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Executive Summary

The Lebanese Healthcare Waste Baseline report employs a comprehensive approach, blending quantitative and qualitative methods to establish an effective and sustainable waste management system. The adopted methodology includes literature review, data analysis, interviews, service provider engagement, waste generation assessment, policy analysis, and technological review.

Estimates indicate that infectious waste generation is 7,255 tons per year from hospitals and 4,941 tons from small generators. Cytotoxic and pharmaceutical waste production amounts to approximately 275 tons annually. Additionally, large hospitals generate around 300 kg/year of short-lived radioactive waste. Key service providers, such as arcenciel, Abbasiyeh, and AWM, play crucial roles in infectious waste collection. However, the treatment capacity of 6,808 tons annually by arcenciel and Abbasiyeh falls short of the estimated annual generation of 12,194 tons.

Lebanon utilizes steam and microwave sterilization methods, effectively reducing infectious waste weight by 20% and volume by 25%. The treated waste from arcenciel centers annually amounts to 3,867 tons. Challenges persist, including improper disposal of hazardous waste in MSW streams and legal hurdles for on-site incineration. Companies like Solution, Treveria, RECYCLAMED, and BlackForest Solutions manage hazardous waste, but the high compliance costs pose accessibility challenges for healthcare facilities.

The inactive incinerator at Rafik Hariri University Hospital, approved in 2005, raises environmental concerns. A key limitation of the current incinerator is its inability to achieve the necessary operational temperatures, reaching only up to 1000°C, below the 1200°C required for the complete destruction of cytotoxic substances. Pharmaceutical waste, particularly cytotoxic substances, faces obstacles due to limited affordable export services.

In healthcare, short-lived radioactive waste is stored until radioactivity decreases, while long-lived waste is temporarily stored before export. The LAEC oversees disposal with a “delay and decay” strategy, ensuring adherence to safety regulations.

Therefore, it is imperative to develop and implement a series of strategic initiatives to enhance the efficiency and effectiveness of healthcare waste management across the nation such as updating the regulatory framework, expanding infectious waste treatment capacities, creating a system for small generators, managing specific hazardous waste types, establishing an integrated data system, and developing sustainable financing schemes.
HEALTHCARE WASTE BASELINE

01 INTRODUCTION
1. INTRODUCTION

The Lebanese Healthcare Waste Baseline report is an in-depth exploration and critical analysis of healthcare waste management in Lebanon. This document serves as a crucial resource for understanding the current state, challenges, and opportunities within the sector. It aims to systematically quantify the waste produced by healthcare facilities, assess the existing management practices, in order to enhance the overall waste management practices.

A key objective of this report is to facilitate the development of a sustainable, efficient, and globally compliant healthcare waste management system in Lebanon, tailored to meet the unique local needs and conditions. To achieve this, the report delves into a comprehensive examination of various critical dimensions, including the physical and the governance components looking into the regulatory frameworks governing waste management, current practices in waste handling and disposal, infrastructure capabilities, and the role and engagement of stakeholders at multiple levels.

The scope of this analysis is broad, encompassing a detailed review of the aspects to provide a holistic view of the healthcare waste management in Lebanon. However, it is important to acknowledge certain limitations including constraints related to data availability, the dynamic nature of the healthcare sector in Lebanon which is subject to rapid changes, and the complex socio-political environment that could potentially affect policy implementation and operational effectiveness. The purpose of a baseline in the waste management planning methodology is not to suggest solutions or discuss changes, as those are to be designed in a masterplan relying on this baseline. Yet, the Baseline is a comprehensive document that assemble the complete parts of what exists today in a waste system, including observations on governance, legislative framework, economy as well as physical components such as existing facilities and processes. This baseline describes healthcare waste production schemes as well and its evolution, for all waste parts.

Through this report, the aim is to provide foundational understanding of the status of the system. The ultimate goal is to support the creation of a robust system that not only adheres to international standards but also addresses the specific challenges and needs of the Lebanese context.

The overall improvement that should be targeted after analysing this baseline and designing the master plan include amelioration of existing infrastructure to include all quantities and typologies of healthcare waste, as well as governance improvement and organizational management.
HEALTHCARE WASTE
BASELINE

02
METHODOLOGY
2. METHODOLOGY

The methodology for preparing a healthcare waste management baseline in Lebanon is a complete process that incorporates a blend of both quantitative and qualitative research methods to ensure a comprehensive understanding of the current situation. The approach includes:

- **Review of Existing Literature and Documents:** This involves a thorough examination of existing literature, policy documents, and regulatory guidelines relevant to healthcare waste management in Lebanon and globally. It provides a background understanding and identifies gaps in the current data.

- **Quantitative Data Analysis:** Analysis of quantitative data derived from healthcare facilities, waste management services, and government reports. This helps in understanding the volume, composition, and disposal methods of healthcare waste in Lebanon.

- **Qualitative Insights through Interviews and Surveys:** Conducting interviews and surveys with healthcare professionals, waste management experts, policymakers, and community representatives to gather qualitative data on practices, perceptions, and challenges in healthcare waste management.

- **Interviews with Service Providers:** Engaging with healthcare waste management service providers to update and verify existing information and to understand their operational challenges and innovations.

- **Assessment of Waste Generation Changes:** Conducting interviews with generators of healthcare waste (like hospitals and clinics) to assess any changes in waste generation patterns, which can inform the development of more tailored waste management strategies.

- **Policy and Regulatory Framework Analysis:** Evaluating the existing policy and regulatory frameworks governing healthcare waste management in Lebanon.

- **Technological Assessment:** Reviewing current technologies used in healthcare waste management in Lebanon.

This comprehensive methodology aims to provide a detailed and accurate baseline of healthcare waste management in Lebanon, serving as a foundation for informed decision-making and strategic planning in this critical sector.
HEALTHCARE WASTE
BASELINE

03

HEALTHCARE SECTOR IN LEBANON
3. HEALTHCARE SECTOR IN LEBANON

The healthcare sector in Lebanon presents a complex picture, shaped significantly by the country’s ongoing economic crisis and political instability. Historically recognized for its high-quality medical services, the sector is a mix of public and private entities, with a strong leaning towards private healthcare. However, the economic crisis has deeply affected this sector, leading to funding shortages, equipment and medication scarcities, and a decline in service quality, especially in public hospitals that serve a large portion of the less privileged population.

In response to these challenges, there has been a notable shift in the population’s reliance from hospitals to smaller, more affordable medical facilities such as dispensaries, clinics, and local health centers. These facilities, often run by NGOs or community organizations, have become crucial in providing basic healthcare services, particularly in underserved areas. They offer primary care, routine check-ups, and vaccinations, addressing the needs of lower-income groups.

The sector’s challenges extend to the management of healthcare waste, a critical yet often overlooked aspect. The efficient segregation and disposal of waste have been compromised, leading to the mixing of hazardous and non-hazardous waste and increasing the complexity and cost of waste treatment. The lack of specialized waste treatment facilities means that a significant portion of healthcare waste is improperly disposed of, posing environmental and public health risks.

Various critical factors underscore the influence of healthcare waste on public health:

- Healthcare waste frequently comprises materials contaminated with pathogens, such as used needles, bandages, and tissues from infected patients. Inadequate disposal or mishandling of these materials escalates the potential for infectious disease transmission, presenting risks to healthcare workers, waste handlers, and the public.

- Specific healthcare waste types of harbor hazardous chemicals, encompassing pharmaceuticals, disinfectants, and other toxic substances. Improper disposal may lead to the release of these chemicals into the environment, culminating in soil and water contamination. Human exposure to such substances can result in adverse health effects, including chronic ailments and developmental issues.

- Improper disposal practices concerning used needles and sharp objects can lead to needlestick injuries among waste handlers, healthcare professionals, and the public. These injuries can facilitate the transmission of bloodborne pathogens, such as HIV, hepatitis B, and hepatitis C.

- Incineration, a prevalent healthcare waste disposal method in certain regions, emits deleterious pollutants into the air, including dioxins, furans, and other toxic substances. Prolonged exposure to these pollutants can induce respiratory and other health impacts on neighboring communities.

- Inadequate disposal of pharmaceutical waste, encompassing antibiotics and medications, can contribute to the emergence of antibiotic resistance in the environment. This poses a substantial public health concern, potentially compromising the effectiveness of antibiotics and complicating the management of bacterial infections.

- Thermal injuries associated with open burning and the operation of medical waste incinerators, alongside the risk of radiation burns, underscore the hazards associated with improper healthcare waste management.
Furthermore, Lebanon’s healthcare sector includes a network of laboratories and specialized medical centers that play a vital role in diagnostics and treatment.

The resilience of the Lebanese healthcare sector is evident in its continued provision of services despite these challenges. However, it is evident that comprehensive reforms and investments are essential to ensure sustainable and equitable healthcare. Such efforts must address the disparities in healthcare access, the need for infrastructure improvement, the enhancement of waste management practices, and the stabilization of the workforce to secure a robust healthcare system for all citizens of Lebanon.

This overview of the Lebanese healthcare sector is critical for understanding the healthcare waste baseline in the country. The increasing dependence on smaller healthcare facilities has direct implications for healthcare waste management. These facilities may not have adequate infrastructure and protocols for effective waste segregation and disposal, leading to heightened risks of improper waste handling. The operational and resource challenges in laboratories and medical centers could result in inefficient waste management practices, complicating the healthcare waste management landscape.

Acknowledging the operational dynamics and limitations of these healthcare providers is essential in developing effective waste management strategies. This knowledge underscores the necessity for waste management solutions that cater to the specific needs and capabilities of various healthcare facilities. It also helps identify crucial intervention areas, such as enhancing waste segregation practices, improving waste treatment and disposal infrastructure, and providing specialized waste management training for healthcare workers. This comprehensive understanding is indispensable for establishing a realistic and effective healthcare waste baseline in Lebanon, which is vital for ensuring environmental safety and protecting public health.
HEALTHCARE WASTE
BASELINE

04

HEALTHCARE WASTE: AN OVERVIEW
4. HEALTHCARE WASTE: AN OVERVIEW

4.1 Healthcare Waste Streams

Global health and environmental agencies, including the WHO, EU, and the US EPA, have established comprehensive guidelines for handling healthcare waste. These guidelines encompass a range of strategies and protocols. Classification Systems play a crucial role in efficiently managing waste by categorizing it into various types for better handling and treatment.

Healthcare waste internationally encompasses items discarded from healthcare facilities that may carry harmful microorganisms or chemicals. This includes waste contaminated with blood, body fluids, or other hazardous substances that pose risks to public health and the environment.

Approximately 80% of healthcare waste is non-hazardous, resembling typical municipal waste. This category, which includes general waste from administrative and maintenance activities, does not pose direct threats to health or the environment and can be disposed of like household waste.

The remaining 20% is considered hazardous due to its potential harmful effects upon exposure. This primarily includes waste from hospitals and clinics, especially those providing acute services like surgery, maternity care, emergency services, mortuaries, intensive care, isolation wards, pharmacies, pathology labs, and other research facilities.

Figure 1 provides an overview of the healthcare waste types.
Infectious waste forms a major part of hazardous healthcare waste. Also known as biomedical waste, this includes materials contaminated with blood or body fluids that contain pathogens. It encompasses various items like medical equipment, biological fluids, culture media, anatomical pieces, and waste from isolation units. Such waste often originates from areas dealing with infectious diseases, surgeries, or laboratories. The handling of infectious waste is critical, as it poses a significant risk of disease transmission if not properly managed.

Another critical type is cytotoxic waste, which is predominantly associated with cancer treatment drugs. It contains genotoxic properties (cancer-causing, mutagenic, or teratogenic). It includes contaminated equipment, expired medications, and patient excretions. These substances are known for their genotoxic properties, meaning they can damage or mutate genes, posing serious health risks to those exposed to them. Cytotoxic waste management is crucial in oncology departments, where these drugs are frequently used.

Pharmaceutical waste is a diverse category, encompassing expired, unused, or leftover medications. The disposal of pharmaceuticals requires careful consideration to prevent environmental contamination and misuse. This type of waste is not limited to hospitals; it also arises in pharmacies, nursing homes, and even households.

Chemical waste in healthcare settings can include a range of hazardous chemicals like formaldehyde, used for preserving biological specimens, and various chemical solvents. The risks associated with chemical waste include toxicity, flammability, and corrosive properties, necessitating stringent handling and disposal protocols.

Lastly, radioactive waste, though less common, is a significant concern in healthcare settings that utilize radioactive materials for diagnosis and therapy, such as in radiology departments and cancer treatment centers. It contains radionuclides used in diagnostics and therapy. It’s categorized by its lifespan and can include sealed sources (encapsulated radioactive substances) and unsealed sources. The management of radioactive waste requires special protocols to ensure safe handling and to prevent radiation exposure.

Each of these types of hazardous healthcare waste requires specific management strategies to mitigate their unique risks. The environmental risks inherent in these waste categories are outlined below:

- **Infectious Waste**: Improper treatment of infectious waste poses a significant risk of disease dissemination, with additional concerns for the dispersion of pathogens during incineration and landfill disposal. This mismanagement results in the pollution of air, water, and land, creating a potential threat to public health and the environment.
• **Chemical Waste:** Inadequate disposal of chemical waste leads to extensive soil and water contamination, adversely impacting ecosystems and human health. The release of hazardous substances poses grave consequences, including the destruction of organisms in aquatic environments, harm to local flora and fauna, reproductive complications, and a threat to the overall survival of ecosystems.

• **Pharmaceutical Waste:** The disposal of pharmaceutical waste contributes to antibiotic resistance and water contamination, raising concerns about pollutant release during incineration and flushing. The environmental repercussions extend to wildlife, climate change, and potential damage to ecosystems and communities, as these substances leach into landfills and waterways.

• **Radioactive Waste:** Improper disposal of radioactive waste results in soil and water contamination, necessitating secure containment to prevent radiation exposure. The environmental hazards associated with radioactive waste include threats to agricultural land, fishing waters, and freshwater sources, posing risks to both ecosystems and human health.

• **Cytotoxic Waste:** Cytotoxic waste, characterized by drugs that inhibit cell growth and division, can have adverse effects on the ecosystem when released into the environment. The consequences involve altered fertility and increase genetic defects, with potential environmental hazards manifesting as growth inhibition and DNA damage in affected areas.

The diversity and potential hazards of healthcare waste highlight the need for comprehensive waste management practices tailored to each waste category, ensuring the safety of healthcare workers, patients, and the broader community.

### 4.2 Healthcare Waste Origins

Understanding the diverse sources and characteristics of healthcare waste is crucial for its effective management. This range of waste, originating from various healthcare environments, presents unique challenges in each setting. The main generators of healthcare waste are shown in Figure 2.

![Figure 2. Generators of Healthcare Waste](image)
Hospitals, both public and private, stand as significant contributors. They generate a high volume of waste, encompassing a broad spectrum from general waste like paper and plastics to more specialized forms including chemicals and radioactive materials. Public hospitals, oft produce considerable quantities of diverse waste. This includes high-risk items such as infectious waste from surgeries or chemotherapy. Private hospitals, while having a similar waste profile, tend to have more resources for managing waste.

Moving to clinics and dispensaries, which include Primary Health Care Centers (PHCCs), humanitarian aid stations, and army clinics, the scenario changes. These facilities typically generate moderate volumes of general waste and specialized items like sharps and infectious waste. PHCCs often lack advanced waste management systems. In contrast, humanitarian aid and army clinics, which operate in crisis situations, need to manage varying amounts of waste efficiently and rapidly, often under temporary and resource-constrained conditions.

Laboratories add another dimension to healthcare waste. They contribute a specialized stream, including not only infectious material but also chemical and sometimes even radioactive waste. Although their volumes are moderate, the high risks associated with the improper handling of these materials cannot be underestimated.

