



HEALTH SECURITY
PARTNERS



ASSOCIATION FOR BIORISK
MANAGEMENT PAKISTAN

Laboratory Waste Management Guidelines

1st Edition 2026





Laboratory Waste Management Guidelines

1st Edition 2026

Association for Biorisk Management

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PREFACE AND ACKNOWLEDGMENTS

The development of the Laboratory Waste Management Guidelines (LWMG) represents a collaborative effort made possible through the contributions and support of numerous individuals and organizations. This initiative reflects a strong partnership among Health Security Partners (HSP), the Association for Biorisk Management (ABM), and the Pakistan Biological Safety Association (PBSA), united by a shared commitment to strengthening laboratory systems in Pakistan.

The initial concept and vision for this project were developed by Dr. Prasad Kuduvalli, Director of the Scientific Program at HSP, to enhance infectious waste management practices in human and veterinary laboratories. These guidelines are intended not only to support laboratory professionals but also to serve as a valuable resource for national stakeholders.

Prof. Dr. Shamsul Arfin Qasmi and Dr. Samreen Sarwar led the coordination of this effort from concept development through to the final, edited, and published document. The HSP team, including Dr. Jason Rao, Executive Director; Dr. Javed Khan, Program Director; and Cecelia Madsen, Program Manager, facilitated both virtual and in-person consultations to shape the guidelines and engage a diverse group of national and international authors and reviewers. Under Prof. Qasmi's leadership, a dedicated team of experts from HSP and ABM defined the scope, structure, and content of the LWMG.

A writeshop held in January 2024 in Karachi, Pakistan, served as a critical milestone in the development process. During this workshop, chapter authors presented and refined their drafts through detailed discussions with reviewers. The insights and feedback generated during this engagement were instrumental in shaping the final version of the guidelines. This collaborative process fostered a strong and productive community of practice grounded in shared expertise and mutual learning.

We extend our sincere appreciation to Dr. Javed Khan and Dr. Asad Ali Shah for their contributions to the veterinary section of the guidelines, developed under the One Health approach. This perspective underscores the interconnectedness of human, animal, and environmental health, ensuring a comprehensive framework for infectious waste management across sectors.

We are deeply grateful to all authors and reviewers whose expertise, dedication, and constructive feedback have significantly strengthened the scientific rigor and practical relevance of this document. Their contributions have been invaluable in ensuring the quality and applicability of these guidelines.

We also acknowledge with thanks the technical, administrative, and logistical support provided by Dr. Asghar Ali, Dr. Shaukat Khan, Natalie Grande, and Khushal Saleem Khan, whose efforts were essential to the successful completion of this work. We also acknowledge the use of ChatGPT for language enhancement of some portions of this text.

The first edition of the LWMG is designed to support the Pakistani laboratory community in strengthening and harmonizing infectious waste management practices. HSP and ABM envision this document as a living resource that will continue to evolve, incorporating emerging technologies and best practices to remain relevant and impactful.

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FOREWORD

As laboratory activities become increasingly complex and the infectious agents they handle become more diverse, properly managing laboratory infectious waste has become more crucial. This is essential for the safety and security of personnel, the environment, and public health. It also helps prevent the spread of communicable diseases, protects the environment, and ensures compliance with regulatory mandates. A comprehensive and standardized approach to laboratory infectious waste management is necessary, not just beneficial.

This document is a practical tool to assist laboratory personnel, biorisk management advisors, waste management officers, and facility managers in implementing best practices. By following these guidelines, they can ensure the safe, secure, and responsible handling of infectious waste from generation to final disposal, thereby contributing to a culture of safety, security, and responsibility in its management.

We have developed these guidelines based on the latest scientific research, industry standards, and regulatory requirements. These guidelines cover a broad range of topics, including current regulations, administrative framework, risk assessment, planning, and different stages of waste management processes, including environmentally preferred procurement (EPP), minimization, identification, segregation, packaging, labelling, storage, transportation, treatment, and final disposal. Furthermore, these guidelines emphasize the significance of roles and responsibilities, occupational health, personal protective equipment (PPE), emerging technologies, employee training, and emergency preparedness in maintaining a safe and secure laboratory environment.

The key objectives of these guidelines include:

- **Minimizing Risk:** Reducing the risk of infection and injury to laboratory personnel, waste handlers, and the public.
- **Environmental Protection:** Preventing environmental contamination through appropriate waste treatment and disposal methods.
- **Compliance:** Ensuring adherence to provincial, national, and international infectious waste management regulations.
- **Standardization:** Promoting consistent and standardized laboratory infectious waste management procedures to enhance safety and efficiency.

These guidelines are designed for clinical, research, academic, veterinary, and industrial laboratories. By following these guidelines, laboratories can maintain a high standard of safety and environmental responsibility while supporting the broader objective of protecting public health.

This document also covers veterinary, slaughterhouses, and aquaculture waste. The central concept of this document is to address gaps not currently covered by existing guidelines and regulations. The content aims to address laboratory-associated waste management challenges in developing countries and provide practical solutions at the grassroots level. As such, it will remain an asset for all research, clinical, and veterinary laboratories. Our vision is to create and publish a local-language version of the document (Urdu) for local audiences and to disseminate it across Pakistan.

This document is not a static set of rules but a dynamic resource that will evolve with advancements in scientific knowledge and changes in regulatory requirements. The first edition of this Laboratory Infectious Waste Management Guideline will be a helpful guide for private- and public-sector facilities operating at provincial and national levels and will serve as a reference for developing robust regulations for Laboratory Waste Management.

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DEFINITIONS

Anatomical waste: A category of waste that comprises human/animal body parts, unused blood products, body fluids, organs, and tissues. Examples include placentas and amputated body parts.

Biodegradable waste: A category of non-risk waste that can be composted. This includes leftover food or garden waste.

Biorisk management: The systematic process of determining, evaluating, and reducing the risks connected to biological agents or hazards to safeguard laboratory workers, the environment, and the community.

Biosafety: The WHO Laboratory Biosafety Manual defines it as “containment principles, technologies, and practices that are implemented to prevent unintentional exposure to biological agents or their accidental release.”

Biosecurity: The WHO Laboratory Biosafety Manual defines biosecurity as “principles, technologies, and practices that are implemented for the protection, control, and accountability of biological materials and/or the equipment, skills, and data related to their handling. Biosecurity aims to prevent unauthorized access, loss, theft, misuse, diversion, or release.”

Chemical waste: It comprises discarded chemicals generated during disinfecting procedures and cleaning processes, and laboratory reagents and solvents used in diagnostic and experimental work. These chemicals can be toxic, corrosive, flammable, reactive, poisonous, explosive, and shock-sensitive.

Contingency: A possible future event or circumstance that cannot be predicted with certainty.

Cytotoxic pharmaceutical waste: A category of waste that arises during the manufacture or use of pharmaceuticals with a cytotoxic effect. These materials contain mutagenic, carcinogenic, and teratogenic properties.

Decontamination: Process of reduction by chemical and/or physical means in the number of viable biological agents or other hazardous substances in space, on a surface or object(s) to an acceptable safe-to-handle level.

Disinfectant: An agent that can decrease the number of viable biological agents and spores on inanimate surfaces or in liquid to a level that makes them safe to handle. Disinfection eliminates or reduces dangerous microorganisms, including bacteria, viruses, fungi, protozoa, and spores, from surfaces, objects, air, or water.

Euthanasia in animal handling: The humane process of inducing a painless death in research animals to alleviate suffering.

Hazard: An object or situation that has the potential to cause harm.

Infectious waste: Waste that contains or is reasonably suspected to be contaminated with pathogens such as bacteria, viruses, parasites, or fungi and poses a risk of disease transmission to humans or animals.

Laboratory waste management: A management system used to develop and implement an organization's waste management policy and manage its risk and non-risk waste through setting objectives, planning activities, assigning responsibilities, implementing best practices, procedures, and processes, and allocating sufficient resources.

Laboratory waste: All the risk and non-risk waste generated from a teaching, research, manufacturing, and human or veterinary diagnostic laboratory.

Microbiological or biomedical laboratory: A room or building used for teaching, research, manufacturing, and/or diagnostic purposes, and involves direct or indirect manipulation and/or study of living organisms.

Non-risk laboratory waste: Non-risk laboratory waste includes waste items that do not pose a risk of disease transmission or other adverse health effects by chemical, radioactive, physical, or other types of hazards. This category mainly includes waste generated from the facility's administrative, housekeeping, packaging, and maintenance functions.

Pathogen: The WHO Laboratory Biosafety Manual defines a pathogen as a biological agent capable of causing disease or infection in humans, animals, or plants.

Personal Protective Equipment (PPE): Equipment and/or clothing that provides a physical barrier between the hazard and the person wearing it. Examples include gowns, gloves, footwear, masks, respirators, and goggles.

