY POINT
Waste duty of care	Full audit trail for waste movements from production to disposal	Ministry of Environment – entry point Organizations involved in the production, transport and disposal of waste
Hazardous waste management	Hazardous waste classification and definitions outlined; Hazardous waste generators required to be registered; Full audit trail for consignment of hazardous waste	Ministry of Environment – entry point Organizations involved in the generation, transport and disposal of hazardous waste
Health care waste management	HCW classification and segregation requirements outlined; Packaging, storage, treatment and disposal requirements identified	Ministry of Health
Permitting, licensing and environmental protection requirements	Facilities that handle, treat and dispose of waste required to be licensed; Minimum requirements for protecting environment from effects of waste activities	Ministry of Environment – entry point Organizations involved in the transfer, treatment and disposal of waste
Medicine and infection control requirements	Requirement for risk assessment and level of control identified	Ministry of Health – entry point Health care facilities
Health and safety in the workplace	Minimum requirement for managing safety in the workplace are outlined; Requirement for risk assessments specified	Ministry of Works/Safety Regulator – entry point Organizations involved in the transfer, treatment and disposal of waste; health care facilities
Hazardous substance handling and classification	Hazardous substances classification and identification defined; Requirements for level of control outlined	Ministry of Works/Safety Regulator – entry point Organizations involved in the generation, collection, transfer, treatment and disposal of waste; health care facilities
Transport of dangerous goods	Appropriate packing, labelling and classification requirements identified; Training requirements specified	Ministry of Transport/Ministry of Works/Safety Executive – entry point Organizations involved in the transport of hazardous waste

Appendix D

Table D1: Waste Treatment Appraisal Summary Table

COMPARATIVE CRITERIA	AUTOCLAVE	MICROWAVE DISINFECTION	FRICTIONAL HEAT	CHEMICAL DISINFECTION (SODIUM HYPOCHLORITE)	HIGH TEMPERATURE INCINERATION	PYROLYSIS/GASIFICATION
Technological Description	<p>A waste autoclave is a form of solid waste treatment that uses heat, steam and pressure within a specifically designed metal vessel. Healthcare waste is deposited (in bins/bags) into the autoclave and air is then extracted from the vessel creating negative pressure. High temperature steam is introduced under pressure for a pre-defined period to kill the pathogens within the waste material. The lack of air and high pressure ensure the steam penetrates the material, raising the internal temperature of the waste mix.</p> <p>Temperatures within an autoclave can typically range from 121°C to 162°C with pressure sitting between 40 and 80 PSI, depending on the autoclave size and amount of material needing to be processed. Waste is typically kept at this level for between 20 to 30 minutes. Autoclaves vary significantly in size and can operate with capacities between 2 and 3,600kg/hr without shredding, and between 18 and 2,200kg/hr with shredding. Once the cycle is complete, steam is extracted from the autoclave through a series of pipes, reducing the pressure so the autoclave vessel can be opened. Once the process is complete the waste has been rendered non-infectious and is safe to dispose of alongside other non-hazardous materials.</p>	<p>Microwave treatment is a process where steam is generated using microwave energy (typically 2450 MHz with a wavelength of 12.24cm) from water contained in the waste to sterilise it. In general, microwave treatment systems consist of a treatment area or chamber into which microwave energy is directed from a microwave generator, where the waste is heated up to 100°C. The processing time and capacity is determined by the manufacturer and experience of the operators, but approximately 20 minutes per batch is typical, with hourly capacities ranging from 1.5 to 31kg/hr for batch processes, and 100 to 810 kg/hr in a continuous process. Waste is considered non-hazardous once treated and is a suitable method to treat biohazardous, infectious, sharps, and sludge waste.</p> <p>The process usually includes front-end shredding of the waste, both to increase the efficiency of the microwave treatment and to reduce the volume of the processed waste that would need to be sent for subsequent disposal. If the infeed waste is too dry, water is added, and the wet waste is then introduced to the microwave chamber. This type of treatment is an emerging technology but is rapidly becoming widely utilised.