Dental clinics and laboratories present a unique challenge with the quantity of infectious waste generated. Additionally, commercial settings like tattoo and beauty centers, while generating lower volumes of waste, produce high-risk waste like sharps. If not managed properly, this waste could lead to cross-contamination.

Lastly, veterinary clinics contribute to the healthcare waste spectrum with their moderate to low volumes of specialized waste, such as animal tissues and pharmaceutical waste. This adds another layer of complexity to the overall healthcare waste management system.

Each healthcare environment contributes distinctively to the overall healthcare waste stream, with variations in volume and types of waste. The management of this waste requires strategies tailored to the specific challenges and risks of each source. This understanding is essential for developing effective and sustainable healthcare waste management systems.
CURRENT STATUS OF THE HEALTHCARE WASTE MANAGEMENT: A BASELINE ANALYSIS
5. CURRENT STATUS OF THE HEALTHCARE WASTE MANAGEMENT: A BASELINE ANALYSIS

A comprehensive baseline analysis serves as the grounds for understanding the effectiveness of Lebanon’s healthcare waste management system and development of a comprehensive masterplan. Figure 3 from the WasteAware methodology presents the main pillars of an integrated waste management system where the ‘Physical’ infrastructure and ‘Governance’ mechanisms are both fundamental and complementary.

![Figure 3. Elements of the ISWM framework are represented by two overlapping triangles comprising the physical and governance components. Figure reproduced from Wilson et al. (David C. Wilson, 2015)](image)

Building on the foundational concepts outlined in the WasteAware methodology, the comprehensive baseline analysis of Lebanon’s healthcare waste management system reveals the link between physical infrastructure and governance mechanisms. According to the WasteAware indicators, an integrated waste management system thrives on the synergy between these two core pillars.

The physical components of healthcare waste management encompass the tangible elements required for handling waste. This includes the healthcare facilities generating waste, the equipment and technologies for collection, treatment, and disposal, and the infrastructure for transporting and storing waste. These physical assets are fundamental because they directly impact the efficiency and effectiveness of waste management. For instance, adequate and well-maintained equipment ensures safe and hygienic handling of waste, while properly designed treatment facilities reduce environmental contamination. The assessment of existing infrastructure underlines areas for development, such as the need for more advanced treatment technologies or expanded storage capacities, vital for handling increasing volumes of healthcare waste.

Parallel to the physical components, governance mechanisms play a pivotal role. This involves not just the establishment of policies and regulations but also their effective implementation and enforcement. Governance in healthcare waste management includes a legal analysis to ensure compliance with national and international regulations, stakeholder mapping to understand the roles and influence of different actors, and delineating service zones for efficient waste collection and treatment. Financial schemes and cost recovery strategies are also a part of this governance...
framework, ensuring the system’s economic viability. These components are crucial as they dictate how well the physical infrastructure operates within the legal, social, and economic contexts. Good governance ensures that the infrastructure is used to its fullest potential and that the system is equitable, sustainable, and adaptable to future needs.

The interplay between the physical and governance aspects cannot be overstated. A robust physical infrastructure without effective governance can lead to inefficiencies, such as underutilized facilities or non-compliance with safety standards. Conversely, strong governance without adequate physical infrastructure may lead to policies and regulations that are impractical or impossible to implement. The success of Lebanon’s healthcare waste management system hinges on this synergy. An integrated approach, where both physical and governance components are given equal importance and developed in tandem, is key to building a system that not only addresses current waste management challenges but is also resilient and adaptable to future developments.

The baseline analysis, therefore, offers a comprehensive overview of the sector’s current state, the analysis sets the stage for the development of a masterplan that is both robust and flexible, capable of addressing the current needs while being adaptable to future challenges in Lebanon’s healthcare waste management.

5.1 Governance

5.1.1 Legal Analysis

The management of healthcare waste (HCW) in Lebanon has been a significant environmental and public health concern. Improper disposal methods, such as open burning and unregulated dumping, have historically led to serious environmental pollution and increased health risks. The legal framework for HCW in Lebanon has evolved over time to address these challenges, with a focus on sustainable management practices and adherence to international environmental standards.

The legal framework for HCW began to take shape with the enactment of Law 444 in 2002, which laid the groundwork for environmental protection in Lebanon. Subsequent decrees, including Decrees 8006 and 13389, provided further clarity and guidelines for the classification, treatment, and disposal of HCW. In 2018, the Integrated Solid Waste Management Policy introduced a more comprehensive approach, emphasizing principles such as the polluter pays principle, administrative decentralization, and the promotion of a circular economy.

Decree 5606 of 2019 stands out as a key legislative text in the HCW management framework. This decree outlines specific management principles for hazardous waste, including segregation, storage, transportation, and disposal. It also establishes the responsibilities of various stakeholders in the HCW management chain, from generators to disposal facilities.

Table 1 provides an overview of all the legal texts related to the HCWM in Lebanon.
Table 1. Overview of All the Legal Texts Related to the HCWM in Lebanon.

<table>
<thead>
<tr>
<th>Legal text</th>
<th>Issuing entity</th>
<th>Title/Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decree 9826/1962</td>
<td>Council of Ministers (COM)</td>
<td>Decree related to private hospitals.</td>
</tr>
<tr>
<td>Decree-law 105/1983</td>
<td>COM</td>
<td>Regulation of the use and protection from ionizing radiation</td>
</tr>
<tr>
<td>Decree 4917/1994</td>
<td>COM</td>
<td>Classification of establishments with hazardous activities or with impacts/harm on health</td>
</tr>
<tr>
<td>Decree 5234/2001</td>
<td>COM</td>
<td>The Classification of Industrial Establishments</td>
</tr>
<tr>
<td>Decree 8006/2002 amended through the decree 13389/2004</td>
<td>COM</td>
<td>Classifying the different healthcare waste categories and addressing their relative disposal condition</td>
</tr>
<tr>
<td>Decree 8018/2002</td>
<td>COM</td>
<td>Determination of the Permitting Essentials, Procedures &amp; Conditions to establish and exploit factories or industrial establishments or enterprises</td>
</tr>
<tr>
<td>Decree 9765/2003</td>
<td>COM</td>
<td>Inspection, measures, and sanctions applied against industrial establishments.</td>
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<tr>
<td>Decree 15512/2005</td>
<td>COM</td>
<td>Application Decree of Legislative Decree No. 105/83 of 6/9/1983 (Regulating the Use and Protection from Ionizing Radiation</td>
</tr>
<tr>
<td>Decree 2275/2009</td>
<td>COM</td>
<td>Regulating units of the Ministry of Environment and defining their functions and terms of appointment</td>
</tr>
<tr>
<td>Decree 5606/2019</td>
<td>MOE</td>
<td>Hazardous Waste Management</td>
</tr>
<tr>
<td>Law 64/1988</td>
<td>Parliament</td>
<td>The Law of Environmental Preservation Against Harmful and Hazardous Substances and Waste</td>
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<tr>
<td>Law 642/1997</td>
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<td>Law 546/2003</td>
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<td>Legal text</td>
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<td>Title/Content</td>
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<td>Law 690/2005</td>
<td>Parliament</td>
<td>Regulating the Ministry of Environment and defining its tasks and mandates</td>
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<td>The ratification of Minamata Convention on mercury</td>
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<td>Law 48/2017</td>
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<td>Regulating Public-Private Partnerships</td>
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<td>Law 80/2018</td>
<td>Parliament</td>
<td>Integrated Solid Waste Management</td>
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<td>Decision No.52/1/1996</td>
<td>MOE</td>
<td>Standards and Limits for the Prevention of Air, Water and Soil Pollution</td>
</tr>
<tr>
<td>Decision No.8/1/2001</td>
<td>MOE</td>
<td>The Classification of Industrial Establishments</td>
</tr>
<tr>
<td>Decision No.422/1/2009</td>
<td>MOPH</td>
<td>This decision supersedes and replaces the decision 35/1 (1985) and sets the standards for Good Manufacturing Practices (GMPs) of pharmaceuticals</td>
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<tr>
<td>Decision No.482/2009</td>
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<td>Decision No.45/2018</td>
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<td>Decision No.998/1/2020</td>
<td>MOE</td>
<td>Procedures and principles for hazardous waste generators in Lebanon</td>
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<td>Circular No.11/1/2011</td>
<td>MOE</td>
<td>Defines the trimestral reporting template for Infectious Healthcare Waste Treatment facilities</td>
</tr>
<tr>
<td>Circular No.7/1/2017</td>
<td>MOE</td>
<td>Guidelines relating to the integrated management of domestic waste for municipalities, unions of municipalities, Qaemmaqams and Governors. This circular provides a list of establishments for potential recycling of material and equipment</td>
</tr>
<tr>
<td>Circular No.7/1/2019</td>
<td>MOE</td>
<td>WWTP in private establishments. This circular requires the submission of periodic reports on self-monitoring as stipulated in Article 46 of Law No. 444 of 2002 for wastewater treatment plants produced by private institutions</td>
</tr>
</tbody>
</table>

On the other hand, Lebanon’s commitment to HCW management is also evident in its ratification of international conventions including the Barcelona, Stockholm, Basel, Minamata, and Rotterdam Conventions, each having implications for healthcare waste management. These conventions set international standards for the management of hazardous wastes and organic pollutants, requiring Lebanon to adopt measures to reduce or eliminate the release of these substances.
The Basel Convention, signed in 1989 and ratified in 1995, governs the control of transboundary movements of hazardous wastes, including clinical waste from healthcare facilities and pharmaceutical waste. It categorizes infectious substances as hazardous materials containing viable microorganisms or toxins potentially harmful to humans and animals. By ratifying this convention, Lebanon agreed to regulate the movement of these materials and seek approvals for their transit through other countries.

The Stockholm Convention on Persistent Organic Pollutants, signed in 2001 and ratified in 2004, aims to limit the impact of these pollutants on health and the environment. This is particularly relevant for healthcare waste management methods like incineration, which can produce such pollutants. Under the convention, Lebanon is required to implement best environmental practices to reduce or eliminate the release of these pollutants within four years of ratification.

Moreover, the Minamata Convention on Mercury, ratified in 2017, addresses the risks posed by mercury in healthcare waste, such as in thermometers. The convention emphasizes the development of strategies for managing mercury-containing waste, ensuring its safe storage, transport, treatment, and disposal. Adherence to the convention is essential for Lebanon to manage mercury-containing healthcare waste effectively, thereby minimizing mercury release into the environment and safeguarding public health and ecosystems.

While Lebanon has established a robust legal framework for HCW management, enforcing compliance remains a significant challenge. Issues such as limited resources, inadequate infrastructure, and the need for more effective monitoring and enforcement mechanisms are prevalent. This section will analyze these challenges in depth, focusing on the Ministry of Environment’s role in enforcement and the need for stronger institutional capacity.

Several important legal texts related to HCW management are still pending issuance. These include decrees and decisions under Law 444 and Law 80, which are crucial for further refining the HCW management framework.

5.1.2 Stakeholder Mapping

To provide a structured overview of the complex healthcare waste management sector in Lebanon, a detailed stakeholder mapping has been conducted. This mapping identifies key entities and outlines their respective roles and responsibilities within this sector. Table 2 serves as a comprehensive guide, summarizing the main elements of the stakeholder mapping. It categorizes stakeholders into governmental institutions, donor organizations, service providers, academic bodies, and other relevant groups, offering a clear insight into the multifaceted nature of healthcare waste management in Lebanon.
### Table 2. Stakeholder Mapping

<table>
<thead>
<tr>
<th>Stakeholder/Entity</th>
<th>Roles and Responsibilities</th>
</tr>
</thead>
</table>
| **Governmental Institutions and Syndicates** | - Setting environmental policies, plans, strategies  
- Drafting laws, standards, and environmental assessments  
- Issuing permits for waste treatment and disposal  
- Reviewing healthcare waste reports and approving hazardous substance imports  
- Classifying healthcare waste and setting disposal conditions |
| **Ministry of Public Health** | - Drafting laws for healthcare sector  
- Licensing waste treatment facilities  
- Setting healthcare waste management practices and accreditation systems for hospitals  
- Supervising waste disposal through the Sanitary Engineering Department |
| **Ministry of Justice** | - Appointing environmental prosecutors |
| **Ministry of Industry** | - Issuing licenses for healthcare waste facilities  
- Conducting inspections of industrial establishments |
| **Health Sector Unions** | - Overseeing waste generators’ capabilities  
- Training on waste segregation  
- Facilitating waste export through MOUs |
| **Council for Development and Reconstruction (CDR)** | - Managing development projects  
- Advising Council of Ministers  
- Proposing related laws  
- Planning public infrastructure |
| **Ministry of Interior Affairs and Municipalities** | - Monitoring healthcare waste management  
- Issuing construction permits for waste management facilities |
| **Directorate General of Urban Planning** | - Approving construction activities for healthcare waste  
- Ensuring compliance with construction laws and regulations |
<table>
<thead>
<tr>
<th>Stakeholder/Entity</th>
<th>Roles and Responsibilities</th>
</tr>
</thead>
</table>
| Order of Engineers and Architects (OEA) | - Overseeing industrial construction activities  
- Issuing construction and occupancy permits |
| High Council for Privatization | - Overseeing Public-Private Partnership contracts |
| Lebanese Atomic Energy Commission (LAEC) | - Overseeing radioactive material management  
- Formulating and enforcing regulations  
- Issuing licenses and conducting inspections  
- Collaborating with international organizations |
| European Union Delegation to Lebanon | - Funding waste management projects  
- Emphasizing assessments and research |
| World Health Organization (WHO) | - Assisting health authorities  
- Strengthening health services and infection control measures |
| UN Agencies | - Providing resources and expertise  
- Enhancing waste management capacity |
| Agence Française du Development (AFD) | - Collaborating with stakeholders  
- Developing sanitation services and governance mechanisms |
| World Bank | - Financial support for waste management project  
- Encouraging recycling and reducing emissions |
| Healthcare Waste Generators | - Generating, segregating, packaging, and storing waste  
- Includes hospitals, clinics, laboratories, pharmacies, and other healthcare-related facilities |
| Healthcare Waste Service Providers | - NGOs, municipalities, and private sector involved in waste management.  
- Collection, treatment, and disposal of healthcare waste  
- Some service providers: arcenciel, Abbasiyeh Facility, AWM, Recyclamed |
| Academics and Research Entities | - Providing laboratory services  
- Engaging in waste management research and initiatives  
- Institutions include USJ, LAU, AUB, Balamand University |
Stakeholder/Entity | Roles and Responsibilities
--- | ---
General Public, Staff, and Patients | - Affected by healthcare waste management.  
- Staff required to be knowledgeable about waste management and safety.  
- Patients potentially impacted by waste-related hazards

Opinion Formers | - Media and CSOs raising awareness.  
- Residents educated on waste disposal.  
- Pharmaceutical companies and medical suppliers aiding in waste minimization.  
- Healthcare professionals responsible for waste segregation and infection control training

The stakeholders as per Table 2 can be categorized into three different categories:

- **Primary Stakeholders**: These are stakeholders with high interest and significant influence. They are directly affected by healthcare waste management policies and decisions.

  - Governmental Institutions and Syndicates: Key entities in setting policies, standards, and laws, and in overseeing and regulating healthcare waste management. This includes the Ministry of Environment, Ministry of Public Health, Ministry of Justice, Ministry of Industry, Ministry of Interior Affairs and Municipalities, and the Lebanese Atomic Energy Commission (LAEC).

  - Healthcare Waste Generators: These include hospitals, clinics, laboratories, pharmacies, and other healthcare-related facilities directly involved in generating, segregating, packaging, and storing waste. Their operations are directly impacted by healthcare waste management policies.