Pharmaceutical waste: It comprises pharmaceuticals that are no longer needed or expired, or any items exposed to them during their handling. This category includes non-hazardous, potentially hazardous, or hazardous pharmaceutical waste.

Radioactive waste: This type of waste includes liquids, gases, and solids contaminated with radionuclides with genotoxic effects.

Recyclable waste: A category of waste that can be recycled for an intended use. This includes items made of plastic, glass, paper, and metal.

Rendering: A thermal process that involves subjecting carcasses to high temperatures (ranging from 130 °C or 265°F) using pressurized steam, converting them into pathogen-free byproducts such as feed protein.

Risk assessment: A systematic process in which risk information(s) arising from the hazard(s) is collected and analyzed to support the risk management process.

Risk control: Reduction in the level of risk to an acceptable range using control measures such as engineering and operational controls, practices and procedures, PPE, and training.

Risk characterization: Process of estimating the likelihood and potential impact of a hazard by combining information from hazard identification and exposure assessment.

Risk evaluation: Process of comparing estimated risks with established criteria to determine whether the risk is acceptable or requires additional control measures.

Sharps: Any object used or unused, with pointed ends or edges that pose a puncture, wound, and/or infection hazard.

Standard Operating Procedures (SOPs): A set of documented and validated stepwise instructions for an organization's routine or repetitive activity.

Sterilization: This process is used to make a product completely free of viable biological agents, including spores.

Veterinary: It is a branch of medicine that deals with the prophylaxis, diagnosis, treatment, and management of diseases and injuries in animals.

Vivarium research facility: An enclosed space designed to harbor experimentally infected and other animals that may naturally harbor zoonotic infectious agents.

Windrow composting: The production of compost by piling organic matter or biodegradable waste, such as animal manure and crop residues, in long rows – windrows.

ABBREVIATIONS AND ACRONYMS

Abbreviation	Full Form
AI	Artificial Intelligence
BI	Biological Indicators
BRM	Biorisk Management
BSL	Biosafety Level
BSO	Biosafety Officer
BWM	Biological Waste Management
CAA	Clean Air Act
CFR	Code of Federal Regulations
CIs	Chemical Indicators
CWA	CEN Workshop Agreement
EHS	Environment, Health, and Safety
EPA	Environmental Protection Agency
EPP	Environmentally Preferable Purchasing
ERI Cards	Emergency Response Intervention Cards
FIFRA	Federal Insecticidal Fungicidal Rodenticidal Act
GBHCC	Gilgit Baltistan Healthcare Commission
HDPE	High-Density Polyethylene
HEPA	High Efficiency Particulate Air Filters
IBC	Institutional Biosafety Committee
IERC	Institutional Ethical Review Committee
IRE	Institutional Review Entity
ISO	International Organization for Standardization
IWM	Infectious Waste Management
KPHCC	Khyber Pakhtunkhwa Healthcare Commission
MDR	Multi-Drug Resistant
NEQS	National Environmental Quality Standards
OSHA	Occupational Safety & Health Administration
PEPA	Pakistan Environmental Protection Act
PHCC	Punjab Healthcare Commission
PI	Principal Investigator
POPs	Persistent Organic Pollutants
PPE	Personal Protective Equipment
PSDS	Patient Safety Data Sheets
R&D	Research and Development
RAM	Risk Assessment Matrix
RCRA	Resource Conservation & Recovery Act
RIA	Rapid Initial Assessment
RRR	Reduce, Reuse, Recycle
SDS	Safety Data Sheets
SHCC	Sindh Healthcare Commission
SOPs	Standard Operating Procedures
SUDs	Single Use Devices
UNEP	United Nations Environment Programme
UV	Ultra-Violet
WHO	World Health Organization
WMC	Waste Management Committee
WtE	Waste-to-Energy Technologies
XDR	Extensively Drug Resistant

SECTION 01

International and National Hazardous Waste Management Regulations

Faisal Hanif, Aamer Ikram

Research and biomedical laboratories are crucial in advancing biotechnology and science. However, generating and handling laboratory waste during the processes requires special attention and care. The government has a critical responsibility to establish regulations and enact laws to ensure the proper functioning of laboratories while prioritizing public and environmental safety. A practical and effective waste management system is essential for managing waste generated by these laboratories. This system should prioritize human health, occupational safety, and minimize environmental impact. It is crucial to entrust this task to specialized personnel trained in biological waste management. They should possess expertise in conducting risk assessments, accurately determining waste quantity and categories, and developing plans and strategies for waste collection, minimization, categorization, transport, treatment, and disposal. International conventions and regulations provide guidelines and invaluable tools for effective laboratory waste management. These global standards must be considered when formulating local policies or legislation, with a focus on environmental protection, occupational safety, and ongoing development. By following these standards, laboratories can implement proper waste management practices, promoting a safer and healthier environment.¹

1.1 International Organizations, Regulations, Standards, and Policies

Several international organizations, conventions, frameworks, and agreements provide overarching guidance on laboratory waste management, as summarized in Table 1-1.

Table 1-1. Conventions, Regulations, Policies, and Standards for Biological Waste Management

Organizations, Conventions, and Frameworks	Summary of Key Provisions
Basel Convention	- Established in 1989, an important treaty governing the movement of infectious and other hazardous waste across international borders to prevent environmental and human health hazards.² - Outlines safe procedures for waste management and disposal. - As of June 2024, 191 parties, including Pakistan, have ratified the convention. These countries are committed to safeguarding the health of healthcare workers and the environment from hazardous waste.
Bamako Convention	- An agreement adopted in Bamako in 1991 and enacted in 1998 by 12 African nations.³ - Regulates the import and transboundary movement of hazardous waste into Africa and aims to protect human health, the environment, and communities. - Prohibits the dumping of hazardous wastes in African countries' oceans and inland waters.

Stockholm Convention	• A universal treaty adopted in 2001 that targets persistent organic pollutants (POPs), which can be generated as laboratory waste and are harmful to the environment and human health.⁴ • Aims to reduce and eliminate POPs and promote the best environmental practices regarding source minimization, recycling, collection, segregation, waste transport, and waste management training. • Prioritize alternative processes with similar efficacy but generating fewer POPs, including microwave treatment, steam or dry heat sterilization, biological treatment, and alkaline hydrolysis.
World Health Organization (WHO)	• Recommends that countries follow waste management protocols using an evidence and risk-based approach.^{5,6} This approach involves conducting risk assessments before choosing methods for healthcare waste management. • Suggests the following strategies: • Short-Term Strategies - Select medical devices without polyvinyl chloride (PVC) and promote recycling. - Find recycling options for glass and plastic, promote alternatives to incineration, and develop new technologies. • Medium-Term Strategies - Compare the risks of waste exposure and incineration and conduct risk assessments. • Long-Term Strategies - Promote final waste disposal using non-incineration technologies.
Occupational Safety and Health Administration (OSHA), USA	• Establishes regulations to protect workers from occupational exposure to hazardous waste and materials in the workplace.⁷ • Provides requirements for safe waste handling, training, and occupational safety practices. • Specifies standards for the use of personal protective equipment (29 CFR 1910.132–138), housekeeping (29 CFR 1910.22), and sanitation (29 CFR 1910.141). • Requires implementation of Exposure Control Plans under the Bloodborne Pathogens Standard (29 CFR 1910.1030). • Includes standards for hazard communication and emergency response under 29 CFR 1910.1200, 1910.120, and 1926.65.
Environmental Protection Agency (EPA), USA	• Incinerator operations must follow EPA standards for gaseous emissions.⁸ • The regulations outlined in the Federal Insecticidal, Fungicidal, and Rodenticidal Act (FIFRA) must be adhered to when employing chemicals to dispose of medical waste.⁹
UN Sustainable Development Goals (SDGs)	• Joint Monitoring Program of WHO/UNICEF covers healthcare waste management under SDG–6 as an indicator of sanitation in such facilities. • SDGs 3, 6, and 12 reinforce Water, Sanitation, and Hygiene (WASH) services to be available in healthcare facilities by 2030, which includes safe healthcare waste management involving segregation, collection, transportation, treatment, and waste disposal.¹⁰

1.2 National Organizations, Regulations, Standards, and Policies

1.2.1 National Hazardous Waste Management Policy

Laboratory waste management is a multifaceted issue requiring cooperation among various entities. The National Hazardous Waste Management Policy (NHWM), published in 2022, is a significant milestone in addressing the issues of hazardous waste management and mandates the involvement of federal, provincial,

and local health regulatory bodies in the implementation process. A national-level implementation committee has been established to oversee the execution of the policy's measures.¹¹

This policy aims to regulate hazardous waste at both global and national levels, emphasizing an environmentally sound approach throughout the waste life cycle, from generation to disposal; however, it is not specific to infectious waste and includes it as one of the several hazardous waste categories. By implementing this policy, Pakistan aims to safeguard public health, protect the environment, and contribute to global efforts in managing hazardous waste effectively.