</p>	<p>This emerging treatment method uses rotor blades (typically 1000 to 2000 rpm) to shred waste material and produce frictional heat from the impact between fractions. This is usually supplemented by resistance heaters to ensure the temperature can be adjusted if required to maintain a temperature of between 135°C and 150°C for several minutes to achieve sterilization. The vapours flow through heat exchangers to condense the water, followed by a series of filters (usually activated carbon and HEPA filters) before being released to atmosphere.</p> <p>Frictional heat treatment systems range in capacity from 10 to 600 kg per hour dependent on the design specification. The cycle time varies between 30 to 50 minutes and includes the time needed for infeed of waste, frictional heat exposure, and output waste removal. Frictional heat is an emerging technology and not well established internationally.</p>	<p>This chemical-physical treatment technology disinfects infectious wastes by using the oxidising nature of sodium hypochlorite (NaOCl). The waste is fed into the system by a conveyor belt or directly into a shredder where it is cut into fractions under negative pressure conditions in an oxidizing atmosphere. The system is automated and continuously controls the chemical-physical parameters during the oxidation process (pH, temperature and conductivity) to ensure effective and safe decontamination of waste. During the oxidization process an air-aspiration system transfers all gases into a liquid chemical trap (neutralization), and then through HEPA and/or carbon filters, so there are no hazardous emissions into the atmosphere once released. No residual hazards are left on the waste after treatment as chemical disinfectants kills both microorganism and bacterial spores.</p> <p>Sodium hypochlorite treatment systems range in capacity from 23kg to 410kg per hour. However, there is limited evidence of how this technology has been effectively applied on a consistent or scaled basis to healthcare waste.</p>	<p>Dual chamber high-heat thermal incinerators (HTI) burn waste for a minimum of six hours in a primary combustion chamber above 850°C using multiple oil or gas burners. Vapours produced in the primary chamber are directed into a secondary chamber which has more burners to bring the temperature to above 1100°C required to treat the most harmful pathogens. If properly equipped, an incinerator is also capable of converting water into steam, which, in turn, can be used to generate power.</p> <p>High temperature incineration technologies can operate at capacities anywhere between 3 and 3,500 kg/hr.</p> <p>Most modern this feature flue gas treatment (dust removal, ceramics filters, cyclonic scrubbers and electrostatic precipitators) to reduce air pollution and emissions and is required in some countries under relevant national legislation. Incineration can reduce the total volume of waste requiring final disposal by up to 80%.</p>	<p>Pyrolysis is a chemical reaction that involves the molecular breakdown of larger molecules into smaller molecules by heating in the absence of oxygen. Pyrolysis of medical waste consists of heating it with an external heating source, such as electrical heaters, infrared energy, or thermal plasmas to kill thermally stable bacteria. Pyrolysis results in gasification which generates 'syngas', this is comprised of CO, H₂, CO₂, H₂O, and CH₄ and hydrocarbons.</p>
Outputs and associated considerations	<p>Aside from pre-treatment shredding, there are no physical changes in waste inputs during the process. If the waste is shredded before treatment, the waste volume can be reduced by up to 90% to produce a non-hazardous floc.</p> <p>The floc can be separated to extract recyclable components such as high-quality ferrous and non-ferrous metals and glass or sent to non-hazardous landfill for disposal.</p>	<p>Aside from pre-treatment shredding, there are no physical changes in waste inputs during the process. If the waste is shredded before treatment, the waste volume can be reduced by up to 90% to produce a non-hazardous floc.</p> <p>The floc can be separated to extract recyclable components such as high-quality ferrous and non-ferrous metals and glass or sent to non-hazardous landfill for disposal.