  - Healthcare Waste Service Providers: Including NGOs, municipalities, and private sectors involved in waste management, they play a role in the collection, treatment, and disposal of healthcare waste.

- **Potentially Active (Secondary) Stakeholders**: This category includes stakeholders likely to have some influence and/or an indirect interest in healthcare waste management. They might not be directly involved but can affect or be affected by the decisions made.

  - Donor Organizations and International Bodies: These stakeholders, such as the European Union Delegation to Lebanon, WHO, UN Agencies, Agence Française du Development (AFD), and the
World Bank, provide resources, expertise, and financial support. They have influence and an indirect interest in healthcare waste management.

- Council for Development and Reconstruction (CDR), Directorate General of Urban Planning, and Order of Engineers and Architects (OEA): While part of government infrastructure, these entities are more specialized in their roles related to development projects, urban planning, and professional standards in engineering and architecture, respectively. Their influence and interest in healthcare waste management are significant but somewhat indirect compared to primary governmental institutions.

- Academics and Research Entities: Institutions like USJ, LAU, AUB, Balamand University contribute through laboratory services, research, and initiatives in waste management.

  - Other Interested Parties: These are stakeholders who may voice opinions or concerns but generally have less interest in the problem. Their influence on decision-making is likely limited.

- General Public, Staff, and Patients: Affected by healthcare waste management, requiring knowledge about waste management and safety.

- Opinion Formers: Includes media, CSOs, residents, pharmaceutical companies, and medical suppliers, who raise awareness and educate about waste disposal.

This categorization helps in understanding the different levels of involvement and influence each stakeholder has in the healthcare waste management sector in Lebanon. Although different stakeholders interacts through the healthcare waste system, coordination mechanism must be defined, approved and activated towards a better sustainability of investments and stakeholders activities.

5.1.3 Service Zones

Proper zoning is a critical component for the effective implementation of services related to healthcare waste management. Zoning refers to the process of designating specific areas or regions for particular types of activities or services. In the context of healthcare waste management, proper zoning ensures that waste disposal and treatment services are efficiently distributed across different regions, minimizing environmental and health risks. This is particularly important for hazardous waste like medical waste, which requires specialized handling and disposal methods to prevent contamination and the spread of diseases.
In Lebanon, the service zones for healthcare waste management is not yet defined at the national level. This lack of a structured zoning system presents significant challenges in managing healthcare waste effectively and safely. Without designated zones, it becomes difficult to ensure that all areas receive adequate waste management services.

Currently, the determination of service zones for healthcare waste management in Lebanon is primarily influenced by the availability of facilities that handle infectious waste. This ad-hoc approach means that some regions might be well-served because they are near a waste management facility, while others may have limited or no access to such services.

Currently, the only zoning is dictated from the service areas of existing providers as per the below:

- **Nabatieh and South Governorates**: The Saida facility, run by arcenciel, mainly services hospitals here, with a few utilizing the Abbasiyeh facility managed by the local municipality.

- **Beirut and Mount Lebanon Area**: The Jisr El Bacha facility, managed by aec, serves this region.

- **Zahle and the Northern Governorates**: Here, the Zahle facility, also operated by aec, provides service.

In alignment with Law 444, there’s a push for balanced development across all governorates. The law suggests adopting the service areas outlined in the Council of Ministers Decision 1 of June 28, 2006, with potential amendments to create six service areas:

1. Administrative Beirut, its suburbs, and parts of Matn and Baabda Districts (the coastal part).
2. Aley and Chouf Districts, and the remaining part of Baabda District.
3. Keserwan and Jbeil Districts, and the remaining part of Matn District.
4. South Lebanon and Nabatieh Governorates.
5. North and Akkar Governorates.

Future changes to these service areas are anticipated, following the 2023-2026 roadmap discussed between the World Bank and the Ministry of Environment. This roadmap could divide Lebanon into more service areas, based on specific criteria. However, healthcare waste, being a unique stream of waste, may require specific zoning to ensure economic scalability and operational feasibility.

5.1.4 Human Resources and Capacity Building

In Lebanon, the human resources aspect of healthcare waste management faces significant challenges due to a notable knowledge and education gap. Despite the critical importance of proper healthcare waste handling for public health and environmental protection, there is a distinct lack of comprehensive
awareness and educational initiatives in this field. This gap is especially pronounced in educational institutions, including universities, and healthcare facilities, where the complexities of healthcare waste segregation, disposal, and potential hazards are not adequately addressed.

The only major material available for guidance in this domain is the DEHO guideline by arcenciel. This guideline is delivered to waste generators and service providers but does not suffice to bridge the educational gap. There are no specific programs in universities that focus on healthcare waste management, and more importantly, there is a lack of capacity for the maintenance of healthcare waste treatment equipment. This situation highlights a critical need for structured educational and training programs at various levels to enhance understanding and skills related to healthcare waste management.

The absence of specialized programs in universities signifies a missed opportunity in educating and preparing a skilled workforce capable of handling healthcare waste efficiently and safely. The lack of such programs not only impacts current practices but also hinders the development of future professionals who are equipped to deal with the complexities of healthcare waste.

Addressing these issues requires a concerted effort from educational institutions, government agencies, and healthcare facilities to develop and implement comprehensive strategies for knowledge dissemination and skill development in this critical area.

5.1.5 Financial Schemes and Cost Recovery

The financial schemes concerning healthcare waste management in Lebanon, as outlined in laws 444/2002, 80/2018, and decrees 13389/2004, 5606/2019, emphasize the implementation of the “polluter pays” principle. This principle requires healthcare facilities to assume financial responsibility for their waste, ensuring they bear the costs associated with managing the waste they generate.

While healthcare facilities are directly responsible for expenses related to the initial stages of waste management, such as separate collection, packaging, and onsite handling, they often outsource more complex and costly processes. This includes off-site transportation, treatment, and final disposal of the waste, which can be more technologically and financially demanding.

Operating without governmental subsidies, these facilities face significant financial burdens, particularly in terms of capital expenditures (CAPEX). These costs are often substantial because they include investment in infrastructure, equipment, and technology necessary for effective waste management. A notable portion of this investment is often sourced from funding, mainly through grants.

Moreover, a significant part of the costs related to managing infectious waste, which requires specialized treatment due to its hazardous nature, is frequently transferred to the patients in hospitals. This practice aligns with the polluter pays principle but raises concerns about the financial impact on patients and the broader implications for healthcare accessibility and equity.
In addition to the challenges associated with infectious healthcare waste management in Lebanon, the handling of specific types of waste, such as cytotoxic pharmaceutical and chemical waste, presents further complexities. Lebanon currently lacks in-country facilities capable of treating cytotoxic pharmaceutical and chemical waste. This gap in the healthcare waste management infrastructure necessitates the export of such waste to specialized facilities abroad. This process is not only logistically complex but also incurs significant costs.

The high costs associated with the export of cytotoxic and chemical waste are particularly challenging for Lebanese healthcare facilities. Given the already substantial financial burden of healthcare waste management, these additional expenses are often beyond the capacity of many healthcare institutions. As a result, the costs associated with the export of this hazardous waste are frequently prohibitive, leading to potential compromises in the safe and effective disposal of these materials.

Concerning the radioactive waste, the management of short-lived radioactive waste is typically included in the overall budget for waste management within hospitals and radiology centers. However, the process of repatriating and exporting radioactive sources, which is an integral part of managing these materials, is usually considered in the purchasing contracts with suppliers. The costs associated with the export of a radioactive source are relatively modest, ranging from US$300 to 500, making it a financially viable option for many healthcare facilities.

This financial structure underscores the need for a balanced approach that ensures effective waste management while considering the financial implications for healthcare providers and recipients. Additionally, it calls attention to the potential role of government support in subsidizing part of these costs to alleviate the financial burden on healthcare facilities and, by extension, on patients. Such support could be vital in maintaining high standards of healthcare waste management without compromising the accessibility and affordability of healthcare services.

5.1.5.1 Infectious Waste Management Costs

The management of infectious waste in Lebanon has become a critical issue, particularly in light of recent economic challenges. As healthcare facilities grapple with the need to dispose of waste safely and cost-effectively, a detailed examination of the associated costs reveals the complexities of the sector.

Table 3. Comparison of Unit Cost of Treated Infectious Waste and Break-Even Price Across Main Operators (ELARD, 2021)

<table>
<thead>
<tr>
<th>Total cost of treated kg of infectious waste (USD)</th>
<th>aec Jisr el Wati**</th>
<th>aec Zahle**</th>
<th>aec Saïda**</th>
<th>Abbassiyeh**</th>
<th>AWM***</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.64</td>
<td>0.67</td>
<td>0.74</td>
<td>1.07</td>
<td>5.63</td>
<td></td>
</tr>
<tr>
<td>Break-even price (USD)</td>
<td>0.38</td>
<td>0.61</td>
<td>3.41</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Break-even is a function of the total treated quantity, fixed costs, and variable costs
** arcenciel and Abbassiyeh Municiaplity are using sterilisation process by autoclaving
***AWM is using the Pyrolysis technology
Table 3, developed through a recent study by ELARD, presents a financial comparison of the treatment costs for infectious waste at various facilities across Lebanon, highlighting the complexities of waste management economics within the country. It showcases the total cost of treating one kilogram of infectious waste, along with the break-even price at different facilities, namely aec - Jisr el Wati, aec - Zahleh, aec Saida, Abbasiyeh, and AWM. The total treatment costs range markedly, from $0.64 at aec - Jisr el Wati to a steep $5.63 at AWM, indicating a disparity likely due to the diverse treatment technologies employed, operational scales, and varying efficiencies. The break-even prices also vary, representing the minimum price point at which costs are covered by revenue. Notably, the break-even price is always lower than the total cost, suggesting that it may only factor in the variable costs, unlike the total cost, which encompasses both fixed and variable costs.

However, the prices charged by the service providers has been adjusted recently, following the economic crisis that Lebanon has been facing since 2019. The financial figures revealing that arcenciel, which manages aec - Jisr el Wati, aec- Saida and aec - Zahleh, has adopted a dynamic pricing strategy post-crisis. Larger hospitals, which generate more waste, are levied $0.47 per kilogram—a rate that falls above the break-even and below the total cost at aec - Jisr el Wati, allowing for economies of scale. Smaller generators face a higher charge of $1.5 per kilogram, which likely encompasses a full coverage of costs along with a profit margin, considering the higher relative costs of collecting smaller waste volumes.

It is important to highlight here that arcenciel is not paying land rentals; its NGO status supports it to operate at low in cost while not seeking benefits. This advantage allows arcenciel to offer competitive pricing, particularly beneficial in times of economic uncertainty, and plays a significant role in the financial dynamics and strategies underpinning their waste management services.

Further context is provided by the footnotes, explaining that the break-even price hinges on the total treated quantity, fixed costs, and variable costs. It also highlights that all entities except AWM use sterilization by autoclaving, a common and cost-effective waste treatment method. AWM, on the other hand, employs Pyrolysis technology, a more complex and costly process that explains its higher treatment cost.

This cost analysis not only sheds light on the financial aspects of infectious waste treatment in Lebanon but also underscores the operational and technological diversity within the sector.

5.1.5.2 Cytotoxic, Pharmaceutical and Chemical Waste Management Costs

The management of cytotoxic, pharmaceutical, and chemical waste in Lebanon is a critical and complex undertaking, with various methods being employed to handle this hazardous waste. Each method comes with its own set of financial and regulatory considerations.

Local treatment of waste primarily involves incineration, a process which was used by the American University of Beirut Medical Center (AUBMC). The cost of this incineration process is multifaceted, encompassing human resources, electricity, fuel, consumables, maintenance activities, encapsulation and disposal of ashes, and air quality monitoring. The annual operating cost of the
incinerator was estimated at approximately 100,000 USD. Given the monthly generation rate of 4 tons of waste, the cost translates to roughly 2,080 USD per ton. Additionally, it’s been highlighted that previously, incineration at facilities like Hotel Dieu was conducted at approximately 2.5 USD per kilogram, covering the costs of fuel, electricity, and staffing, as well as equipment maintenance.

However, it’s crucial to note that this incineration process was undertaken without the necessary permits.

In contrast, the export of waste presents an alternative solution. The exportation and destruction of waste can range from 1,700 to 6,000 USD per ton. This variance in prices depends on the types of waste exported, the destruction destination and the exporting company.

Table 4. Analysis of Different Scenarios (ELARD, 2021)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost per kilogram</th>
<th>Price per kilogram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1: Incineration of Cytotoxic and Pharmaceutical waste in Lebanon Without Donation (Lowest Price of service sales)</td>
<td>2.6</td>
<td>2.7</td>
</tr>
<tr>
<td>Option 1: Incineration of Cytotoxic and Pharmaceutical waste in Lebanon With Donation</td>
<td>1.975</td>
<td>2</td>
</tr>
<tr>
<td>Option 2: Export of Cytotoxic Waste with National central collection</td>
<td>4.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Option 3: Export of Cytotoxic Waste in Lebanon with gate to port operations</td>
<td>4.3</td>
<td>4.5</td>
</tr>
</tbody>
</table>

The financial analysis, presented in Table 4 and developed by UNDP in 2021, provided earlier indicates that in-country incineration can be more cost-effective than exporting waste, especially when capital expenditures are minimized through donations.

Ultimately, incineration within Lebanon is the most cost-effective option, particularly when capital expenditure is subsidized through donations. Exporting waste incurs higher costs likely due to additional logistical requirements, but it still maintains a consistent profit margin. The analysis suggests that while local treatment methods can be optimized for cost-saving, exporting waste is also a viable option, albeit more expensive.

Decision-makers would need to weigh the balance between local capacity for waste treatment, the availability of international partnerships for waste export, and the environmental impact of each option.
The intricacies of managing contaminated infectious-cytotoxic waste present significant challenges, particularly within the context of Lebanon. This category of waste, characterized by infectious materials and cytotoxic substances, demands specialized treatment protocols to mitigate the risks of disease transmission and environmental damage. Compounded by stringent international agreements and regulations governing the cross-border transport of hazardous waste, the logistical feasibility of moving contaminated infectious-cytotoxic waste for treatment becomes impractical.

Consequently, incineration emerges as the predominant and frequently the sole practical solution for locally addressing the treatment of such waste. Despite its effectiveness in neutralizing biological and chemical hazards, incineration raises concerns regarding potential air quality degradation and emissions, highlighting the need for meticulous waste management strategies tailored to the unique challenges posed by contaminated infectious-cytotoxic waste in the Lebanese context.

Despite the clarity of this system, Lebanon faces significant challenges in healthcare waste management, particularly among smaller waste generators. Often, these facilities inadequately segregate their waste, leading to the mixing of healthcare waste with municipal solid waste (Figure 4). This not only violates waste management protocols but also poses serious health risks to waste handlers and the public.

5.2 Physical

5.2.1 Healthcare Waste Generation

The generation and management of healthcare waste in Lebanon is a process that requires strict adherence to standardized practices, particularly in the segregation of different types of waste. A color-coded system is employed internationally to simplify this process, ensuring that each category of waste is easily identifiable, thereby reducing risks of contamination or mishandling (Table 5).