1.2.2 Hospital Waste Management Rules

The Government of Pakistan established Hospital Waste Management Rules in 2005 under S.R.O. 1013 (I)/2005, section 31 of the Pakistan Environmental Protection Act, 1997 (XXXIV of 1997).^{12,13} These waste management regulations were developed to safeguard the environment, specifically under the Environmental Protection Act. All healthcare facilities, hospitals, and research institutions must comply with these standards and regulations to properly manage and dispose of hospital waste.

- In addition, the Environmental Protection Agency has approved specific regulations under the Sindh Environmental Protection Act, 2014 (VIII of 2014).¹⁴ Schedule I outlines proper waste disposal protocols, and laboratory owners must obtain approval for their waste management procedures from the Agency under section 17.
- Other regulations at the provincial level include the Hospital Waste Management Rules 2022 for Islamabad,¹⁵ the Khyber Pakhtunkhwa Hospital Waste Management Rules 2018,¹⁶ and the Punjab Hospital Waste Management Rules 2014.¹⁷

1.2.3 Provincial Healthcare Commissions

The following provincial authorities have waste management guidelines focused on hospital and clinic medical waste or enforce Minimum Service Delivery Standards (MSDS) for healthcare facilities, which include waste management as one of the licensing requirements:

- Sindh Healthcare Commission (SHCC)¹⁸
- Khyber Pakhtunkhwa Healthcare Commission (KPHCC)¹⁹
- Punjab Healthcare Commission (PHCC)²⁰
- Balochistan Healthcare Commission²¹
- Gilgit-Baltistan Healthcare Commission (GBHCC)²²

Additionally, the following regulations and rules have been formulated to cover other hazardous wastes apart from biohazardous waste:

- National Environmental Quality Standards (NEQS)-Pakistan for Municipal and Liquid Industrial Effluents and Gaseous Emissions, 2000²³
- Guidelines for Disposal of CFL Light Bulbs, 2010²⁴
- Sectoral Guidelines for Environmental Reports, Major Chemical and Manufacturing Plants, 1997²⁵
- Self-Monitoring and Reporting by Industries Rules, 2001-Amended²⁶
- Environmental Samples Rules, 2001²⁷
- Pollution Charge for Industry (Calculation and Collection) Rules, 2001²⁸

The regulatory frameworks should adequately address the occupational health and safety requirements of laboratory personnel and other stakeholders involved in the management of infectious laboratory waste. These regulations establish essential requirements for the safe segregation, storage, transportation, treatment, and final disposal of laboratory waste to minimize risks to workers, the public, and the environment. In the absence of detailed local guidelines, laboratory waste should be managed in accordance with applicable international and national regulations and recognized best practices to ensure safe and compliant waste management. Where there is a conflict between national or international laws, regulations, standards, or guidelines, the local requirements applicable to the organization shall prevail.

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SECTION 02

Risk Assessment

Ali Ahmad Sheikh, Furqan Kabir

Biological laboratories and healthcare facilities generate substantial amounts of hazardous waste daily. This waste may contain infectious agents, toxins, chemicals, and other potentially harmful substances that pose risks to healthcare personnel, waste handlers, the public, and the environment. Effective management of such waste requires a risk-based approach that involves systematically identifying hazards, assessing associated risks, and implementing appropriate measures to reduce them to acceptable levels. The World Health Organization (WHO) recommends using structured risk assessment processes to identify and manage biological risks throughout waste handling and disposal activities.¹

2.1 Biosafety Risk Assessment

Effective management of infectious waste relies on a structured and rigorously implemented risk assessment process. This process should systematically identify potential hazards and evaluate both the likelihood of occurrence and the severity of their consequences in the event of exposure. The impact of these risks extends to a wide range of stakeholders, including healthcare workers, laboratory personnel, waste handlers, and veterinarians. Additionally, inadequate management can adversely affect the environment, surrounding communities, and sectors such as agriculture and aquaculture, underscoring the need for a comprehensive and preventive approach. As outlined in the WHO Laboratory Biosafety Manual, risk assessment is a structured process comprising five key steps.² These steps include:

1. Gathering information
2. Evaluating risks
3. Developing a risk control strategy
4. Selecting and implementing risk control measures
5. Reviewing the risks and risk control measures

2.1.1 Hazards and Risks Associated with Laboratory Waste

Improper handling of hazardous waste can lead to several health risks at every stage of the waste management cycle, from generation and segregation to transport, treatment, and final disposal. To classify these risks, the International Committee of the Red Cross (ICRC) has identified five categories:³



To mitigate these risks, strict adherence to approved handling, containment, and disposal procedures is essential. Inadequate handling of chemicals, pharmaceuticals, and other hazardous waste streams can result in burns, toxic exposures, and environmental pollution.⁴ Similarly, improper management of radioactive waste may lead to serious health consequences, including radiation injuries, as well as long-term environmental contamination. These risks (see Table 2-1) underscore the importance of implementing standardized procedures, appropriate training, and the use of suitable protective measures throughout the waste management process.

Table 2-1. Examples of Hazards and Risks Associated with Waste Management Processes

Process	Possible Hazard	Potential Risks
Segregation	Infectious/sharps waste Insufficient training Unavailability of PPE Failure to use PPE properly Absence of SOPs Non-compliance with SOPs Lack of designated waste containers Overfilled waste containers Disposal of liquid waste into sinks Leakage of biohazardous waste bags	Infections and injuries Infection transmission Spread of microorganisms through municipal waste in the community Environmental contamination with infectious substances Contamination of the sewage system Contamination of water bodies
Storage	Lack of a waste storage area Presence of rodents in the area Inadequate electrification Weak access control Absence of record-keeping Open spaces used for storage Storage of infectious and general waste at the same place Waste decomposition due to prolonged storage	Infections and injuries Release and spread of infectious substances into the environment Theft or misuse of waste materials Fire breakouts Contamination of water sources with infectious waste
Transport	Insufficient awareness Lack of appropriate biohazard symbol labelling Disorganized stacking of waste containers Lack of record-keeping Waste spillage	Infections and injuries Environmental pollution Theft and misuse of used PPE, sharps, cannulas, and other materials
Treatment	Improper treatment methods Lack of a dedicated autoclave Lack of validation of waste treatment method Use of expired chemical neutralizers Insufficient contact time Use of low-quality, diluted, or unsuitable disinfectants Failure to use PPE during waste handling	Infections and injuries Acute or chronic health effects due to exposure to chemicals Contamination of agricultural soil and aquaculture areas
Final disposal	Inefficient incinerator operation and calibration Inadequate landfilling practices ^{5,6} Landfilling near water runoff areas	Emission of toxic gases into the environment Contamination of agricultural soil and aquaculture areas

2.1.2 Gathering information and Risk Evaluation

Risk assessment should be conducted as a team effort, bringing together individuals responsible for and knowledgeable about different aspects of the waste management system. The team should include representatives from management and operational levels to ensure a comprehensive understanding of the organization's procedures and workplace practices. The effectiveness of the risk assessment depends on the completeness, accuracy, and relevance of the information provided by the team. A well-coordinated team approach helps ensure that all potential hazards are properly identified and evaluated. Information to be collected should cover facility layout and infrastructure, equipment and tools used, personnel who may be exposed to risk, potential biological, chemical, and physical hazards, and all stages of waste handling processes.

2.1.3 Qualitative Matrix for Risk Evaluation

In quantitative terms, risk can be understood as a function of the probability of occurrence and the severity of its outcomes:

$$R = f(L, C)$$

where R represents risk, L denotes likelihood, and C represents consequences.

A cross-sectional checkboard system can be used to evaluate risks, with likelihoods plotted on the Y-axis and consequences on the X-axis. The overall risk is calculated by assessing the relationship between likelihood and consequences using a matrix table (Figure 2-1).

		Overall, Hazard Severity/Consequences				
		No Effect (1)	Minor (2)	Major (3)	Hazardous (4)	Catastrophic (5)
Likelihood of Exposure	Very Unlikely (1)	Very Low 1 x 1 = 1	Very Low 1 x 2 = 2	Low 1 x 3 = 3	Low 1 x 4 = 4	Medium 1 x 5 = 5
	Unlikely (2)	Very Low 2 x 1 = 2	Low 2 x 2 = 4	Medium 2 x 3 = 6	Medium 2 x 4 = 8	Medium 2 x 5 = 10
	Possible (3)	Low 3 x 1 = 3	Medium 3 x 2 = 6	Medium 3 x 3 = 9	Medium 3 x 4 = 12	High 3 x 5 = 15
	Likely (4)	Low 4 x 1 = 4	Medium 4 x 2 = 8	Medium 4 x 3 = 12	High 4 x 4 = 16	Very High 4 x 5 = 20
	Very Likely (5)	Medium 5 x 1 = 5	Medium 5 x 2 = 10	High 5 x 3 = 15	Very High 5 x 4 = 20	Very High 5 x 5 = 25

Figure 2-1. Risk Assessment Matrix

2.1.4 Developing a Risk Control Strategy and Selecting Risk Control Measures

The risk control strategy should be developed in consideration of available resources, operational capacity, and any institutional or contextual constraints. Control measures must be practical, feasible, and sustainable within the specific setting. While some institutions may have the financial and technical capacity to upgrade infrastructure or invest in new equipment, others may need to implement alternative measures that are effective yet more cost-efficient. Accordingly, the risk control strategy should prioritize interventions based on their feasibility, risk-reduction potential, and overall impact. This ensures that identified risks are managed through realistic and appropriate actions, while maintaining safety standards and supporting continuous improvement in biomedical waste management practices. Table 2-2 shows examples of accidental exposure and/or release of infectious waste, along with appropriate control measures for the identified risks. It illustrates the nature of the waste produced, the potential hazards of the waste, possible routes of transmission, the types of diseases that may result from incidental exposure, and potential control measures.