</p>	<p>The output from frictional heat waste treatment comprises 20-25% of the original waste volume and will weigh 70-75% of the original waste mass. Due to reductions in volume and weight, the cost of disposal is likely to be lower than untreated waste.</p> <p>The process product is a Refuse Derived Fuel (RDF) or floc with a high calorific value and is dry, sterile, and finely ground. The product is safe to store on site for more than 90 days without bacterial proliferation, but is flammable, so will need careful fire risk planning.</p> <p>The floc can be separated to extract recyclable components such as high-quality ferrous and non-ferrous metals and glass or sent to non-hazardous landfill for disposal.</p>	<p>The resulting liquids from the process are released into the sewer system following appropriate treatment, while solid residues are disposed in of landfills in reduced volumes.</p> <p>Toxic chemicals, aerosols, and particulate matter can be released during the disinfection process which necessitates the use of air-pollution control systems. For liquid systems, wastes should go through a dewatering stage to remove and recycle the disinfectant.</p> <p>The treatment of healthcare wastes with chemical disinfectants can result in the release of chemical substances into the environment if those substances are not handled, stored and disposed in an environmentally sound manner.</p>	<p>Incinerator bottom ash (IBA) is the equivalent of approximately 20% of the total input volume and is the solid undestroyed waste that remains following combustion. IBA consists of unburned organic material (char), large pieces of metal, glass, ceramics, and inorganic fine particles. IBA can be collected in a quench pit beneath the burnout section of the grate.</p> <p>The disposal route for IBA is dependent on the infeed and needs to be sampled to assess its classification. If non-hazardous, this can be sent for reprocessing to extract metals. The remaining largest fraction can be used for construction as a secondary aggregate, principally as a sub-base for highways, car parks and other constructions for vehicle traffic.</p> <p>Fly ash is the solid and condensable vapor-phase matter that leaves the furnace chamber suspended in</p>	<p>The outputs produced from pyrolysis are as follows:</p> <ul style="list-style-type: none"> Gas phase: H₂, CO, CO₂, CH₄, H₂O (syngas) Solid phase: Ash, coke Liquid phase: Pyrolysis oil, water <p>The solid residues are estimated at approximately 10% of the original volume and 25% of the original weight. The solid residues would typically be disposed of in hazardous landfill.</p>

COMPARATIVE CRITERIA	AUTOCLAVE	MICROWAVE DISINFECTION	FRICTIONAL HEAT	CHEMICAL DISINFECTION (SODIUM HYPOCHLORITE)	HIGH TEMPERATURE INCINERATION	PYROLYSIS/GASIFICATION
					combustion gases and is later collected in air pollution control devices (APCDs). It is a mixture of fine particles with volatile metals and metal compounds, organic chemicals (carbon and lime), and acids condensed onto particle surfaces. Fly ash is classified as hazardous due to the lead and cadmium content. This must be disposed of in an appropriately constructed hazardous landfill, the volume produced is typically approximately 2% of the total input. Abatement pollution control (APC) residue is typically a mixture of ash, carbon and lime and is a hazardous output of the incineration process. APC residues are often a combined with fly ash into one waste stream. Scrubber water is a slurry that results from the operation of wet scrubbers and contains salts, excess caustic or lime, and contaminants (particles and condensed organic vapours) scrubbed from the flue gas.	
Track record of technology and regions of operation	Autoclaves have been used for more than a century to sterilize medical equipment, and over the last several decades they have been adapted for the treatment of healthcare waste. The healthcare waste market has been using autoclaving technologies for more than 30 years. Today, 95% of healthcare waste generated in North America is treated by steam autoclave systems.	This type of treatment is an emerging technology but is rapidly becoming widely utilised, including in low- and middle-income settings and developing countries.	Frictional heat is an emerging technology with a limited track record.	The supplier market is not well established with limited or no evidence of application on a large scale.	This technology is widely adopted in countries with developed waste management systems. Around 50% of global clinical waste treated is through incineration ⁴¹ .	The supplier market is not well established with limited evidence of application on a large scale.