<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Color-Symbol Coding</th>
<th>Container Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Hazardous waste</td>
<td>Black</td>
<td>Plastic Bags, Plastic Containers</td>
</tr>
<tr>
<td>Rejects and Organic</td>
<td>Green</td>
<td>Plastic Bags, Plastic Containers</td>
</tr>
<tr>
<td>Recyclables</td>
<td>Yellow with</td>
<td>Plastic Bags, Plastic Containers</td>
</tr>
<tr>
<td>Infectious Waste</td>
<td>Purple</td>
<td>Plastic Bags, Plastic Containers</td>
</tr>
<tr>
<td>Cytotoxic Waste</td>
<td>Red</td>
<td>Plastic Bags, Plastic Containers</td>
</tr>
<tr>
<td>Pharmaceutical and Chemical</td>
<td></td>
<td>Bags Lead Containers</td>
</tr>
<tr>
<td>Waste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharps</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Color-Symbol Coding System for Waste Segregation
In this system, non-hazardous waste like rejects and organics are placed in black plastic bags or containers, while recyclables are designated to green containers. The management of hazardous waste is more nuanced. Infectious waste, which may include materials contaminated with bodily fluids, is disposed of in yellow containers that are sturdy and leak-proof to prevent exposure and cross-contamination. Cytotoxic waste, known for its potential to cause genetic mutations and cancer, is segregated into red containers. This segregation is critical as cytotoxic waste requires specialized handling. Similarly, pharmaceutical and chemical waste, as well as radioactive waste, are also assigned to red containers, with the latter sometimes requiring additional protective measures like lead lining.

Despite the clarity of this system, Lebanon faces significant challenges in healthcare waste management, particularly among smaller waste generators. Often, these facilities inadequately segregate their waste, leading to the mixing of healthcare waste with municipal solid waste (Figure 4). This not only violates waste management protocols but also poses serious health risks to waste handlers and the public.

Regarding infectious waste generated from hospitals, the process is refined by service providers in Lebanon, who supply healthcare generators with plastic containers of varying capacities. This variation is tailored to the rate at which each facility generates infectious waste, ensuring a customized approach to waste management. Within healthcare facilities, smaller containers are used initially, allowing for easy collection and internal transportation. These smaller containers are then transferred to larger ones, which are eventually collected by service providers. This two-tier system – involving smaller containers within the premises and larger ones for external collection – exemplifies a thorough and efficient approach to managing infectious waste, ensuring safety and hygiene at every step of the disposal process.
For cytotoxic waste, known for its particularly hazardous nature due to its potential to cause genetic mutations and cancer, red containers are utilized. This segregation is crucial, as cytotoxic waste demands specialized handling and disposal methods to mitigate its hazardous nature. The red containers act as a clear indicator to staff, signaling the need to handle these materials with the utmost care and caution. However, it’s important to note that this rigorous segregation in purple containers is predominantly observed among some of the larger waste generators.

Similarly, for pharmaceutical and chemical waste, which also pose significant health risks, red containers are designated for segregation. Despite the critical need for careful handling of these types of waste, it appears that adherence to this practice is limited and more commonly implemented by larger generators. This highlights a gap in the consistent application of safety protocols across different sizes and types of healthcare facilities.

The prevailing situation in Lebanon, characterized by incomplete guidelines and inadequate law enforcement, highlights a significant discrepancy between recommended waste management procedures and their actual implementation. This gap is particularly pronounced in smaller healthcare facilities for all streams of waste and among larger waste generators across all waste streams except for infectious waste.

Addressing these issues is crucial for ensuring the safety of healthcare workers, patients, waste handlers, and the environment. Moreover, fostering a culture of compliance and responsibility within healthcare facilities is key to achieving more effective and sustainable waste management practices in Lebanon.

5.2.1.1 Infectious Waste

In Lebanon, the management of infectious waste has become an increasingly complex and pressing issue, particularly considering the country’s evolving healthcare landscape and recent crises. This
waste, generated from various medical sources, is broadly categorized into two main groups based on their volume of production: large generators like hospitals and small generators including clinics, laboratories, and other healthcare facilities.

Hospitals, as the primary generators of this waste, contribute significantly to the nation’s overall waste output. A comprehensive, nuanced method has been developed to accurately calculate the waste generated by these healthcare facilities, combining statistical data, historical trends, and operational variables. This method is essential for formulating effective waste management strategies and ensuring environmental protection.

The estimation process begins with integrating historical data from service providers, forming a baseline that offers insights into waste generation trends over time. A key component of this method is a thorough literature review, placing the local data within a broader context of regional and global healthcare waste management trends.

Central to the estimation process is the calculation of waste per hospital bed, categorized by hospital size. The core of the estimation process is the calculation of waste per hospital bed, categorized by hospital size:

- Hospitals with <100 beds: Approximately 1 kg of waste per bed, per day.
- Hospitals with 100-200 beds: About 1.3 kg of waste per bed, per day.
- Hospitals with >200 beds: An estimated 1.6 kg of waste per bed, per day.

However, a significant challenge in this process is the limited data available from governmental ministries. The reliance on service provider reports highlights the need for more robust data collection and analysis mechanisms at the governmental level.

To aid in understanding and visualizing Lebanon’s healthcare waste generation, several tables and figures will be included.

In 2021, UNDP conducted a comprehensive Data Collection exercise, with a comprehensive Baseline completion methodology. In this exercise, it was shown that different scenarios can be considered for infectious healthcare waste production in Lebanon as shown in the Table 6 below:
Table 6. Different Scenarios for Infectious Healthcare Waste Production in Lebanon

<table>
<thead>
<tr>
<th>Scenario 1 (tons/year)</th>
<th>2021</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lebanon</td>
<td>3,882</td>
<td>3,882</td>
<td>3,882</td>
<td>3,882</td>
</tr>
<tr>
<td>Scenario 2 (tons/year)</td>
<td>7,255</td>
<td>7,255</td>
<td>7,255</td>
<td>7,255</td>
</tr>
<tr>
<td>Scenario 3 (tons/year)</td>
<td>7,924.3</td>
<td>8,638.5</td>
<td>9,820.1</td>
<td>10,958.6</td>
</tr>
</tbody>
</table>

In the event of scenario 1 (worst case scenario), waste quantities are expected to decline based on 50% occupancy and zero growth rate. With scenario 2 (no economic growth, 100% occupancy), which is a theoretical scenario, the total quantity of waste generated reaches (the most likely scenario). In Scenario three a full growth of 30% is considered with 100% occupancy rates at hospitals (Unlikely scenario).

Below, the Table 7, exposed the break down per casa of these estimations, based on the scale of the large producer as well as the scenario two, the most likely figure.

Table 7 presents an overview of the estimated waste generation from Large generators.

Table 7. Estimated Infectious Waste Generation from Hospitals

<table>
<thead>
<tr>
<th>Casa</th>
<th>Large Generators (ton/day)</th>
<th>Large Generators (ton/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beirut</td>
<td>3.80</td>
<td>1,388</td>
</tr>
<tr>
<td>Mount Lebanon</td>
<td>6.42</td>
<td>2,345</td>
</tr>
<tr>
<td>Kesrwen-Jbeil</td>
<td>1.37</td>
<td>500</td>
</tr>
<tr>
<td>Nabatieh</td>
<td>0.60</td>
<td>219</td>
</tr>
<tr>
<td>South</td>
<td>2.25</td>
<td>821</td>
</tr>
<tr>
<td>North</td>
<td>2.64</td>
<td>964</td>
</tr>
<tr>
<td>Beqaa</td>
<td>1.50</td>
<td>548</td>
</tr>
<tr>
<td>Baalbeck-Hermel</td>
<td>0.98</td>
<td>342</td>
</tr>
<tr>
<td>Akkar</td>
<td>0.35</td>
<td>128</td>
</tr>
<tr>
<td>TOTAL</td>
<td>19.92</td>
<td>7,255</td>
</tr>
</tbody>
</table>

Rising Waste from Small Generators

The rising contribution of small generators to Lebanon’s infectious waste problem has become more pronounced in recent years. This trend is closely tied to the changes in healthcare behavior during times of crisis. A noticeable shift shows more individuals favoring smaller clinics and dispensaries over larger hospitals. Such a shift has profound impacts on waste management strategies. While each of these smaller facilities individually contributes less waste compared to larger hospitals, their collective output amounts to a significant volume.

To accurately assess the waste generated by these small generators, a comprehensive methodology is employed. This approach is multi-dimensional, involving direct interviews with healthcare professionals, including dentists, doctors, and laboratory technicians. These interviews are crucial for gathering first-hand information about waste generation practices and challenges.
Additionally, the methodology includes benchmark studies. These studies compare the waste generation metrics of Lebanon’s small healthcare facilities with similar establishments in other regions or countries. This comparison helps in understanding how local practices align with or differ from global trends, and what lessons can be learned.

Moreover, there is a thorough review of existing data, which might include waste generation records mainly from few laboratories and medical centers. This review helps in painting a broader picture of the waste generation across Lebanon.

A unique aspect of this methodology is its consideration of population density in each Governorate and the estimated frequency of medical interventions per person per year. This aspect ensures that the waste generation estimates are not just generic but tailored to the specific demographic and healthcare dynamics of each region in Lebanon (Annex 4).

By employing this multi-faceted approach, a more accurate and representative understanding of the waste generated by these smaller, yet increasingly significant, sources are achieved.

Table 8 presents an overview of the estimated waste generation from small generators.

<table>
<thead>
<tr>
<th>Casa</th>
<th>Small Generators (ton/day)</th>
<th>Small Generators (ton/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beirut</td>
<td>1.03</td>
<td>377.1</td>
</tr>
<tr>
<td>Mount Lebanon</td>
<td>3.78</td>
<td>1,377.9</td>
</tr>
<tr>
<td>Kessrwen-Jbeil</td>
<td>0.74</td>
<td>270</td>
</tr>
<tr>
<td>Nabatieh</td>
<td>0.96</td>
<td>351.9</td>
</tr>
<tr>
<td>South</td>
<td>1.48</td>
<td>541.8</td>
</tr>
<tr>
<td>North</td>
<td>1.98</td>
<td>722.7</td>
</tr>
<tr>
<td>Beqaa</td>
<td>1.33</td>
<td>486</td>
</tr>
<tr>
<td>Baalbeck-Hermel</td>
<td>1.16</td>
<td>424.8</td>
</tr>
<tr>
<td>Akkar</td>
<td>1.07</td>
<td>388.8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>13.55</strong></td>
<td><strong>4,941</strong></td>
</tr>
</tbody>
</table>

Total Infectious Waste Generation

After separately analyzing the infectious waste generation from both large and small generators in Lebanon, the comprehensive assessment concludes in a detailed visualization of the total waste generation across the country’s governorates. This is vividly illustrated in Figure 7, which provides a critical comparison between the waste quantities generated by large and small generators. The distinction made in this figure is instrumental in understanding the scale and scope of waste generation from different types of healthcare facilities.

Complementing this analysis, Figure 8 offers a holistic view of the total waste generation per governorate. This comprehensive overview is essential for grasping the geographical spread of waste production across Lebanon. The data presented in these figures are both revealing and concerning. They indicate a total generation of 33.5 tons of infectious waste across the country. This substantial figure highlights the urgent need for robust and effective waste management strategies.
On the other hand, Figure 9 makes a careful distinction between the waste contributions of large and small generators. This differentiation is crucial as it sheds light on the specific challenges and needs of different types of healthcare waste management approaches.

These figures are not just illustrative but are designed to be instrumental in shaping subsequent recommendations. They serve a dual purpose: firstly, by offering a clear and comprehensive understanding of the current waste generation landscape in Lebanon, and secondly, by laying a solid foundation for the development of targeted strategies and policies. These strategies are aimed at not just addressing the current waste management issues but also at preemptively tackling potential future challenges.

By meticulously analyzing and presenting the waste generation data per governorate and type of generator, these figures are a crucial step towards enhancing Lebanon’s waste management practices. They highlight the disparities in waste generation across different regions and types of healthcare facilities, underscoring the need for tailored solutions.

Figure 7. Estimated Infectious waste generation by governorate.
5.2.1.2 Cytotoxic, Pharmaceutical and Chemical Waste

Cytotoxic, pharmaceutical, and chemical waste represents a significant and complex component of healthcare waste, necessitating precise estimation and effective management strategies. This type of waste poses unique risks due to its potentially hazardous nature, thus making its accurate quantification and safe disposal critical for both environmental and public health safety.
The challenge of accurately estimating the quantities of cytotoxic, chemical, and pharmaceutical waste generated in healthcare facilities is compounded by the limited data availability. However, the current estimation methods—comprising direct interviews with healthcare professionals, comprehensive literature reviews, and benchmarking against similar healthcare settings offer a substantial degree of accuracy and relevance, despite the limitations of unofficial data sources.

These estimation methods are supported by a rigorous methodology that lends credibility to the findings. Direct interviews with healthcare professionals provide valuable first-hand insights into the handling and management of this waste, offering a practical perspective grounded in the reality of healthcare operations. These interviews are complemented by extensive literature reviews that aggregate and analyze a wide range of published data, research findings, and studies. This broadens the understanding of waste generation patterns, providing a more nuanced and comprehensive analysis. Additionally, benchmarking—comparing waste management practices and quantities with those in similar healthcare settings in different regions or countries—offers a vital comparative perspective. This approach helps in identifying trends, variations, and best practices in waste management, thereby contextualizing the data within a broader global framework.

The triangulation of data from these diverse sources is a key strength of this approach. By cross-verifying information and findings from interviews, literature, and benchmarking studies, the accuracy of the data is significantly enhanced, leading to more reliable and robust estimations. Although each individual method has its limitations, such as potential biases in interviews or the variable quality of literature sources, their combined use effectively offsets these shortcomings. This synergistic approach enhances the overall quality and reliability of the waste quantity estimations.
In the context of limited data availability, these methodologies represent the most pragmatic and effective means currently available for estimating waste quantities. They provide crucial insights into the scale of waste generation, which is vital for planning and implementing effective waste management strategies in healthcare facilities. Understanding the magnitude and nature of the waste generated is crucial for developing tailored waste management solutions that are both efficient and environmentally responsible.

Moreover, these estimations play a pivotal role in shaping future research directions and policy development in healthcare waste management. By highlighting the scale and complexity of the issue, they underscore the urgent need for establishing formal data collection and reporting mechanisms. Such mechanisms would not only improve the accuracy of waste estimations but also facilitate the development of more effective waste management policies and strategies.

Specifically, the generation of cytotoxic waste, which is particularly prominent in hospitals offering chemotherapy treatments, is a key area of concern. This waste, along with the broader spectrum of pharmaceutical and chemical waste from healthcare facilities like clinics and laboratories, presents unique challenges in management and disposal. A critical obstacle in quantifying these waste types accurately is the widespread lack of systematic documentation and reporting practices among healthcare facilities. This issue is further exacerbated by inconsistent reporting to relevant governmental bodies, such as the Ministry of Environment (MoE) and the Ministry of Public Health (MoPH), and the lack of stringent regulatory enforcement.

Previous studies have provided some quantitative insights, estimating that the rate of cytotoxic and pharmaceutical waste production in hospitals is around 0.073 kilograms per bed per day. This figure, extrapolated to encompass all potential sources, including hospitals, research centers, and the disposal of expired chemicals and medications, amounts to an estimated annual total of approximately 275 tons.

![Figure 11. Cytotoxic, Chemical and Pharmaceutical Waste Generation Projection](image-url)
Figure 11 offers a quantitative projection of cytotoxic, pharmaceutical, and chemical waste generation in Lebanon from 2023 to 2033, highlighting a linear increase over the 10-year period. This projection is anchored by a Compound Annual Growth Rate (CAGR) of 2.02%, a rate that has been consistent since 2003 despite the nation’s experiences of political and economic upheavals.

The data points plotted on the graph provide a detailed and methodical estimation reflecting a comprehensive analysis.

Given a CAGR of 2.02%, and based on some calculations, it is expected that waste generation will increase from 275 tons per year to reach around 315 tons by 2033. The projection thus serves as an indicator of the critical need for waste treatment infrastructure development. It’s important to note that this number might fluctuate depending on the cancer rate fluctuation within a few years, which will affect the quantity of infectious cytotoxic and cytotoxic waste generation.