Table 2-2. Nature of Waste, its Impact, and Control Measures

Type of Waste	Potential Hazards	Routes of Transmission	Potential Risks	Control Measures
Infectious waste	Contaminated blood Feces from infected patients Respiratory secretions from infected patients	Contact Parenteral Ingestion Inhalation	Infection with HIV, HBV, HCV, and brucellosis Typhoid fever, enteritis, cholera, poliomyelitis Tuberculosis, anthrax, rabies	Proper segregation and collection Use of PPE Development of SOPs for safe handling Development of emergency response procedures
Sharps	Needles, broken glassware, ampoules, scalpel blades, lancets, vials	Punctures Cuts	Injury, infection	Collection in sharps containers Use of PPE Development of SOPs for safe handling Development of emergency response procedures
Pharmaceutical and chemical waste	Chemical and pharmaceutical substances (flammable, corrosive, toxic, cryogen, or explosive)	Contact Absorption Inhalation Ingestion	Intoxication, injuries, burns	Packaging in specific containers Dedicated treatment facilities Use of proper PPE Safety Data Sheet (SDS) availability Development of SOPs for safe handling Development of emergency response procedures
Pathological waste	Tissue waste, removed organs, amputated body parts, placentas	Contact Parenteral	Infection	Collection in properly color-coded bags Use of proper PPE Development of SOPs for safe handling Development of emergency response procedures
Radioactive waste	Solid, liquid, and gaseous waste contaminated with radionuclides	Contact	Headache, dizziness, vomiting, irradiation	Placement in proper color-coded containers (made of lead, if required), sealed, marked, and indicated with the international radioactive symbol Use of proper PPE Development of SOPs for safe handling Development of emergency response procedures

Animal waste	Urine/faeces from infected animals	Ingestion Contact	E. coli infection, cryptosporidiosis, hookworm infection, hydatid disease, psittacosis	Collection in infectious waste bags or containers marked as regulated waste
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Risk assessment should be reviewed at regular intervals and whenever there are changes in procedures, operations, or risk conditions, to ensure that control measures remain effective and appropriate. Periodic evaluation helps verify that existing risk controls continue to adequately address identified hazards and adapt to emerging risks. Routine review also supports continuous improvement in biomedical waste management practices, ensuring sustained compliance, safety, and operational effectiveness.

2.2 Biosecurity Risk Assessment

Biosecurity is a set of measures aimed at safeguarding biological materials from theft and misuse and countering the intentional release of such materials.⁷ In waste management, biosecurity is particularly relevant because of the potential risks associated with the deliberate mishandling and improper disposal of biological waste materials. Laboratory biosecurity, like biosafety, should be based on scientifically credible and intellectually substantive methodologies, achieved by proactively identifying vulnerabilities and threats, and assessing potential risks. This approach is crucial to prevent risks from escalating, to enhance security, and to prevent illicit use or release of laboratory infectious waste.

Biosecurity risks are assessed by considering the likelihood of security breaches and their consequences. For a biosecurity risk assessment, potential threats associated with waste management processes are identified to understand the threat environment; the likelihood and consequences of biosecurity breaches are estimated; and the risks of potential security breaches, such as intentional disease transmission and environmental contamination, are assessed. Some of the factors that contribute to an increased likelihood of biosecurity risks include:

- Lack of capacity to conduct biosecurity risk assessment and implement risk-appropriate control measures
- Insufficient monitoring and enforcement of security regulations
- Lack of awareness and training of waste management personnel

At the institutional level, risk-based mitigation strategies include implementing stringent waste management protocols, training waste management personnel in biosecurity measures, and enhancing surveillance and monitoring.

At the national level, biosecurity risks associated with hazardous waste can be managed by developing national and international regulations governing biosecurity in waste management, setting compliance requirements for waste generators, transporters, and disposal facilities, facilitating coordination between waste management authorities and public health agencies, and emphasizing the importance of community engagement and public awareness campaigns.

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Checklist - Risk Assessment

Sr. No.	Description	Yes	No	N/A	Remarks
Nature of work					
1.	Research				
	Diagnostic				
	Veterinary				
	Academic				
	Others (please specify)				
Agent hazards					
2.	Risk Group 1				
	Risk Group 2				
	Risk Group 3				
	Risk Group 4				
	Route of transmission				
	Infectious Dose (ID ₅₀)				
	Host range				
	Stability in the environment				
	Exotic/indigenous				
	GMOs/cell cultures				
	Preventive measures available				
	Treatment available				
	Others (please specify)				
Procedural hazards					
3.	Agent concentration				
	Suspension volume				
	Procedures that produce aerosols/droplets				
	Sharps use				
	Animals use				
	Others (please specify)				
Risk level					
4.	Very low				
	Low				
	Moderate				
	High				
	Very high				
Biosafety level determined through risk assessment					
5.	BSL-1				
	BSL-2				
	BSL-3				
	BSL-4				

	Risk assessment review responsibility				
6.	Biosafety professional				
	Institutional Biosafety Committee (IBC)				
	Subject Matter Experts (SMEs) Or an equivalent resource				
Risk-based application of the hierarchy of controls					
7.	Elimination/substitution				
	Engineering controls				
	Administrative controls				
	Good Microbiological Practices and Procedures (GMPPs)				
	Personal Protective Equipment (PPE)				
Evaluation of staff proficiency in safety practices in					
8.	BSL-1				
	BSL-2				
	BSL-3				
	BSL-4				
Verification and certification of safety equipment					
9.	Biosafety cabinets				
	Centrifuge safety cups				
	Sealed rotors				
	Fume hoods				
	Animal cages				
	Malfunctioning equipment				
	Others (please specify)				
Risk communication					
10.	Top management/administration				
	Institutional biosafety committee				
	Scientific management				
	Laboratory personnel				
	Waste handlers and support staff (housekeeping and janitorial staff)				
	Safety officers or occupational health personnel				
	Others (please specify)				
Review and verification of risk mitigation measures and documentation					
11.	Regular review of the effectiveness of risk control measures				
	Documentation of the risk mitigation measures				

SECTION 03

Administrative Framework for Laboratory Waste Management System

Shamsul Arfin Qasmi, Luis Alberto Ochoa Carrera

Effective management of infectious waste is a critical component of laboratory operations. Ensuring its safe handling, segregation, and disposal is essential to protect laboratory personnel, surrounding communities, public health, and the environment. A well-defined administrative framework provides the structural basis for managing infectious waste generated during routine laboratory activities.^{1,2} It establishes clear roles, responsibilities, and procedures to ensure compliance with safety standards and regulatory requirements. This framework should be designed to:

- Identify and define stakeholders, their responsibilities, and duties
- Create a biowaste management plan for laboratories engaged in human, animal, and agricultural activities
- Explain the cost factors affecting biowaste disposal
- Outline emergency response procedures
- Establish and enforce training programs for all relevant personnel to properly handle related risks

The laboratory waste management system can be broadly categorized into two main components, as shown in Figure 3-1. This division helps clarify responsibilities, improve organization, and support effective planning and implementation of waste management practices.