Regions of operation	<ul style="list-style-type: none"> Europe North America Africa Asia (China) Australia Middle East 	<ul style="list-style-type: none"> Asia South America North America (no shredding) Africa Europe Malaysia 	<ul style="list-style-type: none"> Bosnia Egypt 	<ul style="list-style-type: none"> Morocco Europe 	<ul style="list-style-type: none"> Europe Africa Asia North America 	<ul style="list-style-type: none"> North America (on a laboratory/pilot scale) UK
Ease of installation/ construction	Autoclaves are widely used and come in a variety of sizes and configurations. They can be small enough for laboratory level disinfection, or large enough to disinfect waste and equipment for a large metropolitan hospital. Larger systems may include built in driers and shredders and can be installed in a modular fashion or as part of a bespoke design.	Systems are commercially available, and units are sold with all accessories and can be fitted by suppliers inside the area of the healthcare facility. Units can take up to one week to install and become operational. This includes the installation process and training of operators by supplier teams.	Units are modular and can be installed by technology supplier or will require fitting by site engineers.	Limited information is available on the installation of chemical treatment plants with sodium hypochlorite.	The ease of construction and installation is dependent on the size and scale of the HTI. Installation can take between two weeks and four months with flue gas treatment, dependent on the scale of the facility. Installation is simplified when flue gas treatment is not adopted and can take as little as 1-5 days.	All pyrolysis units are bespoke built, and therefore take a long time to design and install compared to the modular units available for other treatment technologies.
Ease of operation, monitoring, and maintenance	Waste bags used in autoclaves must be heat resistant and must allow steam to enter the bag. Polyethylene bags are the most widely available and can withstand a temperature of 121°C, however polypropylene bags are required for machines operating at 134°C.	The treatment process can be partially or fully continuous through from the hopper to shredder, conveyor screw, steam generator, microwave generators, discharge screw and controls in a typical system using hydraulics. Units with an integrated rotor blade shredder last between 800 and 1000 cycles with	Some technologies are mainly automatic, only requiring the operator to load and unload the chamber. <u>Drawbacks</u> Mechanical faults more likely due to internal moving parts, leading to	The system automatically controls chemical-physical parameters during the oxidation process (pH, temperature and conductivity), so no live manual monitoring is required. For a small chemical treatment unit, daily and weekly preventive	Operation within the key parameters of the combustion process are monitored by computer controls. These systems make automatic adjustments to key functions as necessary. <u>Drawbacks</u>	The technology is mainly automatic and does not require any pre-treatment. <u>Drawbacks</u>

⁴¹ Zhao et al., (2009) Comparative life cycle assessments of incineration and non-incineration treatments for medical waste [online]. Available at: [Comparative life cycle assessments of incineration and non-incineration treatments for medical waste | SpringerLink](#). Accessed August 2022.