![Figure 12. Waste Generated by Different Generators](image)

Figure 12 illustrates the distribution of cytotoxic, pharmaceutical, and chemical waste generation among different contributors. Healthcare providers emerge as the primary source, accounting for 60% of the waste. This suggests that hospitals, clinics, and medical centers, particularly those providing treatments that generate cytotoxic waste, such as oncology departments, are the most significant contributors. Pharmaceutical importers and industries come next, responsible for 35% of the waste. Their contribution is substantial, likely due to the disposal of expired medications, packaging, and by-products from pharmaceutical manufacturing processes. Research labs, although the smallest contributors, still account for 5% of the waste. These facilities, engaged in scientific studies and experiments, contribute a smaller portion of waste, including chemical reagents and materials used in research and development.

The primary generation of pharmaceutical, chemical, and cytotoxic waste occurs predominantly within the BML region, driven by several critical factors:
1. Concentration of Pharmaceutical Importers and Industries in BML Area: The BML region is renowned for being a hub for pharmaceutical importers and manufacturers, also functioning as a key distribution center for pharmaceutical products throughout the country. This area is characterized by a high density of facilities handling a wide array of pharmaceuticals, including those needing special storage or having a short shelf-life, which escalates the risk of waste generation. Additionally, the close proximity of these facilities in the BML area enhances logistical efficiency but also leads to a concentration of waste generation, thereby necessitating the need for specialized waste management systems.

2. High Density of Hospitals with Oncology Departments: Hospitals in the BML area are not only numerous but also well-equipped with advanced oncology departments. These departments offer a range of cancer treatments such as chemotherapy, radiation therapy, and surgical procedures. Due to the intensive nature of these treatments, a variety of waste types, including the hazardous cytotoxic waste, are produced and require careful disposal. Moreover, the high patient influx in these hospitals further increases the volume of medical waste.

3. Comparison with Other Governorates: The contrast is clear when comparing hospitals in other governorates with those in the BML area, especially in terms of advanced facilities in oncology departments. The limited capacity for cancer care in other regions translates into a lower production of medical waste, particularly cytotoxic waste. This regional disparity in healthcare infrastructure is a key factor in the uneven distribution of cytotoxic waste generation across the country, emphasizing the need for healthcare waste management strategies that are tailored to the specific needs and capacities of different regions.

4. Widespread Generation of Pharmaceutical and Chemical Waste: Across the nation, pharmaceutical and chemical waste is a common issue, but its scale and impact are most pronounced in the BML area, owing to the high concentration of healthcare facilities and pharmaceutical industries. Although smaller clinics and healthcare providers in other parts of the country also contribute to the waste stream, their impact is less significant due to their smaller scale of operations and patient numbers. This scenario highlights the importance of a decentralized waste management approach, with a greater focus and allocation of resources in high-impact areas like the BML region.

In conclusion, it’s evident that the BML region stands as the primary contributor to the production of cytotoxic, pharmaceutical, and chemical waste due to its concentration of pharmaceutical activities and advanced medical facilities, particularly in oncology. This significant role of the BML area in waste generation demands the implementation of specialized and region-specific environmental management strategies. The substantial volume and hazardous nature of the waste produced in this region require the development of effective and customized waste management solutions.
5.2.1.3 Radioactive Waste

Radioactive waste in healthcare, primarily generated through procedures like nuclear medicine, radiation therapies, and scans such as PET and CT, includes a variety of materials. These range from contaminated medical equipment and patient clothing to personal protective equipment. The waste manifests in different forms, including sealed and unsealed sources, with sealed sources often being returned to suppliers, thus not forming a part of the waste stream.

The radioisotopes commonly used in hospitals, such as Technetium-99m, Iodine-131, Iodine-125, Iodine-123, Fluorine-18, Tritium, and Carbon-14, typically have short half-lives.

In the context of healthcare waste generation, radioactive waste constitutes a significant concern, particularly in larger hospitals with capacities exceeding 250 beds. The generation of radioactive waste in these healthcare facilities, although comparatively lower in volume when placed against other waste streams, holds critical importance due to its hazardous nature.

Large hospitals are typically found to generate approximately 300 kg/year of short-lived radioactive waste. This figure, however, can fluctuate considerably based on the hospital’s size and the extent of its radiological services.

The variability in the generation of radioactive waste is also influenced by the range of services a hospital offers. Facilities with more extensive radiological services, for instance, tend to produce higher quantities of this waste. Despite its hazardous nature, the detailed registration and quantification of radioactive waste is often limited due to the practice of storing the waste until it decays to safer levels, after which it is usually reclassified and combined with other types of waste for disposal.

5.2.2 Existing Infrastructure

5.2.2.1 Infectious Waste

5.2.2.1.1 Waste Collection

The collection and proper segregation of infectious waste at its source are critical components in effective waste management. Proper segregation ensures that different types of waste are handled appropriately, reducing risks to public health and the environment. While Lebanon has a partially existing system in place for the collection of infectious waste, primarily from large generators, this system requires optimization to enhance its efficiency and inclusivity.
Currently, the service providers, such as arcenciel, manage the collection of infectious waste. These providers play a pivotal role in collecting waste from various healthcare facilities and ensuring its safe and efficient transport to treatment centers. arcenciel, for example, operates a well-maintained fleet, including 11 pick-up trucks, a van, and a Renault Kangoo vehicle, adhering to strict maintenance and cleaning protocols.

However, while this system effectively serves large waste generators, it reveals significant gaps, particularly concerning smaller waste generators like clinics, laboratories, dental practices, and veterinary clinics. These smaller entities often lack access to specialized waste collection and treatment services, leading to their waste being disposed of in regular MSW streams.

On the other hand, the infectious waste collection requires comprehensive audit at the national level to ensure efficient and collection. Such an audit would enable the identification of areas where the system falls short, and how to improve it. It would also help pinpoint inefficiencies in the collection routes and operational practices of existing service providers.

Finally, there is a pressing need for route optimization and service expansion. Optimizing collection routes can significantly improve operational efficiency, reduce environmental impacts, and lower operational costs. Expanding or developing new services to include smaller waste generators is also essential. By ensuring that these entities have access to specialized waste collection services, the system can become more inclusive, thereby reducing the likelihood of infectious waste being improperly handled and treated.

**Existing Fleets and Collection Details**

Table 9 offers a detailed overview of the country’s current fleet deployed for collecting infectious waste. This information is essential serving as a foundational benchmark for analyzing sector-specific needs and requirements.
Table 9. Overview of the Country’s Current Fleet Deployed for Collecting Infectious Waste (Elard, 2021)

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Fleet Composition</th>
<th>Vehicle Details</th>
<th>Features</th>
<th>Operations</th>
<th>Routing/ Schedule</th>
<th>Coverage Area</th>
</tr>
</thead>
</table>
| arcenciel        | 11 pick-up trucks, a van, and a Renault Kangoo | - Scania Pick-up: 1 truck (10 bins, 1100 L)  
- Hiace Pick-up: 5 trucks (15 bins, 240 L)  
- Dyna Pick-up: 5 trucks (20 bins, 240 L)  
- Van: 1 (8 bins, 240 L)  
- Renault Kangoo: 1 (5 bins, 240 L) | Automatic bin lifters, sealed compartments, first aid and spill kits, biohazard labels | Fixed schedules and routes, 2 staff per truck, daily cleaning, regular maintenance | Distributes waste to treatment centers, adjusted based on capacity and location | Various regions including hospitals, labs, dispensaries, and medical clinics |
| Abbasiyeh        | 1 closed vehicle  | Capacity: 300 to 500 kg per trip | Regular maintenance and painting | Collection from Monday to Friday, 7:30 AM to 6:00 PM | Schedule based on requests from healthcare facilities | 5 Cazas including Sidon, Tyre, Nabatieh, Marjayoun, and Bent Jbeil |
| AWM              | 2 trucks          | - North truck: 18 bins (240 L each)  
- BML truck: 12 bins (240 L each) | First aid kit, meets MoE requirements | Collection upon request | No fixed schedule | 1 hospital and 1 center in the north, 4 healthcare centers in Beirut, 1 hospital in the south |
5.2.2.1.2 Waste Treatment

The treatment of infectious waste is done through several facilities. The core of this system is the network that treats waste generated by hospitals. Facilities like arcenciel and Abbasiyeh are pivotal in this network, managing the majority of hospital waste. Additionally, some hospitals like Clemenceau Medical Center and Haykal Hospital have a sterilizing unit on their premises. Only a small fraction of this waste is directed to the AWM facility. Additionally, there’s a minor yet notable flow of hospital waste into Municipal Solid Waste (MSW) streams, highlighting a crossover in waste management practices. The Lebanese Red Cross, in particular, channels its waste exclusively through the arcenciel network, emphasizing specialized treatment pathways for certain waste generators.

The laboratory waste management is more diverse and less structured. While a minority of laboratories opt for disposal through the arcenciel network, a significant amount of laboratory waste is indiscriminately mixed with MSW streams. This pattern extends to waste from clinics, dental practices, veterinary clinics, and other health-related facilities, where standard practice often involves merging potentially hazardous waste with regular municipal waste. This disposal raises concerns about the efficacy of waste segregation and the potential risks associated with improper handling.

The situation’s is also critical when considering the fate of sterilized waste from arcenciel and Abbasiyeh. Post-treatment, this waste frequently ends up in open dumpsites or piled on-site. This disposal method poses questions about the long-term environmental and health impacts, particularly in terms of the waste’s final destination and the effectiveness of sterilization processes in mitigating risks.

The most critical issue, however, lies in the disposal of infectious waste within MSW streams. This waste, often untreated and mixed with regular trash, follows conventional disposal methods such as open burning, dumping in unregulated sites, or landfilling. These practices are problematic as they do not neutralize the infectious agents present in the waste. The implications of such disposal methods are far-reaching, affecting public health and environmental safety. The lack of specialized treatment for infectious waste in these scenarios underscores the need for more stringent waste management protocols and raises alarms about the potential spread of infectious diseases and environmental contamination.

The upcoming section provides a comprehensive overview of the current service providers involved in the management of infectious waste in Lebanon.
Arcenciel has emerged as a pivotal organization in Lebanon, dedicated to the management of infectious healthcare waste (IHCW) for nearly two decades. Established in 2003 with support from LIFE and AECID, it has built a robust network that now handles over 80% of large generators’ infectious waste, signifying its crucial role in this domain.

At the heart of arcenciel’s operations are three main waste treatment centers located in Jisr el Wati, Saida, and Zahle. These facilities collectively process an average of 4,650 tons of medical waste daily. Notably, the bulk of this waste comes from hospitals, which are the primary contributors to the infectious waste arcenciel manages.

While hospitals form the core of arcenciel’s waste collection efforts, the organization also deals with smaller quantities of waste from other sources. These include laboratories, few clinics, and the Lebanese Red Cross, though the quantities received from these facilities are relatively minimal.

The evolution of arcenciel’s treatment facilities over the years highlights its commitment to innovation and adaptation. The centers employ sterilization technologies such as the Hydroclave H100 steam sterilization and microwave sterilization units.

The waste processing at these centers is meticulous. Upon arrival, waste is weighed, checked for radiation, and stored in cold storage rooms, adhering to environmental standards. The cleaning process of the waste bins, using an oxonium solution, further emphasizes the rigorous hygiene standards upheld by arcenciel.

Arcenciel’s workforce of about 50 professionals is another cornerstone of its operations. Comprehensive training in safety, operations, and PPE usage ensures that the team is well-prepared to handle the complexities of waste management. The organization’s adherence to ISO 9001 standards is a testament to its commitment to quality and operational excellence.

Faced with Lebanon’s economic challenges, arcenciel has shown remarkable resilience by adjusting its tariff structure, striking a balance between USD and Lebanese pound charges. This strategic financial management has been essential in sustaining its operations amidst the financial crisis.

In summary, arcenciel stands as a beacon in Lebanon’s healthcare sector, efficiently managing a large volume of infectious waste, primarily from hospitals, with unwavering dedication to environmental sustainability, safety, and quality.
Figure 15. arcenciel Facilities
Abbasiyeh

The Abbasiyeh Infectious Waste Treatment Facility, since its inception in 2010, has been a critical component in managing infectious healthcare waste in Tyre Caza and its surrounding areas in Lebanon.

The facility processes around 900 kilograms of waste daily from primary hospitals and laboratories in Tyre Caza and surrounding areas. In 2020, the facility received substantial upgrades funded by UNDP, aiming to increase its capacity for treating and storing infectious waste to 1,550 kg/day, anticipating a rise in waste generation over the next five years. Presently, the facility is not functioning at its maximum capacity.

The facility is mainly composed from essential components, including a control room, a weighing unit, and a specialized area for waste reception and storage. The facility is equipped with an autoclave unit integrated with a shredder, which plays a pivotal role in the sterilization of infectious waste. This is complemented by a steam generation boiler, a compressor, and a designated area for storing sterilized waste, ensuring a comprehensive approach to waste management.

Transportation and collection of waste are managed through a single closed vehicle, capable of carrying 300 to 500 kg per trip. The collection process at Abbasiyeh is unique in that it doesn’t follow a fixed schedule; instead, it’s based on the needs and requests of healthcare facilities. Servicing a wide range of establishments across five Cazas, the facility’s reach extends to about 11 hospitals and around 20 medical centers, reflecting its extensive impact in the region.

The facility’s treatment technology was initially a hybrid autoclave unit from Ecodas, it features a vertical cylindrical jacketed steam sterilizer merged with an internal shredder.

The facility includes a wastewater treatment system that ensures that the wastewater produced from both the waste processing and bin cleaning processes is treated effectively, aligning with environmental standards.

The facility is staffed by a team of five, including a truck driver and assistant, all trained in facility operation and equipped with the necessary personal protective equipment.

The Abbasiyeh facility faces significant financial and operational challenges. The facility’s operations have been largely supported by the Abbasiyeh Municipality, which covers fuel and other recurrent expenses. However, the economic crisis in Lebanon poses substantial risks, including potential government budget cuts or devaluation, which could impact the facility’s future operations. Furthermore, the facility is confronted with various threats, such as interruptions in fuel supply, financial constraints, and challenges in waste collection and disposal.
AWM

Advanced Waste Management (AWM) is a unique entity in Lebanon’s infectious healthcare waste management landscape, being the only private sector operator in this field. AWM operates a pyrolysis treatment plant in Choueifat, Aley Caza, with the capability to process up to 4 tons of medical waste per day.
Operating under a preliminary permit from the Ministry of Environment (MoE) since 2019, AWM has faced challenges in convincing the MoE of the viability of treating infectious medical waste through pyrolysis. The permit required the installation of necessary filters and air quality monitoring equipment, with the trial period not exceeding a month. The technology’s effectiveness and the safety of its end products are not yet fully proven, and the facility lacks proper licensing from the MoE.

Despite its innovative approach, AWM has only a small market share, having treated just 11 tons of infectious waste over a four-month period.

The facility's manpower needs are relatively low, with only 2 drivers, 2 assistant drivers, and 4 operational staff. While it is still in the testing and commissioning stage, the staff is trained for operation and timely maintenance and repair. However, there is no wastewater treatment plant foreseen in the near future. AWM operates two trucks for waste transportation, but these trucks are not yet licensed by the MoE or the Ministry of Interior. The lack of a fixed collection schedule means that waste is collected upon request, making planning more challenging.

AWM is currently operating without an operational permit, as it has not yet provided the MoE with required monitoring and quality data. This includes the quantity of waste treated, air quality monitoring results, and analysis of the end products like carbon black and pyrolysis oil, which the MoE considers hazardous until proven otherwise. Financially, AWM’s situation is precarious. It operates at a much lower capacity than its potential (around 200Kg/day against a capacity of 4,000Kg/day), and its financial sustainability is in question, as it is ineligible for donor assistance as a private company.