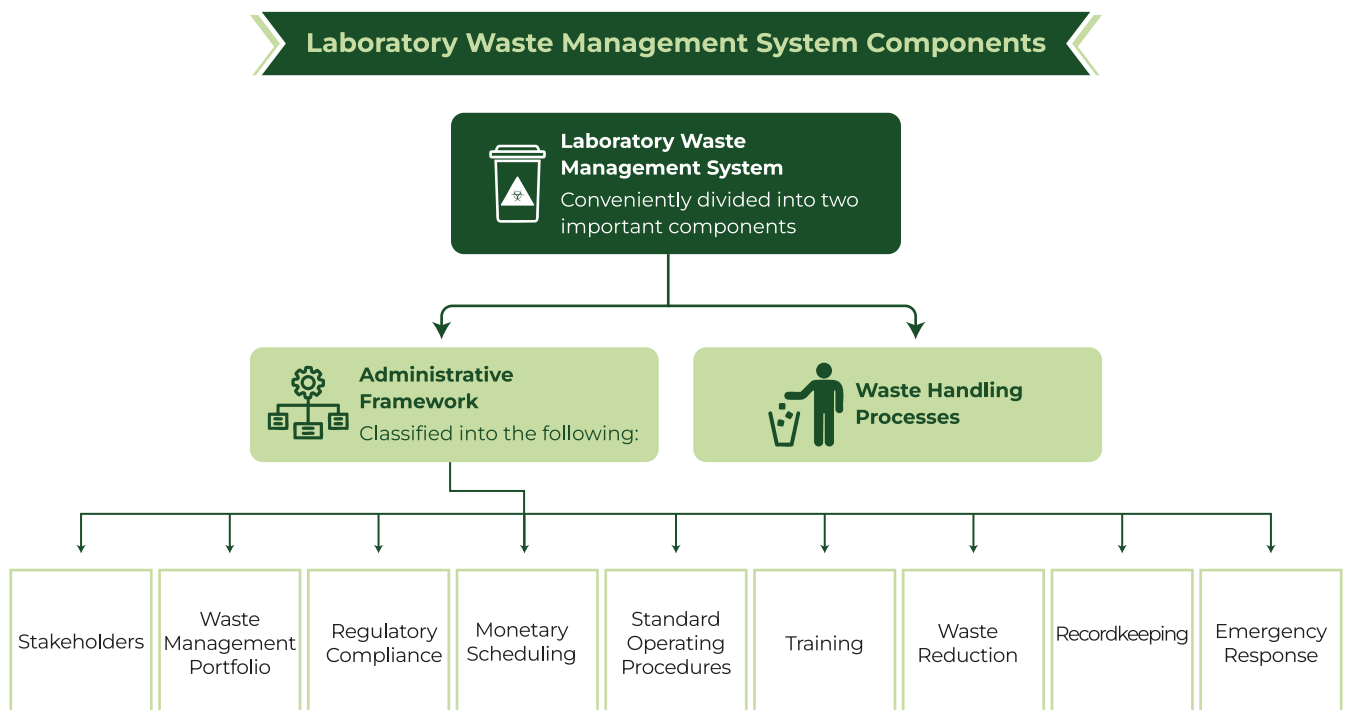


Figure 3-1. Administrative Framework of a Laboratory Waste Management System

3.1 Stakeholders

Effective management of hazardous laboratory waste requires clearly defined roles and coordinated efforts among all relevant stakeholders. Each individual or group helps ensure that waste is handled safely, efficiently, and in compliance with established standards. The key responsibilities within a laboratory waste management system are outlined below:

- a. **Laboratory Director:** Holds overall accountability for the safe management of biomedical waste. This includes ensuring adequate resource allocation, developing and approving institutional policies and guidelines, and overseeing their implementation.
- b. **Principal Investigator (PI):** Plays a central role in risk assessment and capacity building. The PI's expertise in handling specific agents (e.g., pathogens and toxins), along with the use of Safety Data Sheets (SDS) and laboratory equipment, supports informed decision-making and promotes safe practices within the team.
- c. **Biosafety Officer:** Provides oversight on biosafety matters and supports or reviews risk assessments conducted by the PI. This role includes developing standard operating procedures (SOPs) for waste management and delivering training to laboratory and support staff to ensure adherence to safe and compliant practices.
- d. **Laboratory Manager:** Oversees day-to-day laboratory operations and ensures compliance with institutional and regulatory requirements. Responsibilities include addressing operational issues (such as equipment maintenance, including autoclave validation) and maintaining overall laboratory safety.
- e. **Biomedical Engineer/Technician:** Supports the design and maintenance of engineering controls related to waste management. This includes maintaining waste transport systems, monitoring storage conditions (e.g., temperature control), and ensuring proper functioning of autoclaves, incinerators, and other biosafety equipment through preventive and corrective maintenance.
- f. **Community Members:** Engagement with the local community is important for transparency and trust. Including community representatives in discussions or committees and addressing their concerns about potential environmental and health risks help foster mutual understanding and responsible waste management practices.

3.1.1 Overview of Stakeholders' Responsibilities at a Glance:

- Identifying all those responsible for the management of waste
- Conducting risk assessment
- Making decisions on the procurement of equipment
- Determining the effects of specific equipment selection choices
- Monetary scheduling
- Writing and implementing SOPs
- Managing biological waste management processes
- Keeping correct waste disposal records
- Emergency response planning
- Complying with institutional and regulatory requirements
- Contingency planning
- Developing training based on institutional plans or SOPs for handling and treating waste
- Annual refreshing training
- Minimizing injuries, increasing awareness, maintaining compliance, and cultivating accountability and a team approach

3.2 Laboratory Waste Management Portfolio

- The laboratory waste management portfolio (Figure 3-2) is structured with the laboratory director at the helm, supervising the activities of the laboratory manager.
- The laboratory manager is directly responsible for the correct management of the waste generated from the laboratories with different activities and risks.
- The structure will also incorporate a biosafety advisor or officer, a waste management officer, or an infection control advisor to tackle ongoing challenges in managing laboratory waste across various biosafety levels, including levels 2 and 3 (and level 4 where applicable)
- The laboratory director must appoint an official responsible for developing the laboratory waste management plan and for the day-to-day operation and monitoring of the waste disposal system.³

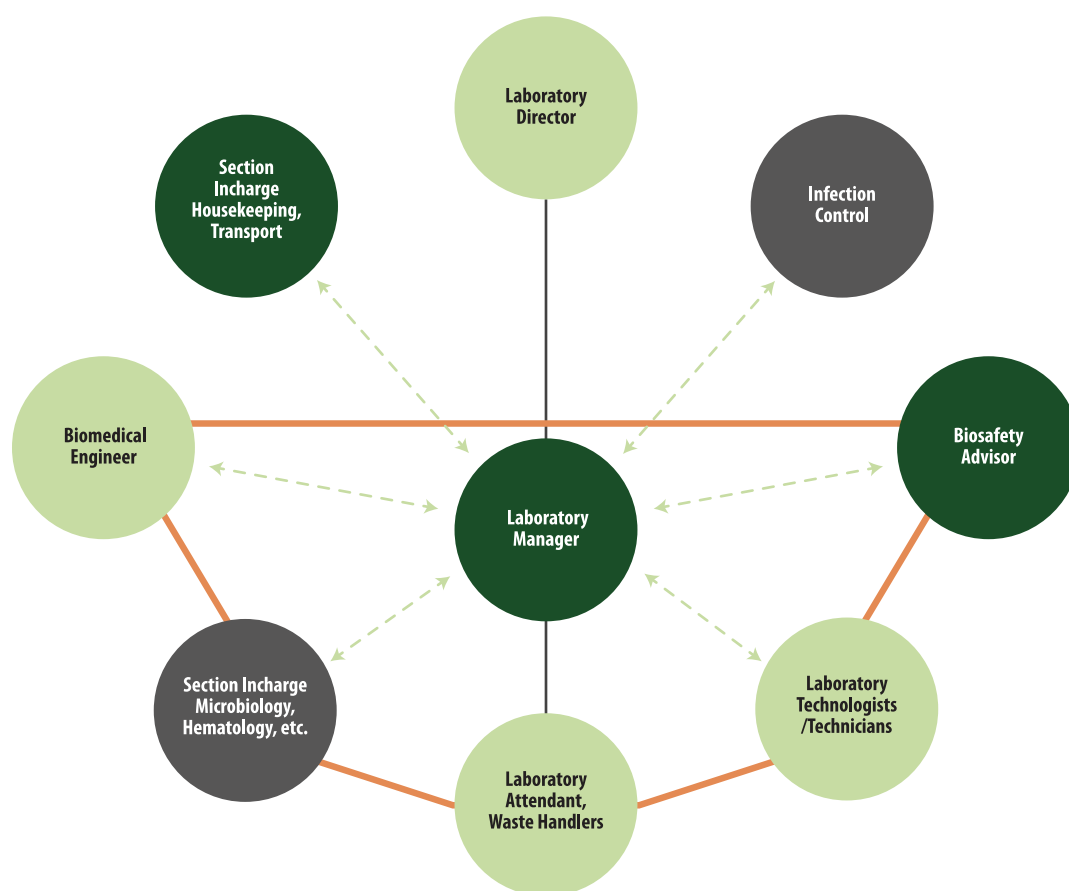


Figure 3-2. Laboratory Waste Management Portfolio⁴

Dotted lines depict liaison paths, while solid lines indicate line-management paths.