COMPARATIVE CRITERIA	AUTOCLAVE	MICROWAVE DISINFECTION	FRICTIONAL HEAT	CHEMICAL DISINFECTION (SODIUM HYPOCHLORITE)	HIGH TEMPERATURE INCINERATION	PYROLYSIS/GASIFICATION
	<p>There are no specific pollutant emission limits to adhere to for hybrid autoclaves due to the technology's low emissions.</p> <p>Autoclaves can range in operational requirements, from fully automatic systems with touch screens or PLC/microprocessors, as well as semi-automatic and manual sections.</p> <p>Autoclaves require daily and weekly checks, to ensure safe and efficient operation.</p> <p><u>Drawbacks</u> If shredding is incorporated in the process, bulky items should not be treated in this way. Materials such as glass can reduce the operational life of the blades, which will require sharpening/replacing.</p>	<p>proper use. Cost of replacement is approximately \$300.</p> <p><u>Drawbacks</u> If shredding is incorporated in the process, bulky items should not be treated in this way. It should be noted that materials such as glass can reduce the operational life of the blades, which will require sharpening or replacing.</p> <p>If the operational conditions of the equipment are not adequately controlled, the inactivation treatment is ineffective. Without tight control of parameters, in particular moisture, a complete inactivation can never be guaranteed with microwave technologies.</p>	<p>downtime and possible waste build up. Bulky items should not be treated in this way, so some level of sorting is required from operational staff. Materials such as glass can reduce the operational life of the blades, which will require sharpening/ replacing.</p>	<p>maintenance takes approximately 5-10 minutes.</p> <p><u>Drawbacks</u> Sodium hypochlorite is a strong oxidizer and oxidation reactions are corrosive. Solutions burn the skin and cause eye damage, especially when used in concentrated forms. The system must therefore be enclosed and automated. If shredding is incorporated in the process, bulky items should not be treated in this way. Materials such as glass can reduce the operational life of the blades, which will require sharpening/ replacing.</p>	<p>The emissions from the process require strict controls, as the process produces toxic and carcinogenic substances such as dioxins, polychlorinated biphenyls, polycyclic aromatic compounds, and harmful gases (HCl, HF, SO₂). In most low- and middle-income countries, few laboratories are available to analyse dioxin and furans, so performance cannot easily be monitored.</p>	<p>Frequent maintenance is required to ensure proper functioning of the equipment.</p> <p>The efficiency of pyrolysis can be affected by the moisture content, volume and consistency of the infeed material.</p>
Types of waste suitable for treatment	<ul style="list-style-type: none"> • Infectious • Sharps 	<ul style="list-style-type: none"> • Infectious • Pathological • Sharps 	<ul style="list-style-type: none"> • Infectious • Pathological • Sharps 	<ul style="list-style-type: none"> • Infectious • Pathological • Sharps 	<ul style="list-style-type: none"> • Infectious • Pathological • Sharps • Chemical • Pharmaceutical • Cytotoxic & Cytostatic 	<ul style="list-style-type: none"> • Infectious • Pathological • Sharps
Indicative OPEX	0.14-0.33USD/kg	Batch - 0.13 USD/kg Continuous - 0.15USD/kg	>0.13 USD/kg	0.12-0.52 USD/kg	0.27-1.6 USD/kg	0.27-1.6 USD/kg
Indicative capacity range of at hospital scale (per unit)	2 to 3,600 kg/hr (without shredder), 18 to 2,200 kg/hr (with shredder)	1.5 to 31 kg/hr (batch), 100 to 810 kg/hr (continuous)	10 to 1,500 kg/hr	23 to 410 kg/hr	5 to 3,500 kg/hr	unknown
Installation requirements	<ul style="list-style-type: none"> • Electricity: 400 Volt • Water connection • High quality water for steam generation (soft water or demineralised water) • Wastewater connection • Compressed air 	<ul style="list-style-type: none"> • Electricity: 400 Volt for batch processing (smaller units may require 220/2230/240 Volt), 380/400 Volt for continuous processing • Enclosure and foundation • Electrical connections • Water/steam supply • Drainage • Ventilation • Water softening system 	<ul style="list-style-type: none"> • Electricity: 400 Volt – 50Hz • Foundation • Reliable electrical connections • Water supply • Drain for wastewater discharge • Exhaust vent for vapor discharge 	<ul style="list-style-type: none"> • Adequate floor space and foundation • Electricity: 380/400 Volt • Water supply • Drain to the sanitary sewer • Ventilation possibly including local exhaust ventilation • Separate well-ventilated area for chemical storage • Eyewash station, sink, and safety shower as needed; storage area for personal protection equipment" 	<ul style="list-style-type: none"> • Heavy-duty all welded construction with high strength, durable high temperature refractory lining • Fully automated electrical controls • Single batch or continuous waste loading • Maybe in vertical or horizontal design, plus modular construction for easy installation • Full swing combustion chamber door for total access 	<p>Pyrolysis treatment is always bespoke built and therefore can be designed to integrate into allocated space for waste treatment.</p>