The main challenges AWM faces are related to the financial crisis, such as fluctuations in the USD price, hospitals’ unwillingness to pay at non-official rates, and increasing transportation costs. Additionally, the facility’s operation is contingent on receiving full approval from the MoE, which hinges on compliance with regulatory requirements and the safety of its end products.

In summary, AWM’s operation faces significant challenges in terms of operational licensing, proving the safety of its technology, financial sustainability, and navigating the complexities of the current economic climate. The success of AWM will largely depend on its ability to address these challenges and achieve compliance with the MoE’s standards.

**Existing In-Country Treatment Techniques**

The table presented below (Table 10) offers a comprehensive overview of the current treatment units operating within the country. It’s important to highlight that while pyrolysis is included in this overview, it is crucial to note that the pyrolysis remains not approved for treatment of infectious waste.
Table 10. Current Treatment Units Operating in Lebanon

<table>
<thead>
<tr>
<th>Feature/Unit</th>
<th>Hydroclave H100</th>
<th>Ecosteryl 250</th>
<th>ECODAS T300</th>
<th>Pyrolysis Unit (AWM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Jisr el Wati &amp; Zahle</td>
<td>Saida</td>
<td>Abbasiyeh</td>
<td>Choueifat</td>
</tr>
<tr>
<td>Operational Method</td>
<td>Steam Sterilization</td>
<td>Microwave Sterilization</td>
<td>Steam Sterilization with Shredder</td>
<td>Pyrolysis (Thermal Decomposition)</td>
</tr>
<tr>
<td>Capacity (Daily)</td>
<td>Up to 6 tons/day</td>
<td>7 tons/day</td>
<td>800 kg to 1200 kg/day</td>
<td>Up to 4 tons/day</td>
</tr>
<tr>
<td>Flow Rate (Capacity per Cycle)</td>
<td>500 kg per batch</td>
<td>250 kg/hr</td>
<td>350 l/cycle</td>
<td>-</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>Low operating cost</td>
<td>Fully automated, high efficiency</td>
<td>High efficiency</td>
<td>High due to thermal process</td>
</tr>
<tr>
<td>Installation Year</td>
<td>Jisr el Wati (2012), Zahle (2014)</td>
<td>2020</td>
<td>Operational since 2003</td>
<td>2019</td>
</tr>
<tr>
<td>Equipped with Shredder</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>Automation</td>
<td>Semi-automated</td>
<td>Fully automated</td>
<td>Semi-automated</td>
<td>Semi-automated</td>
</tr>
<tr>
<td>Electrical Consumption</td>
<td>16-17 kW per batch</td>
<td>60 kW</td>
<td>14 kW</td>
<td>-</td>
</tr>
<tr>
<td>Technical Datasheet</td>
<td>Annex 1</td>
<td>Annex 2</td>
<td>Annex 3</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Key Findings – Infectious Waste Treatment in Lebanon

The current state of infectious waste management in the sector reveals a significant disparity between the generation and treatment capacities. Key players like aec and the Abbasiyeh municipality have been pivotal, but the recent introduction of AWM and its unverified pyrolysis technology adds complexity to the situation. Notably, AWM’s technology is excluded from capacity considerations due to its unproven efficacy and potential risks.

The treatment capacity for infectious waste is primarily calculated on a 312-day operational year, except for the Jisr El Wati facility, which operates continuously throughout the year. This brings the national capacity for treating infectious waste to 6,808 tons annually. However, this figure starkly contrasts with the estimated generation of infectious waste – hospitals alone may generate 7,253 tons annually at full capacity, with an additional 4,941 tons from smaller sources, totaling approximately 12,194 tons.

This significant shortfall in treatment capacity signals an urgent need for a comprehensive reassessment and restructuring of the infectious waste management system. A proposed solution to bridge this gap is to extend operation hours across all treatment centers to a 24/7 schedule, potentially increasing the capacity to 20 tons per day. However, this would necessitate major changes in operational logistics, workforce management, technology, and facility upgrades, introducing complex challenges.

These challenges include more intricate operational logistics, with equipment maintenance requiring careful scheduling to minimize disruptions. Many facilities would need extensive technological upgrades, incurring additional financial costs and time for installation and training. Continuous operations could also lead to increased operational costs, including higher utility bills, accelerated equipment wear and tear, additional staffing needs, and overtime compensation. Moreover, the safety risks associated with non-stop machinery operation and the potential for increased mechanical failures or human errors cannot be overlooked.

Despite these hurdles, extending operational hours might only partially address the capacity issue. Another critical problem is the absence of treatment facilities in certain regions, leaving them underserved. This gap leads to logistical backlogs, environmental concerns, and the need to transport waste over long distances, each with its unique challenges.

Waste Disposal

The infectious waste treatment adopted in Lebanon involves the use of steam and microwave sterilization, these techniques cut down the waste weight by 20% and the volume by 25%. Annually, the treatment of infectious waste results in approximately 3,867 tons of sterilized waste. The majority of this waste, coming from aec centers (Table 11):
- The waste resulting from Jisr el Wati and Saida is disposed of at the Costa Brava landfill, which has an approximately current capacity of 438,000 tons per year. Initially, Costabrava landfill has a planned lifespan to receive higher quantities but that was impacted by the crisis situation in Lebanon.

- Waste from aec Zahle is disposed in Zahle landfill, capable of handling 54,750 tons yearly. It is to be noted that prior to the landfill was receiving around 74,000 tons yearly.

- Abbasiyeh center relies on a local dumpsite to dispose the sterilized waste.

Table 11. Quantity of Sterilized Waste and Landfills Capacities (UNDP, 2021)

<table>
<thead>
<tr>
<th>Existing facility</th>
<th>Quantity of infectious waste treated (t/yr)</th>
<th>Quantity of sterilized waste (t/yr)</th>
<th>Current disposal location</th>
<th>Landfill capacity (t/yr)</th>
<th>Percentage of landfill capacity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aec Jisr wati</td>
<td>2,666</td>
<td>2,132</td>
<td>Costa Brava landfill</td>
<td>438,000</td>
<td>0.64</td>
</tr>
<tr>
<td>Aec Saida</td>
<td>884.7</td>
<td>707</td>
<td></td>
<td>54,750</td>
<td>1.6</td>
</tr>
<tr>
<td>aec Zahle</td>
<td>1,094</td>
<td>875</td>
<td>Zahle landfill</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Abbasiyeh</td>
<td>192.6</td>
<td>153</td>
<td>Abbasiyeh dump</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>TOTAL (t/yr)</td>
<td>4,837.3</td>
<td>3,867</td>
<td></td>
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</tr>
</tbody>
</table>

Despite these efforts, the Costa Brava landfill is approaching its maximum capacity. This has prompted the Lebanese Government to seek alternative municipal solid waste disposal sites in the BML region to avert a potential crisis. Given that sterilized waste constitutes less than 1% of the nation’s total MSW, creating separate landfills for this type of waste is not considered a practical element of infectious waste management plans.

A detailed plan for landfill capacity and expansion is outlined in the technical SWM committee’s masterplan, which was formulated in June 2020. Lebanon currently operates six sanitary landfills, distributed between the BML area, the north, and the Bekaa region. The masterplan proposes the addition of five new landfills to accommodate future needs. It’s noteworthy that landfills in Jdeideh and Costa Brava are nearing full capacity, thus highlighting the need for either expansion or the establishment of new landfills.

At present, the national landfill capacity stands at 2,775 tons per year, with an expected increase to 4,075 tons per year once the planned landfills come into operation. Consequently, the annual landfill capacity, currently at 1,012,875 tons, is projected to rise to 1,487,375 tons in the near future.
In Lebanon, the sterilized waste produced from both small and large waste generators is projected to constitute no more than 0.9% of the total landfill capacity. This relatively minor proportion indicates that integrating sterilized waste into the existing and planned network of sanitary landfills is a more practical approach compared to building new, specialized landfills exclusively for this type of waste. This strategy is contingent on the approval of the regulatory framework and the national strategy, which would allow for such disposal in existing municipal solid waste facilities. Furthermore, if the expansion of current landfill capacities is implemented as planned, the disposal of sterilized waste will not pose a significant risk within the country’s waste management system and ensures that sterilized waste is properly managed.

5.2.2.2 Cytotoxic, Pharmaceutical and Chemical Waste

5.2.2.2.1 Waste Collection

In Lebanon, the healthcare sector faces considerable challenges in the treatment and management of cytotoxic, pharmaceutical, and chemical waste, largely due to the absence of a comprehensive network for managing such waste and a reliance on individual interventions. The current practices center around exporting the waste or using on-site incinerators.

Companies such as Treveria, Solution, BlackForest Solutions, and RECYCLAMED are specialized in exporting hazardous waste, complying with international standards like those of the Basel Convention. However, the complexity and cost associated with this method have hindered its widespread adoption. As a result, a significant quantity of hazardous waste ends up in Municipal Solid Waste (MSW) streams or sewage systems, leading to serious environmental and health concerns.

On the other hand, facilities like Rafic Hariri University Hospital, Hotel Dieu, and AUBMC have resorted to on-site incineration. This approach, however, is marred by inadequate legal and regulatory frameworks. Many of these incinerators operate without valid permits, highlighting a broader issue of non-compliance with established standards and regulations in the management of hazardous waste.

5.2.2.2.2 Waste Handling/Treatment

Export of Waste

Currently, the most adopted technique for the disposal of mainly pharmaceutical and chemical waste is the export for treatment offshore; however, this process is complex and requires several steps. The main key steps are described below to provide an overview of the existing scheme:
1. Segregation and Storage: Once generated, cytotoxic, chemical and pharmaceutical waste must be segregated from other types of waste at the source. Segregation is crucial for ensuring that the waste is handled appropriately throughout the subsequent stages of its management.

2. Packaging: The segregated waste is then carefully packed into containers that are approved for such use, typically as per United Nations standards. These containers are designed to be secure and leak-proof to ensure safe handling and transportation. The packaging process must be done meticulously to prevent exposure and spillage.

3. Labeling and Documentation: After packaging, each container is labeled clearly with details about its contents, including hazard warnings and handling instructions. Alongside labeling, detailed documentation is prepared. This includes packing lists that describe the types of waste, quantities, and other relevant information. This step is crucial for regulatory compliance and the safety of all individuals who will handle these containers subsequently.

4. Compliance Check: Before the waste can be transported, it must be verified for compliance with relevant regulations and standards, such as those set forth in the Basel Convention. This step ensures that the waste is being managed in an environmentally responsible manner and in accordance with international laws.

5. Transportation Preparation: The packed and labeled waste is then prepared for transportation. This involves moving the containers to a designated area, ready for pick-up by a transport service. The transportation must be arranged with vehicles capable of safely carrying hazardous materials.

6. Export: The final step in the process is the export of the waste to a treatment facility abroad. This is done following the approval of necessary documents such as Trans Frontier Shipment (TFS) paperwork. The export is usually to countries that have specialized facilities for treating such hazardous waste according to international standards.

Figure 18. Containers for Cytotoxic Waste Export
Overview of the Current Services Providers

1. Solution

Solution, a subsidiary of Design Engineering Partners, was established as part of their Corporate Social Responsibility initiative to address the critical issue of cytotoxic and pharmaceutical waste management in Lebanon. This company is the first of its kind in the country to undertake the responsibility of exporting such waste to specialized treatment facilities in Europe, adhering to the Basel Convention regulations.

Solution does not possess its own storage or dispatch facilities. Instead, their activities are primarily conducted at the premises of their clients. They assist in the packaging, labeling, and storage of waste in UN-approved drums, and coordinate the collection and shipping of this waste once all necessary documentation and transport arrangements are finalized.

Engagement with waste generators begins with contract signing, followed by the initiation of export licensing processes. Solution collaborates with a Swedish disposal facility and handles all documentation required for export and transit country approvals, including preparing the Transfrontier Shipment of Waste (TFS) documents. The responsibility of purchasing UN-approved drums, packing, and labeling the waste lies with the waste generators. Solution then manages the shipment logistics to the treatment facilities.

To date, Solution has successfully shipped significant quantities of cytotoxic waste to Sweden, strictly adhering to specific waste category guidelines and ensuring the absence of mercury, radioactivity, and infectious materials in the waste. Efforts to ship waste to Cyprus are in progress, pending regulatory approvals.

The company also faces financial and logistical challenges, including varying export costs and the need for UN-approved drums, which are not included in the export cost. Their collaboration with the Syndicate of Hospitals in Lebanon through a Memorandum of Understanding highlights their commitment to training healthcare staff in waste management practices.

However, Solution encounters numerous challenges, including weak institutional governance, regulatory hurdles in obtaining Environmental Impact Assessment (EIA) approvals, financial constraints, and the lack of a cohesive national waste management strategy.

2. Treveria

Treveria Environment, operating in Lebanon, specializes in managing hazardous medical and industrial waste, collaborating with SARP Industries, a member of the Veolia Group. The company’s primary services include clean-up operations, repacking, storing hazardous waste, and exporting it to SARP Industries’ 75 treatment sites in Europe. Aimed at scientifically solving Lebanon’s hazardous waste problem, Treveria’s practices align with local and international environmental laws, focusing on exporting waste under the Basel Convention to facilities capable of processing it to international standards.
Having secured approval from the Ministry of Environment for the construction and operation of a medical waste storage facility in Fanar, Treveria now manages a facility for storing expired medicines and cytotoxic waste. This facility plays a critical role in protecting Lebanon’s environmental resources, like groundwater and surface water, from hazardous waste contamination. The facility is equipped with warehouses for different waste types and includes advanced storage systems with significant storage capacities.

Treveria’s operations encompass distributing new waste packaging to healthcare facilities, ensuring safe packing and proper labeling of hazardous waste. They also collect waste using a specially equipped truck, conforming to strict safety and environmental standards. At their storage facility, Treveria conducts rigorous inspections and stores the waste safely, while working on obtaining necessary documentation for waste export.

While they have stored significant quantities of cytotoxic waste, Treveria has faced challenges in exporting certain waste categories due to shipping constraints. However, they have successfully exported expired pharmaceuticals to Europe. Financially, the investment in their storage facility has been substantial, and the company has faced delays and financial losses due to the challenging economic situation in Lebanon.

Treveria has also established a Memorandum of Understanding with the Syndicate of Hospitals in Lebanon, underscoring its commitment to managing hazardous waste effectively. This agreement covers various aspects of waste management, including collection, repacking, documentation, and training for medical staff.

Looking forward, Treveria envisions integrating High Temperature Incineration (HTI) for hazardous waste treatment in Lebanon. They have explored possibilities for building or operating an incinerator, including upgrading existing facilities to meet international standards. However, various challenges have led to the postponement of these plans.

The challenges Treveria faces are substantial, including weak institutional governance, lack of law enforcement, difficulties in obtaining necessary approvals and licenses, and the severe financial crisis in Lebanon. These obstacles have hindered their expansion plans and made investments in the sector risky and less viable. Despite these challenges, Treveria continues to strive towards improving hazardous waste management in Lebanon, albeit with cautious future planning given the current economic and regulatory environment.

### 3. Recyclamed

RECYCLAMED is a French company that specializes in managing special wastes, primarily focusing on international transfers of hazardous waste to France for destruction in VEOLIA incinerators. The company adheres to the proximity principle, prioritizing treatment in Veolia facilities but considering closer incinerators when transport distances are significant. The primary method for waste destruction is thermal destruction at 1,200 degrees Celsius.
Operating since 2000, and active in the Lebanese market since 2010, RECYCLAMED’s operations in Lebanon have been remote, particularly since the Beirut Port Explosion in 2020. The company offers door-to-door services, starting from packaging the waste to providing an official destruction certificate to clients. Their process involves waste identification, validation and waste acceptance, quotation and contract signature, logistics, and provision of documentation or proof of destruction. All waste movements comply with the Basel Convention and European Regulation EC No. 1013/2006.