3.3 Regulatory Compliance

It is important to ensure that an organization is aware of its regulatory obligations at the provincial, national, or international levels and that it develops its waste management system in compliance with these regulations. Each regulatory layer can make operating procedures more stringent and should be considered while conducting risk assessments, developing risk control strategies, and conducting periodic performance reviews.⁵ Organizations often need help interpreting several regulations, particularly if one compliance requirement conflicts with another rule. Globally available guidance and international agreements are discussed in the first section of these guidelines.

3.4 Monetary Scheduling

Monetary scheduling in the administrative framework for laboratory waste management involves allocating and managing financial resources to ensure effective handling and disposal of laboratory waste. This framework encompasses:

- Budgeting
- Cost estimation
- Procurement of equipment
- Ordering of services
- Financial monitoring and reporting

It aims to optimize resource utilization while adhering to regulatory requirements and maintaining sustainability. Efficient financial planning in this context ensures that adequate funds are allocated across all stages of waste management. This includes the collection, segregation, treatment, and disposal, as well as promoting safety, compliance, and cost-effectiveness in laboratory operations.

3.5 Standard Operating Procedures (SOPs)

Standard Operating Procedures are step-by-step instructions that laboratory administration prepares to help staff perform routine operations. An SOP aims to achieve routine performance competency, quality efficiency, and homogeneity. They strive to reduce communication disagreements, improve conformity, and implement best practices in the laboratory environment. SOPs are also crucial for ensuring the safety of laboratory and housekeeping personnel. They outline accurate steps for handling, segregating, coding, storing, treating, and disposing of various types of waste while reducing the risks posed by infectious waste, which can lead to exposure to biohazardous materials, accidents, and potential harm to individuals, the community, and the environment. SOPs should usually include the following standard institutional norms:

- Details on the nature and function of the SOPs.
- Terms of Reference (TOR) for personnel working within and outside the Laboratory.
- Equipment and consumables needed for work-related tasks.
- Step-by-step, understandable directions for completing well-defined tasks, including biosafety and biosecurity procedures, effective primary barriers, and facility design requirements.
- Purchase request forms in accordance with institutional formats for supply chain maintenance.
- Incident report forms for waste management incidents for corrective and preventive actions. An incident reporting form template is provided in Appendix A.
- Resources and references required for waste management.

Standard operating procedures (SOPs) should be developed in clear, user-friendly language tailored to the intended audience. Where appropriate, this may include using local languages and/or visual aids (e.g., diagrams or pictograms) to ensure comprehension and effective implementation. Any updates on operational improvements should be communicated immediately to the relevant people, and the updated SOP should be distributed to stakeholders accordingly.

3.6 Training

Training is essential in laboratory waste management to ensure safety, sustainability, and compliance with the established standards. Effective training programs are critical in educating laboratory staff, housekeeping personnel, and janitorial staff about the proper containment, handling, treatment, and disposal of various laboratory waste types and should consider the following:

- Identification of all persons responsible for waste management who need training, such as laboratory personnel, housekeeping/janitorial personnel, and so on
- Training based on infectious waste management guidelines, safety protocols, institutional plans, and SOPs for the handling, treating, and disposing of waste

- Training employees before starting work that involves biohazardous waste
- Training focused on raising understanding, maintaining compliance, and cultivating accountability and team approaches to minimize injuries
- Annual refreshing training - hands-on and guided in the classroom
- Regular training and simulation exercises to enhance personnel preparedness and emergency response effectiveness

The training and drills should cover the following critical areas, along with additional topics identified through training needs assessments and risk assessments:

- Emergency response procedures, including emergency evacuation
- Safe handling of hazardous waste, including sharps, and awareness of associated hazards
- Spill management, including its simulation exercises
- Needle stick injury response
- Fire safety
- Ergonomics
- Rapid initial assessment and the use of contingency measures

3.7 Waste Reduction

It is crucial to prioritize waste reduction for a multitude of reasons. This includes the protection of the following:

- Environment
- Improvement of Occupational Health and Safety (OHS)
- Cost savings and decreased liabilities
- Adherence to regulations
- Fostering better community relations

Organizations can achieve positive and sustainable outcomes by taking recycling initiatives and embracing the principles of reduce, reuse, and recycle (the Three R's).

3.8 Recordkeeping

Recordkeeping is a systematic process by which facility records are shaped, noted, maintained, shredded, or disposed of. A recordkeeping system should create a way to collect and manage all required regulatory compliance and institutional documentation. Records can be kept electronically or as hard copies. Some examples of facility records are:

- Policy documents (include copies of laboratory waste management policies and procedures)
- SOPs and plans
- Training records
- Audits & inspections (internal or external) records
- Maintenance records
- Incident reports, including accidental spills, exposures, or other occurrences involving infectious waste
- Corrective actions and improvements made in response to audit findings
- Inventory of waste streams generated in the laboratory, including details on waste categorization, quantity, and disposal methods
- Waste manifests and disposal certificates
- Maps of waste collection routes, evacuation routes, and spill containment resources
- Others based on the local requirements

This arrangement also ensures their preservation by approved staff only for evidence purposes, accurate and practical updating, timely availability, and controlled access.

3.9 Emergency Response/Contingency Plan

The WHO recommends performing a Rapid Initial Assessment (RIA) of an accident linked to a given waste.^{6,7} During RIA, a team of stakeholders determines the unpredictable situation in real-time. An emergency management plan outlining SOPs, training requirements, and service disruption contingency measures helps staff prepare for incidents and accidents and better respond to them immediately.

What if...

- Suddenly, the autoclave is out of order.
- The waste collection truck failed to arrive as planned.
- Mixed waste is created; no outsourcing authority wants to collect it.
- Housekeeping workers are infected with a needle stick by untreated biohazardous waste containers.
- Biohazardous bags are torn during transport, resulting in significant spills.

The first steps towards responding to these kinds of scenarios are:

- Follow an established plan for communication by identifying whom to notify in an emergency and how to contact each responsible person

Next steps:

- Emergency management, such as spill cleanups
- Medical guidance, surveillance, and emergency maintenance

Further details are available in Section 11, which focuses on emergency preparedness and contingency planning.

3.10 Four Principles of Biological Waste Management

Several principles governing the safe management of hazardous waste are embedded in international agreements.⁸ These principles should be considered when formulating national guidelines or regulations for the management of laboratory infectious waste:

- The "polluter pays" principle asserts that all waste producers bear legal and financial responsibility for the safe and environmentally sound treatment and disposal of the waste they generate.
- The "precautionary" principle is a compelling health and safety protection guideline. When the magnitude of a particular risk is unknown, it should be presumed significant, and appropriate measures should be planned to safeguard health and safety.
- The "duty of care" principle mandates that individuals involved in handling or managing hazardous waste, substances, or associated equipment are morally responsible for exercising the utmost care in performing their duties.
- The "proximity" principle recommends that the treatment and disposal of biological and hazardous waste occur at the nearest possible location to its source to minimize the dangers or risks associated with transportation. In alignment with a similar principle, each community should recycle or dispose of the waste it produces within its local territory.

This administrative framework can provide a comprehensive approach to laboratory waste management, promoting compliance, sustainability, and biosafety. Regularly reviewing and updating the documents and continuous training and awareness sessions will help laboratories manage infectious waste more effectively while protecting laboratory and housekeeping staff, the community, and minimizing environmental impact.

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Checklist - Risk Assessment

Sr. No.	Description	Yes	No	N/A	Remarks
1.	Regulatory compliance has been observed and implemented.				
2.	Documentation of the waste management processes is completed.				
3.	Monetary scheduling has been done and approved.				
4.	Specific equipment selection choices have been reviewed and approved.				
5.	Decisions on the procurement of equipment have been made.				
6.	Waste reduction strategies comply with regulations.				
7.	All individuals accountable for waste management have been identified.				
8.	Standard Operating Procedures (SOPs) have been developed and approved.				
9.	Standard Operating Procedures (SOPs) have been communicated.				
10.	Accurate disposal records are maintained.				
11.	Training programs for handling and treating the waste have been developed.				
12.	Annual waste management training is practiced and documented.				
13.	An emergency preparedness plan has been developed and practiced.				
14.	A contingency plan has been developed and practiced.				

SECTION 04

Laboratory Waste Management Planning

Faheem Shahzad, Shamsul Arfin Qasmi

Laboratory waste management planning involves designing and implementing a systematic, comprehensive approach to managing waste generated by biological activities.¹ It aims to ensure that the waste is handled, stored, transported, treated, and disposed of safely and in an environmentally sound manner while minimizing costs and risks. This helps prevent infections, injuries, pollution, and the spread of drug-resistant microorganisms, and addresses biosecurity issues that may result from improper management of biological waste. Laboratory waste management planning in laboratory settings requires the following:

- Establishing a clear waste management policy and obtaining administrative support
- Developing a strong rationale for waste management planning
- Establishing a Waste Management Planning Committee
- Reviewing the regulatory landscape
- Setting the mission and objectives

Completing these steps will align key stakeholders and equip them to address the multifaceted aspects of waste management effectively.