In the Lebanese market, RECYCLAMED caters to international clients like Pfizer, Mersaco, and Pierre Fabre, covering 80% of the market. The company primarily deals with pharmaceutical waste, medical devices, cosmetics, and smaller quantities of cytotoxic waste. They are also exploring new ventures, including working with clients like SANOFI and bidding for tenders with the UNIFIL for managing military waste.

The quantity of waste exported from Lebanon has been increasing each year. For instance, in 2021, Recyclamed shipped 64.5 tons of pharmaceutical waste in 8 shipments. The total cost for export and destruction varies based on the waste type, typically ranging from 1,200 to 1,600 euros per ton.

Looking ahead, Recyclamed plans to expand operations in Lebanon, particularly in managing hazardous and military waste and building a pretreatment platform for hazardous industrial waste. This plan aligns with European legislation and depends on site availability and Ministry of Environment approval. However, implementing an incinerator in Lebanon is challenging due to high capital expenditure.

Recyclamed has not been significantly impacted by Lebanon’s economic crisis, as transactions are conducted in euros in French accounts. One of the operational challenges they face is the treatment of infectious cytotoxic waste, which is constrained by international and European regulations requiring destruction within 72 hours. This requirement poses practical difficulties due to the distance factor and the time required for transport, affecting Recyclamed’s capability of exporting mixed waste classes.

4. Blackforest

BlackForest Solutions is a company that focuses on the packaging, notification management, transportation, and final disposal of cytotoxic wastes in Europe, along with consulting Lebanese hospitals about in-house hospital waste management. They have successfully completed four shipments of hazardous waste under the Basel Convention, totaling 25 tons to France and Germany.

The operations of BlackForest Solutions encompass a range of activities. They begin with site assessment and material sampling, where they record and examine available quantities, types of packaging, and specific waste compositions at various locations, including plants, interim storage facilities, and landfills for both hazardous and non-hazardous wastes. This is followed by analysis
and classification of waste, involving laboratory analyses and classification according to global standards such as Basel, EWC, IMDG, etc. This step is crucial, especially for mixed or contaminated waste types with unknown compositions. The company takes charge of on-site sampling, sample transportation, and final categorization of hazardous waste.

An essential part of their process is hazardous waste professional packaging. To comply with international packaging rules for hazardous waste transfers, BlackForest Solutions often repackages waste volumes on-site, providing UN-certified packaging materials to ensure safe interim storage.

Another key aspect of their operation is international logistic management. BlackForest Solutions coordinates and monitors hazardous waste logistics worldwide. This service includes transport notification, international maritime transports, and cargo services for national routes, particularly in crisis and development zones.

In instances of hazardous waste leaks during manufacturing, storage, or transport, such as mercury contamination, BlackForest Solutions offers emergency response services and remediation actions globally.

Finally, BlackForest Solutions provides a complete onsite service package for hazardous waste projects, leveraging their professional network to handle each specific situation and waste type.

Overall, BlackForest Solutions’ approach to managing hazardous waste is comprehensive and globally responsive, adhering to international standards and regulations while offering critical services in hazardous waste management.

**Main Observations**

The services provided by these companies, though crucial in managing hazardous waste, come with substantial costs. This financial aspect is particularly challenging for many healthcare facilities in Lebanon, especially given the country’s current economic context. The expensive nature of these solutions, largely due to the need for compliance with international standards, specialized handling, and transportation logistics, limits their accessibility to all waste generators. As a result, many healthcare facilities may resort to less expensive, but potentially less safe and compliant, methods of waste disposal, such as disposal in Municipal Solid Waste (MSW) streams.

In summary, while the companies like Treveria, Solution, BlackForest Solutions, and RECYCLAMED provide essential services in the management of hazardous waste in Lebanon, the high costs associated with their solutions present a significant barrier. This financial challenge underscores the need for more accessible, cost-effective, and sustainable waste management options in the healthcare sector.

**Overview of the Existing Incinerator in Rafik El Hariri Hospital**

Rafik Hariri University Hospital, prominently located on the southern outskirts of Beirut, is not only Lebanon’s largest public health facility but also a crucial center for healthcare waste management. Within its premises, the hospital hosts the Hariri Incinerator, a project approved by the Ministry of Environment in 2005. However, this facility has remained dormant since its establishment, creating a significant gap in the hospital’s waste management capabilities, especially for waste that necessitates high-temperature incineration.
The administration of Rafik Hariri University Hospital is responsible for managing the site and its installations, including the incinerator. To date, the facility has not been operational, presenting a major issue considering the hospital’s generation of specialized waste.

The incinerator, designed with a Hoval Type GG7 and a Seiler Flue Gas Cleaning system, had an intended capacity to process up to 1200 kg of waste daily for 6-8 hours. Its primary function was to handle various waste types, including infectious, cytotoxic, and pharmaceutical wastes.

A key limitation of the current incinerator is its inability to achieve the necessary operational temperatures. It reaches only up to 1000°C, which is below the 1200°C required for the complete destruction of cytotoxic substances, as outlined in EU directives, WHO recommendations, and the EU Commission Note 2020/C. This shortcoming poses significant environmental and health risks, particularly due to the potential release of hazardous cytotoxic vapors if operated below the required temperatures.

The site of the Hariri Incinerator, with its existing permits and infrastructure, offers a unique opportunity. It could serve as a strategic location for a national incinerator, addressing not only RHH’s waste management needs but also those of the wider region. This could be achieved either through an extensive upgrade of the existing facility to meet the necessary operational standards.
or by constructing a new, state-of-the-art incinerator. This project would enable the efficient and safe disposal of healthcare waste, crucial for both environmental protection and public health safety.

Conclusive Remarks

The management of pharmaceutical waste in Lebanon is facing several challenges, particularly when it comes to cytotoxic substances. While pharmaceutical companies are actively dispatching various medical waste quantities, there is a notable exception for cytotoxic waste, which requires specialized handling due to its highly hazardous nature. Current export services, which could potentially offer a solution for the treatment of such waste, are prohibitively expensive and thus not a viable option for many facilities.

Furthermore, the situation is compounded by the absence of a dedicated treatment process for infectious cytotoxic waste within the country. This gap in waste management infrastructure indicates a lack of a comprehensive system that could safely manage and dispose of this type of waste, which is crucial for preventing potential health risks to the population and the environment.

Additionally, the absence of an established collection network exacerbates the problem, leaving healthcare facilities without a reliable means to dispose of their hazardous waste. The lack of coordination and infrastructure suggests an urgent need for the development of a robust system that can handle the complexities of cytotoxic and other infectious waste streams, ensuring that they are managed in an environmentally sound and health-conscious manner.

5.2.2.3 Radioactive Waste

5.2.2.3.1 Waste Collection

In healthcare settings, the collection of short-lived radioactive waste is typically managed internally within the hospital. This waste, generated from various medical procedures and sources, does not require special external collection processes. Instead, it is stored on-site until its radioactivity decays to safer levels. Following this period of decay, it is then integrated into the appropriate waste streams for standard collection and disposal procedures.

Conversely, long-lived radioactive waste is sorted and temporarily stored within the hospital premises until it is ready for export.

5.2.2.3.2 Waste Handling/Treatment

Proper and safe disposal of radioactive waste is critical to minimize exposure risks to both individuals and the environment, with the overarching aim of keeping radiation exposure within safe, regulated limits to prevent short and long-term health and environmental consequences.

The Lebanese Atomic Energy Commission (LAEC) meticulously oversees the disposal of radioactive waste from healthcare facilities. This management involves a “delay and decay” strategy, where waste is securely stored until it loses significant radioactivity. The decay period varies, with some isotopes requiring a few days and others, like Iodine I-131, taking up to three months. After reaching safe radioactivity levels, the waste is treated as ordinary and disposed of in standard waste systems.

Healthcare facilities must adhere to rigorous guidelines for radioactive waste management. These guidelines include segregating different types of radioactive waste at the point of generation,
ensuring proper collection and handling in designated containers with clear labeling, and controlled storage in licensed facilities equipped with adequate safety measures. Detailed record-keeping of waste generation, storage, and disposal is also a critical component of the management process. Sealed sources, especially those used in radiotherapy and blood irradiators, are typically sent back to the supplier for appropriate disposal or recycling. In the case of high-dose rate brachytherapy with Iridium-192, these sources are securely stored before being returned to the supplier, with LAEC overseeing the process through authorization and licensing.

Regular inspections by LAEC ensure adherence to radiation safety regulations. The Commission also participates in repatriation missions for long-lived radioactive sources, sometimes with support from international organizations like the International Atomic Energy Agency (IAEA). Furthermore, efforts are made to replace high-risk sources, such as Cesium blood irradiators, with safer alternatives like X-ray machines, with the original sources being repatriated to their suppliers. The ultimate goal of these practices is to ensure public and environmental safety by maintaining radiation exposure within prescribed limits through careful handling, storage, and disposal of radioactive waste.

As conclusive remarks after comprehensive data analysis and information gathering, we can find that:

Healthcare waste management inefficiencies present significant challenges in Lebanon, as in many other countries. These inefficiencies can lead to environmental pollution, public health risks, and inefficient resource utilization.

Below are some of the challenges faced in healthcare waste management in Lebanon:

1. **Lack of completed Infrastructure**: Many healthcare facilities in Lebanon lack the infrastructure for safe and efficient waste management. This includes proper storage, segregation, treatment, and disposal facilities.

2. **Incomplete Regulatory Framework**: There may be gaps or inconsistencies in regulations governing healthcare waste management in Lebanon. This can lead to confusion among healthcare providers and inadequate enforcement of proper waste management practices.

3. **Limited Awareness and Training**: Healthcare staff may not receive adequate training on waste management practices, including segregation, handling, and disposal. This can result in improper disposal methods and increased risks to public health and the environment.

4. **Insufficient Financial Resources**: Healthcare facilities in Lebanon, particularly those in rural or underserved areas, may lack the financial resources to invest in proper waste management infrastructure and equipment.

5. **Informal Waste Handling Practices**: In some cases, healthcare waste may be handled informally by untrained personnel or informal waste collectors, leading to unsafe practices and increased risks of exposure to hazardous materials.

The master plan Potential Solutions may address:

1. **Strengthening Regulatory Framework**: Lebanon can strengthen its regulatory framework for healthcare waste management by implementing clear guidelines, standards, and enforcement mechanisms. This includes ensuring compliance with international best practices and standards.
2. **Investing in Infrastructure**: The government and healthcare facilities can invest in the development of proper waste management infrastructure, including waste segregation systems, treatment facilities (for all healthcare waste types), and safe disposal methods.

3. **Training and Capacity Building**: Healthcare workers should receive regular training on proper waste management practices, including segregation, handling, and disposal of different types of waste. This can help raise awareness and ensure compliance with best practices.

4. **Promoting Public Awareness**: Public awareness campaigns can educate healthcare workers, patients, and the general public about the importance of proper waste management practices and the potential risks associated with improper disposal.

5. **Encouraging Research and Innovation**: Lebanon can encourage research and innovation in healthcare waste management technologies and practices. This includes exploring environmentally friendly treatment methods and technologies for recycling or repurposing healthcare waste.

6. **Collaboration and Partnership**: Government agencies, healthcare facilities, NGOs, and the private sector can collaborate to address healthcare waste management challenges in Lebanon. This may involve sharing resources, expertise, and best practices to improve overall waste management systems.

By addressing these challenges and implementing effective solutions, Lebanon can improve healthcare waste management practices, reduce environmental pollution, and protect public health.
HEALTHCARE WASTE
BASELINE

06

PRIORITIES FOR MASTER PLANNING
6. PRIORITIES FOR MASTER PLANNING

Based on the comprehensive baseline analysis conducted for the Lebanese healthcare waste master plan, it is imperative to develop and implement a series of strategic initiatives to enhance the efficiency and effectiveness of healthcare waste management across the nation. These initiatives are designed to address the current challenges and future needs identified in the analysis, thereby contributing significantly to public health safety, environmental protection, and sustainable waste management.

Update of the Regulatory Framework: A key initiative is the thorough update of the existing regulatory framework governing healthcare waste management. The revisions should align national regulations with evolving international standards and best practices. The updated framework should encompass comprehensive guidelines for waste classification, handling, storage, transportation, treatment, and disposal. Emphasis needs to be placed on ensuring compliance with these regulations at all levels of healthcare provision, from large hospitals to small clinics, thereby standardizing HCW management across Lebanon.

Increase in Infectious Waste Treatment Capacities: Recognizing the growing volume and complexity of infectious waste, a significant expansion of treatment capacities is essential. This expansion will involve upgrading existing treatment facilities and/or establishing new ones equipped with state-of-the-art technology. These facilities should be designed to handle a variety of infectious waste streams effectively and safely, minimizing the risk of contamination and disease transmission. The capacity increase will also include training for personnel in advanced waste treatment processes and safety protocols.

Establishment of a Collection, Treatment, and Disposal System of Infectious Waste for Small Generators: A specialized system needs to be developed for the efficient collection, treatment, and disposal of infectious waste generated by small-scale healthcare providers, such as clinics, laboratories, and local pharmacies. This system will ensure that even the smallest waste generators comply with national waste management standards, thereby closing any gaps in the waste management chain. It should include convenient waste collection services, access to local treatment facilities, and clear guidelines on waste segregation and handling.

Proper Management of Cytotoxic, Chemical, and Pharmaceutical Waste: The master plan should also prioritize establishing a robust management system for cytotoxic, chemical, and pharmaceutical waste at the national level. This system will include specific protocols for the safe handling, storage, and disposal of these types of waste, which pose significant risks to human health and the environment. Specialized treatment methods, such as incineration or export, should be employed to render these waste types harmless.
Establishment of a Healthcare Waste Data System: An integrated data system for healthcare waste management is another critical component of the master plan. This system is crucial to facilitate the collection, analysis, and dissemination of data related to HCW generation, composition, treatment, and disposal. The data system needs to be instrumental in monitoring the effectiveness of waste management practices, identifying areas for improvement, and aiding in the planning of future initiatives. It will also serve as a platform for reporting and compliance monitoring with national and international standards.

Definition of Financing Schemes: To support these initiatives, the development of sustainable financing schemes is essential. These schemes will involve identifying potential funding sources for establishment of new infrastructure, and for the ongoing operation and maintenance of the infrastructure. They will also include mechanisms for financial incentives to encourage compliance with waste management standards and support for research and development in waste treatment technologies.

It is important to note that these recommendations are preliminary and should be further developed and refined in the master plan document. This development process will involve highlighting strategic milestones and incorporating insights from stakeholder consultation meetings. These consultations will ensure that the master plan reflects a wide range of perspectives and meets the diverse needs of all stakeholders involved in healthcare waste management in Lebanon. By engaging stakeholders in this process, the master plan will benefit from a wealth of experience and expertise, ensuring that the final plan is comprehensive, pragmatic, and attuned to the realities on the ground. This collaborative approach will also facilitate a sense of ownership and commitment among stakeholders, which is essential for the successful implementation of the plan.
7. REFERENCES

aec (2014). Guide de la gestion des Déchets d'Activités de Soins. aec


ELARD (2021). Provision Of Services For An Assessment Of Healthcare Waste (HCW) Management In Lebanon And Priority Interventions - Results Of Task II- HCW Legal And Policy Analysis


ELARD (2021). Provision Of Services For An Assessment Of Healthcare Waste (HCW) Management In Lebanon And Priority Interventions - Results Of Task V- Other Types Of HCW Management


HEALTHCARE WASTE
BASELINE

08

ANNEXES
8. ANNEXES

Annex 1 – Hydroclave H100 Datasheet

MODEL H-100

HYDROCLAVE ADVANTAGES

- Very low operating cost: almost all the steam is recycled.
- Complete waste dehydration, including liquid content of the waste.
- Low temperature steam process produces no harmful emissions
- Treats all infectious waste, including pathological waste
- Achieves 6 Log10 sterility, and meets or exceeds all international standards
- Site specific design/build services available
- Extensive User Training program
- Customer product support worldwide
- Compliant with all North American and EU regulations

OPTIONAL ACCESSORIES

Ask about our optional accessories designed especially to aid you in efficient plant and facility operation. From Bin Tippers/Lifts to shredders and testing equipment, Hydroclave Systems can provide you with a total equipment package custom designed to suit your specific and unique application.