4.1 Developing a Waste Management Plan

Creating an effective Waste Management Plan involves several essential steps (Figure 4-1) to ensure an efficient and compliant waste management system in laboratory facilities.² These steps include:

- **Baseline Establishment**
 - Conducting an initial assessment to gather data and creating detailed diagrams of waste flows
- **Review of Baseline Data**
 - Assessing existing data to identify key needs, potential risks, and common challenges, while also evaluating the current infrastructure and availability of waste management equipment
- **Prioritization and Goal Setting**
 - Prioritizing issues, setting goals, evaluating available technologies, and developing detailed procedures
- **Waste Minimization Plan**
 - Developing strategies aimed at minimizing waste through prevention, reduction, reuse, recycling, composting, bio-digestion, rendering, and energy recovery³
- **Training, Safety, and Security Measures**
 - Conducting comprehensive training programs and implementing safety protocols, including biosafety and biosecurity controls essential for safeguarding workers' health
 - Providing adequate PPE, implementing engineering controls, and securing storage and transport
 - Regularly reviewing and updating biosecurity measures to address evolving threats and ensuring the plan's effectiveness
- **Regular Review, Audit, and Updates**
 - Establishing a structured system for ongoing monitoring, auditing, record-keeping, reporting procedures, and continuous improvement mechanisms to drive adherence to standard waste management practices

- o Planning to facilitate necessary revisions to adapt to evolving standards and advancements⁴

- **Adherence to Regulatory Standards**

- o Aligning with national and international waste management laws, standards, and guidelines for ensuring compliance and ethical waste management practices⁵

- **Participatory Infectious Waste Management Planning Approach**

- o Stakeholder Consultation: Organizing consultation sessions involving departmental staff and relevant stakeholders to gather input on proposed practices, identifying required resources, transitioning timelines, and appointing environmental advocates and waste management representatives from various departments
- o Raising Awareness and Engagement: Increasing stakeholders' awareness of the importance of effective waste management, encouraging active participation and collaboration in planning, and fostering interest in adopting new practices and technologies

- **Documenting and Finalizing the Waste Management Plan**

Documenting and finalizing comprehensive documentation to ensure effective dissemination of all relevant aspects among departments, culminating in an easily navigable waste management plan

An inclusive approach to planning establishes a sustainable, compliant waste management system. It ensures the plan is well-informed and garners stakeholders' support for effective implementation.

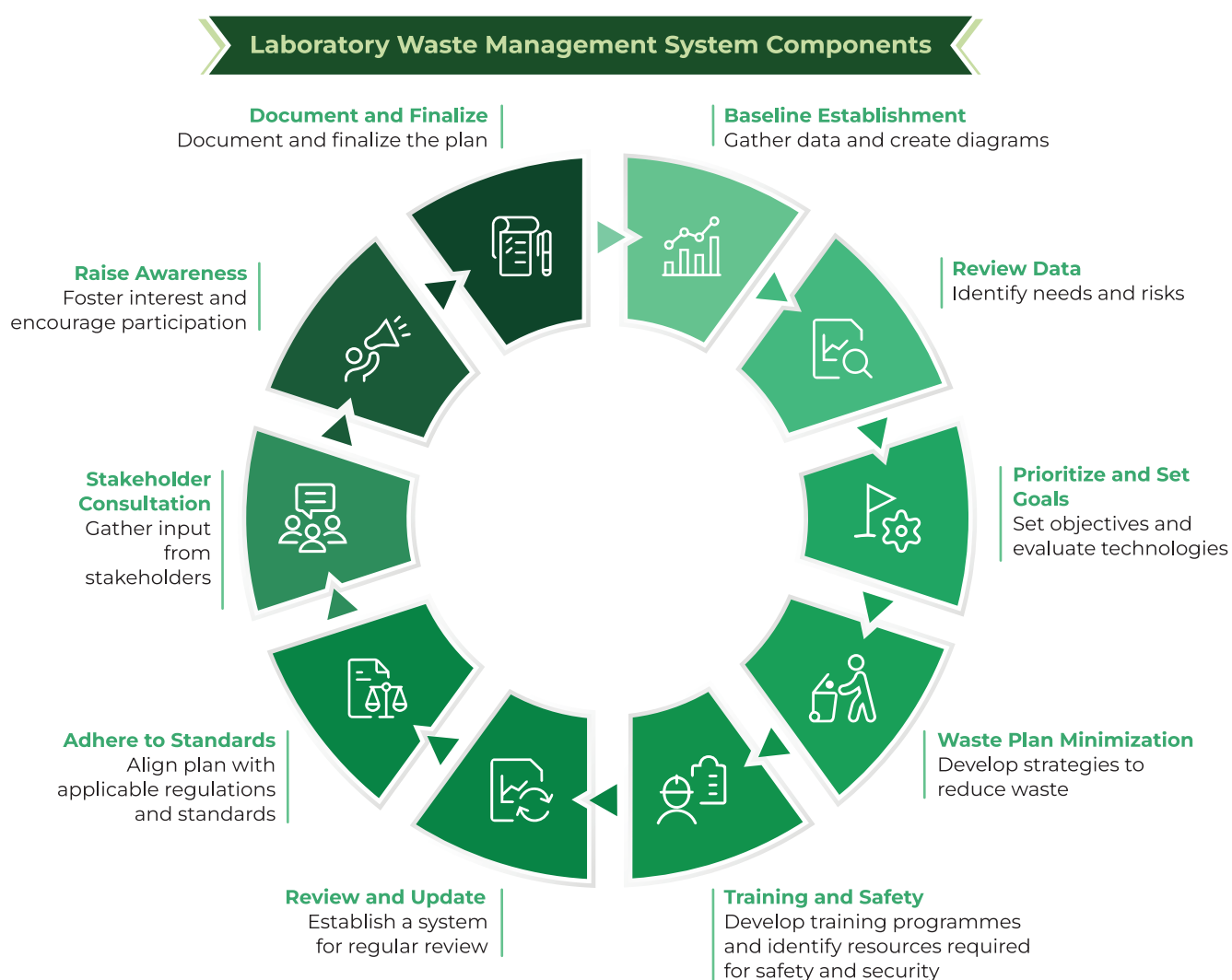


Figure 4-1. Developing a Laboratory Waste Management Plan

4.2 Additional Considerations When Developing a Waste Management Plan

- **Anticipating Future Growth and Expansion**
 - o Considering a facility's growth trajectory for an effective waste management plan
 - o Anticipating increased lab work, patient intake, facility size, or new services to reduce the need for constant revisions and ensure the plan's longevity and effectiveness
- **Assessing Effectiveness and Impacts**
 - o Assessing current methods for cost and environmental impacts while evaluating potential changes for cost savings and ecological sustainability for effective waste management
- **Reusables versus Disposables Evaluation**
 - o Conduct a comprehensive evaluation of the usage of reusable and disposable materials to minimize waste generation without compromising patient safety
 - o Strike a balance between resource conservation and community well-being by exploring safe and efficient reusable alternatives
- **Embrace Environmentally Friendly Technologies**
 - o Use eco-friendly waste treatment technologies such as plasma pyrolysis, gasification, autoclaving, and ozone disinfection
 - o Promote sustainability, ensure compliance with regulations, and align with global goals
- **Implementation of Incentives and Punitive Actions for Compliance**
 - o Build an incentive program to encourage waste management engagement and implement punitive actions to ensure SOP compliance

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Checklist – Laboratory Waste Management Planning

Sr. No.	Phase	Description	Yes	No	Remarks
1.	Preparation Phase	Mission and objectives are aligned.			
		Waste management policy and administrative support are in place.			
		Rationale has been established.			
		The Laboratory Waste Management Planning Committee is functional.			
		The Regulatory Landscape has been reviewed.			
2.	Development Phase	An initial assessment has been conducted to establish a baseline.			
		Laboratory Waste Management needs, risks, and issues have been identified.			
		The waste flow map has been established.			
		Laboratory Waste Management equipment and infrastructure have been evaluated for safety.			
		Improvement targets have been identified.			
		Standard Laboratory Waste Management practices have been established.			
		Technological evaluation and selection have been made.			
		A waste minimization plan is active.			
		Training and safety measures have been provided and communicated.			
		Regular review, audit, and updates have been adopted.			
		Applicable regulatory standards are regularly updated to reflect current requirements.			
		Input and feedback from relevant stakeholders have been obtained.			
		The stakeholders' awareness and engagement process has been followed.			
3.	Final Phase	Finalization and documentation of the Laboratory Waste Management Plan is complete.			