CERTIFICATION

CSA, CE, UL, ASME

Specifications are subject to change without any notice or obligation on the part of the manufacturer. While due caution has been exercised in the production of this document, possible errors and omissions are unintentional.
# MODEL H-100

## DIMENSIONAL DATA

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## PERFORMANCE

### Consumptions*

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<td>Approx. electrical consumption per batch</td>
<td>16 - 17 kW</td>
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<td>Water Consumption per batch cycle</td>
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<td>Design Pressure</td>
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### Operating Ranges*

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<td>Pressure Ranges</td>
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## INSTALLATION REQUIREMENTS

- Water piping (city water)
- Drainage for waste waters
- Electrical Power Supply (Standard Wiring)

## CAPACITIES

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<td>Drive Motor (280v/460v/600v)</td>
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Actual operating conditions may vary, due to variations in waste density and material. For average capacities, please submit waste characteristics for analysis.

Specifications are subject to change without any notice or obligation on the part of the manufacturer. While due caution has been exercised in the production of this document, possible errors and omissions are unintentional.
Ecosteryl 250

Ecosteryl 250 is designed for service providers who want a sustainable solution for infectious medical waste treatment.

- Capacities: 250–300 kg/h
- Capacities: 2–7 t/day

100% Electric and ecological
Microwave is the most eco-friendly solution for infectious medical waste treatment. Proven disinfection at min. 6log<sub>10</sub> (reduction of 99.9999%).

Powerful shredder with an anti-blocking system and waste reduced by 80% of its volume.

Dry, decontaminated, unrecognizable and recyclable waste.

**Capacities**

The minimum processing capacity of Ecosteryl 250 is 250 kg per hour. This is 3334 liters/h with a density of 0.075 kg/liter.

Ecosteryl 250 is an ideal solution if you have to treat from 2 to 7 tons medical waste per day.

**Technical data – Ecosteryl 250**

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<td>15.5 tons</td>
</tr>
<tr>
<td>Type of process</td>
<td>Automatic and continuous process</td>
</tr>
<tr>
<td>Electrical powers</td>
<td>4 axes shredder, 37 kW power</td>
</tr>
<tr>
<td></td>
<td>Microwave generator, 24 kW power and 2450 MHz frequency</td>
</tr>
<tr>
<td>Average power consumption</td>
<td>60 kWh</td>
</tr>
<tr>
<td>Staff required</td>
<td>1 person can operate 2 machines</td>
</tr>
<tr>
<td>Installation, commissioning and training</td>
<td>On-site, by our team</td>
</tr>
<tr>
<td>Options</td>
<td>Remote monitoring via Wi-Fi or 4G</td>
</tr>
<tr>
<td></td>
<td>Automated container registration using barcode</td>
</tr>
<tr>
<td></td>
<td>Link to the R-steryl sorting center</td>
</tr>
</tbody>
</table>

**Certifications and approvals**

Contact: sales@ecosteryl.com

www.ecosteryl.com
T300 - Process volume capacity 350 L per cycle.

Our patented process is designed to shred and sterilize infectious waste by saturated steam. Shredding and sterilization are achieved in one fully enclosed and automated, stainless steel, system with no intermediate waste handling.

The contaminated waste is loaded into the upper chamber where a heavy-duty shredder reduces the waste into small pieces. Using gravity, the processed material drops into the lower treatment chamber.

After shredding, waste and all the inner parts of the machine are steam heated to 138°C (280°F) and pressurized to 3.5 bar (51 psi).

Sterilization is achieved by maintaining a temperature of 138°C (280°F) at the core of the waste for 10 minutes.

After the cooling process, the final product is safe to recycle or to dispose as ordinary waste. Waste are both sterilized (Microbial inactivation = 99%) and volume-reduced by up to 80%.

The 30 minutes duration of an average cycle process is fully automated and totally monitored. A computerized control system scans the process and automatically prints and records on a memory card a batch report at the end of each cycle with the essential sterilizing parameters for accurate record keeping.
### Technical specifications

**General Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (L x W x H)</td>
<td>270 x 210 x 380 cm</td>
</tr>
<tr>
<td></td>
<td>9.8 x 6.8 x 12.8 ft</td>
</tr>
<tr>
<td>Shipping Weight</td>
<td>2000 kg</td>
</tr>
<tr>
<td>Max weight when filled with water for a special hydraulic test</td>
<td>3100 kg</td>
</tr>
<tr>
<td>Stress</td>
<td>2 kg/cm²</td>
</tr>
<tr>
<td>Steam Pressure</td>
<td>8 bar</td>
</tr>
<tr>
<td>Max Steam Flow</td>
<td>170 kg/h</td>
</tr>
<tr>
<td>Compressed Air</td>
<td>6 bar</td>
</tr>
<tr>
<td>Electricity 380 V / 3-Phase</td>
<td>14 kW</td>
</tr>
</tbody>
</table>

**Operating Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Cycle Time</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Process Volume Capacity</td>
<td>350 liters</td>
</tr>
<tr>
<td>Average Waste Density</td>
<td>100 - 150 kg/m³</td>
</tr>
<tr>
<td>Average Process Weight Capacity</td>
<td>35 - 55 kg/cycle</td>
</tr>
<tr>
<td>Microbial Inactivation</td>
<td>10⁶</td>
</tr>
<tr>
<td>Waste Volume Reduction</td>
<td>80%</td>
</tr>
</tbody>
</table>

**Consumption / cycle**

<table>
<thead>
<tr>
<th>Consumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam</td>
<td>15 kg</td>
</tr>
<tr>
<td>Electricity</td>
<td>1.7 kWh</td>
</tr>
<tr>
<td>Water</td>
<td>25 liters</td>
</tr>
</tbody>
</table>
ANNEX 3 – TECHNICAL SPECS RHH INCINERATOR

Hoval AG Equipment Data

<table>
<thead>
<tr>
<th>Equipment Plant</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model number</td>
<td>V0180</td>
</tr>
<tr>
<td>Feeder</td>
<td>BS14</td>
</tr>
<tr>
<td>Primary chamber</td>
<td>GG7 (V0180)</td>
</tr>
<tr>
<td>Thermal reactor</td>
<td>TR8/1000°C /2S</td>
</tr>
<tr>
<td>Burner fuel</td>
<td>Diesel oil, 35S</td>
</tr>
<tr>
<td>Start – up burner</td>
<td>EL01A8</td>
</tr>
<tr>
<td>Reactor burner 1</td>
<td>EK3.35L-RO</td>
</tr>
<tr>
<td>Reactor burner 2</td>
<td>EK3.35L-RO</td>
</tr>
<tr>
<td>Burner</td>
<td>EL03.30-1DV</td>
</tr>
<tr>
<td>Hydraulic system</td>
<td>ND-LEFT</td>
</tr>
<tr>
<td>Control Panel</td>
<td>SBS 14 -UDC 1500</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>1000°C</td>
</tr>
<tr>
<td>Burning capacity</td>
<td>150 kg/hour</td>
</tr>
</tbody>
</table>

Technical data

A. Hydraulic system

Standard: BS14

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging chamber volume</td>
<td>m²</td>
<td>0.4</td>
</tr>
<tr>
<td>Width of charging aperture</td>
<td>mm</td>
<td>720</td>
</tr>
<tr>
<td>Length of charging aperture</td>
<td>mm</td>
<td>1120</td>
</tr>
<tr>
<td>Depth of charging aperture</td>
<td>mm</td>
<td>510</td>
</tr>
<tr>
<td>Hydraulic pump - Feed flow</td>
<td>L/min</td>
<td>15</td>
</tr>
<tr>
<td>- Operating pressure</td>
<td>Bar</td>
<td>60</td>
</tr>
<tr>
<td>- Maximum pressure</td>
<td>Bar</td>
<td>120</td>
</tr>
<tr>
<td>Capacity of hydraulic tank</td>
<td>Liters</td>
<td>60</td>
</tr>
</tbody>
</table>
### B. Primary chamber

<table>
<thead>
<tr>
<th>Unit Value</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usable volume primary chamber</td>
<td>m³</td>
<td>2.4</td>
</tr>
<tr>
<td>Thickness of steel envelope</td>
<td>mm</td>
<td>5</td>
</tr>
<tr>
<td>Length of charging aperture</td>
<td>mm</td>
<td>175</td>
</tr>
<tr>
<td>Temperature resistance</td>
<td>ºC</td>
<td>1400</td>
</tr>
<tr>
<td>Charging aperture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Width</td>
<td>mm</td>
<td>950</td>
</tr>
<tr>
<td>- Height</td>
<td>mm</td>
<td>1250</td>
</tr>
<tr>
<td>Weight</td>
<td>kg</td>
<td>4500</td>
</tr>
<tr>
<td>Ventilation combustion air requirement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Exhaust volume</td>
<td>m³/hour</td>
<td>5000</td>
</tr>
<tr>
<td>- Combustion air</td>
<td>m³/hour</td>
<td>1400</td>
</tr>
<tr>
<td>- Required air intake</td>
<td>m³/hour</td>
<td>6400</td>
</tr>
<tr>
<td>Cross section intake minimum</td>
<td>m²</td>
<td>1.0</td>
</tr>
<tr>
<td>Pressure difference inside/outside</td>
<td>Pa</td>
<td>5</td>
</tr>
</tbody>
</table>

### C. Primary air fan

Manufactured by: STAFA

Type: TKVO008

<table>
<thead>
<tr>
<th>Unit Value</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output volume</td>
<td>m³/hour</td>
<td>250</td>
</tr>
<tr>
<td>Total pressure at 20 C</td>
<td>Pa</td>
<td>1300</td>
</tr>
<tr>
<td>Noise level at 1m distance</td>
<td>dBA</td>
<td>71</td>
</tr>
</tbody>
</table>
## Unit Value

- **- Speed of rotation**  
  -/min  2900
- **- Power output**  
  kW  0.37
- **- Voltage**  
  V  220/380
- **- Current demand:**
  - Operation  A  2
  - Starting  6

*Motor for flaps Manufactured by Landis and Gyr – Type SQB71.1*
- **- Power output**  
  W  25
- **- Voltage**  
  V AC  24

## D. Start-up burner oil

*Burner manufactured by SB01 – Type EL 01 A.B*

<table>
<thead>
<tr>
<th>Unit Value</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating mode, number of stages</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Operating fuel</td>
<td>-</td>
<td>Diesel oil 35S</td>
</tr>
<tr>
<td>Calorific value</td>
<td>kWh/kg</td>
<td>11.86</td>
</tr>
<tr>
<td>Operating value</td>
<td>kW</td>
<td>60</td>
</tr>
<tr>
<td>- Minimum load</td>
<td>kW</td>
<td>60</td>
</tr>
<tr>
<td>- Maximum load</td>
<td>kW</td>
<td>83</td>
</tr>
<tr>
<td>- Recommended load</td>
<td>kW</td>
<td>60</td>
</tr>
<tr>
<td>Turndown ratio</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oil consumption</td>
<td>Kg/hour</td>
<td>1.2</td>
</tr>
<tr>
<td>- Minimum load</td>
<td>Kg/hour</td>
<td>7</td>
</tr>
<tr>
<td>Oil pressure</td>
<td>bar</td>
<td>12</td>
</tr>
<tr>
<td>Oil supply line</td>
<td>mm</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit Value</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burner motor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Speed of rotation</td>
<td>-/min</td>
<td>2820</td>
</tr>
<tr>
<td>- Power output</td>
<td>kW</td>
<td>0.15</td>
</tr>
<tr>
<td>- Voltage</td>
<td>V</td>
<td>220</td>
</tr>
<tr>
<td>- Current demand:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Operation</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>- Starting</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>
### E. Thermo – Reactor

**Type TR (0.5s/1000°C) – TR08**

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal flue gas volume (± 20%)</td>
<td>Nm³/h</td>
<td>1400</td>
</tr>
<tr>
<td>Volume of combustion zone</td>
<td>m³</td>
<td>0.91</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>°C</td>
<td>1000</td>
</tr>
<tr>
<td>Dwell time of the gases</td>
<td>seconds</td>
<td>2</td>
</tr>
<tr>
<td>Thickness of steel envelope</td>
<td>mm</td>
<td>6</td>
</tr>
<tr>
<td>Thickness of refractory cladding</td>
<td>mm</td>
<td>175-220</td>
</tr>
<tr>
<td>Temperature of resistance</td>
<td>°C</td>
<td>1650</td>
</tr>
<tr>
<td>Weight</td>
<td>Kg</td>
<td>-</td>
</tr>
</tbody>
</table>

### F. Reactor burner oil

Burner manufactured by: ELCO – Type: EK3.35L-RO

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating mode modulating</td>
<td>-</td>
<td>M</td>
</tr>
<tr>
<td>Operating fuel</td>
<td>-</td>
<td>Diesel oil 35S</td>
</tr>
<tr>
<td>Calorific value</td>
<td>kWh/kg</td>
<td>11.86</td>
</tr>
</tbody>
</table>

**Operating value**

- Minimum load | kW | 95  
- Maximum load | kW | 360 
- Recommended load | kW | 90  

**Turndown ratio**  
- 1:2.5

**Oil consumption**

- Minimum load | Kg/hour | 8  
- Minimum load | Kg/hour | 30.4  

**Burner motor**

- Speed of rotation | -/min      | 2800  
- Power output | kW | 0.55  
- Voltage | V | 220/380  

**Current demand:**

- Operation | A | 2.7  
- Starting | 8.1  

---

84 Healthcare Waste Baseline
ANNEX 4 – ESTIMATION OF SMALL GENERATOR PRODUCTION OF INFECTIOUS HEALTHCARE WASTE

In Lebanon, there is no accurate inventory of small healthcare waste generators. To estimate the generation of infectious waste from small generators such as veterinary clinics, laboratories, pharmaceutical industries, and clinics, the EPA 1990 methodology was followed, where a mathematical calculation can be derived based on several factors. For human small generators production, the quantities were estimated based on average of clinic visit and lab analysis per capita, where

- Gi: Generation of infectious waste from each type of small generator (laboratory, pharmaceutical industry, clinic).
- Np: Number of patients in a geographic zone
- Pi: Number of procedures or patients served by each type of small generator.
- Ri: Rate of infectious waste generation per procedure or per patient for each type of small generator.

The generation of infectious waste (Gi) from each type of small generator can be estimated by multiplying the number of procedures or patients (Pi) served by each type of small generator by the corresponding rate of infectious waste generation per procedure or per patient (Ri) to obtain the total generation of infectious waste (Gi) for each type of small generator.

To estimate the total generation of infectious waste from all small generators, sum up the individual estimates for each type of small generator:

For veterinary waste, a rough estimation was done conducting some interviews with veterinary hospitals in different regions.

For pharmaceutical industry and research Lab, a prorata of production was calculated based on the last 3 year overall production.
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