SECTION 05

Laboratory Waste Management Processes

Samreen Sarwar, Saeed Khan

Healthcare providers generate a significant amount of waste, with 75-90% classified as non-hazardous and suitable for disposal through regular municipal waste disposal methods. The remaining waste is classified as hazardous and poses risks to public health and the environment. However, the proportion of hazardous waste can vary significantly between different types of laboratories. For example, a clinical diagnostic laboratory performing histopathology, hematology, or microbiology work produces different types and proportions of waste than a research laboratory. When creating a waste management plan, it is essential to consider these variations to determine waste collection frequency and timings, size and capacity of waste containers and storage areas, selection of treatment and disposal methods, and other necessary equipment such as biohazard bins and waste collection trolleys to handle respective quantities of waste.

The laboratory waste management follows a series of planned steps, starting with Environmentally Preferable Purchasing (EPP) and waste minimization, followed by segregation, packaging, labelling, collection, transportation, treatment, and ultimate disposal (Figure 5-1). Each step is crucial in ensuring that biological waste is managed safely and responsibly. Proper execution of these steps minimizes risks to public health and protects the environment from contamination.

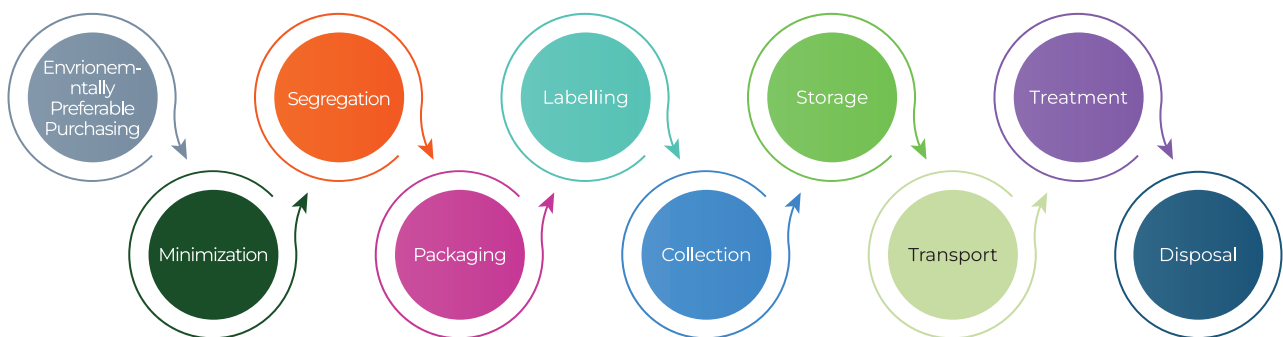


Figure 5-1. Biological Waste Management Processes

5.1 Green Procurement and Environmentally Preferable Purchasing

Implementing green procurement, also known as Environmentally Preferable Purchasing (EPP), can help select items with reduced environmental impact or that can be reused/recycled wherever possible. Addressing the environmental implications proactively during the procurement phase is more cost-effective than dealing with pollution-related issues downstream.¹ For this purpose, an EPP team should be established, comprising environmental experts, materials management specialists, central services personnel, clinical staff, facility staff, and waste management experts. This team should ensure the effective development and implementation of EPP practices. Green procurement practices encompass acquiring energy-efficient equipment and materials, collaborating with vendors that have established EPP policies, and prioritizing options for recycling, remanufacturing, or responsible disposal.²

5.2 Minimization

Every laboratory manages its waste until it is correctly disposed of. The greater the amount of hazardous waste produced, the higher the potential risks to the environment and human health; therefore, implementing a waste minimization program for both contaminated and non-contaminated waste is recommended. This approach is preferable as it provides a solution at the source rather than trying to address the problem after it has occurred.³

A waste minimization program should take into account the following factors:

- **Inventory and Stock Management**
The laboratory's inventory must be managed efficiently to prevent wastage of expired sera, blood products, reagents, chemicals, and pharmaceuticals. At the time of purchase, an item's expiration date should be cross-checked with its per-day or per-week usage. An item likely to expire before its intended use should not be purchased and must be managed on a first-in, first-out basis (FIFO).
- **Product Selection**
Products with minimum packaging layers and no unnecessary items or accessories should be preferred. For example, single-use items should be replaced with reusable alternatives, and non-essential items that do not contribute to the experiment's success should be avoided. Some accessories can be reused across different kits for similar or related purposes, thereby minimizing waste.
- **Supplier Collaboration**
Suppliers are essential stakeholders and responsible partners in a waste minimization plan. They must be able to deliver small quantities of products quickly and accept the return of unopened products, providing you with the flexibility you need.
- **Method Selection**
Appropriate cleaning, disinfection, testing, and documentation practices should be implemented in a way that reduces the generation of waste. Physical cleaning and disinfection methods are preferred over chemical methods. In some instances, electronic documentation can be preferred over paper documentation due to its ease of storage, retrieval, and sharing, and environmental benefits (Table 5-1).

These waste minimization practices should be encouraged in all laboratories and related departments, along with proper employee training.⁴ Furthermore, the supplier, product, and method selection criteria should be documented in purchase procedures, policies, and the waste management plan. An in-depth understanding of the types and quantities of waste will help set quantitative (quantity of waste) and qualitative (substituting items to produce less hazardous waste) targets.

Table 5-1. Types of Wastes and Possible Waste Minimization Solutions	
Waste Type	Possible Solution
General Waste	Promote recycling and segregation to divert recyclable materials from the general waste stream, thus reducing the volume of waste
Paper and Cardboard Waste	Encourage electronic health records and document management systems to reduce the use of paper and cardboard and promote double-sided printing and recycling
Electronic Waste (E-Waste)	Refurbish or recycle old medical equipment and electronic devices to extend their lifespan
Pharmaceutical Waste	Reduce the volume of expired and unused medications through better inventory management and disposal practices

Regulated Medical Waste (Biohazardous Waste)	Effectively segregate waste streams to avoid contaminating non-infectious waste types
Single-use Plastics, such as Disposable Devices & Packaging Materials	Encourage the use of reusable and biodegradable alternatives, wherever possible
Radiological Waste	Use the As Low as Reasonably Achievable (ALARA) methodology and the Time, Distance, and Shielding Strategy
Sharps Waste	Reduce sharps waste by implementing safe needle disposal programs, using safety-engineered medical devices, and educating staff on proper handling techniques
Chemotherapy Waste	Adopt safe handling procedures to reduce chemotherapy waste by preparing only the required quantities of medication and preventing unnecessary disposal of excess doses
Hazardous Waste	Substitute them with safer, non-hazardous alternatives whenever possible

5.2.1 Reuse

Promoting the use of reusable items in laboratories can provide substantial environmental and operational advantages. Items that have not been exposed to biological agents or toxic substances are generally suitable for reuse, recycling, or energy generation.⁴ However, conducting a risk-benefit assessment (RBA) is crucial to determine whether laboratory items should be designated as disposable or reusable. Table 5-2 summarizes the key benefits associated with both reusable and disposable laboratory materials.

Decontamination of Reusable Items

- Before reusable items are considered non-infectious, they should undergo an initial pre-cleaning if needed, followed by an appropriate decontamination process. Decontamination may include disinfection or sterilization, depending on the level of risk and intended use. For instance, pressurized gas cylinders can often be safely refilled for reuse, whereas reusable surgical instruments must be able to endure thermal or chemical sterilization without damage.

Reusable vs Disposable Culture Media Plates

- While reusable culture media plates generate less waste, they can pose exposure risks during cleaning and sterilization. Therefore, it is crucial to prioritize safety and efficiency when weighing the pros and cons of both options.

Single-Use Wire Loops vs. Reusable Wire Loops

- Single-use loops offer accurate volume delivery, less potential for cross-contamination, and reduced aerosol generation. However, reusable wire loops are more economical. A risk and benefit assessment in the local context will help make a decision.

Items that should not be reused

- It is important to note that not all items can be reused. Considering the risk of disease transmission, plastic syringes, needles, ESR tubes, glass slides, cover slips, and blood culture bottles should not be reused.
- Similarly, reuse is not recommended in maximum containment laboratories due to high-risk pathogens and procedures.

Purpose Diversion

- Purpose diversion is an innovative approach that involves finding new uses for items initially meant for something else.
- Containers that once held chemicals or detergents can be repurposed for disposing of sharp objects, with some minor adjustments, if they meet the requirements for a sharp container.
- This approach helps reduce waste and showcases the resourcefulness of laboratory personnel and waste management staff.

Documenting Reusable Items in Waste Management Plan

- Organizations should document reusable items in their waste management plan and follow written procedures for separate collection and processing, which may include thermal and chemical sterilization.
- Documenting reusable items is crucial to ensure a systematic approach and maintain clear records.

Table 5-2. Benefits of Disposable vs Reusable Items in a Laboratory Facility

Benefits of Reusable Items	Benefits of Disposable Items
Cost-effective	Infection control and cross-contamination prevention, but at an increased cost
Environment-friendly due to reduced waste generation	Convenience and efficiency – save time in fast-paced healthcare environments
Durability for reuse	Easy disposal, reduced labor and maintenance costs
Reduced supply chain impact	Consistent quality and performance

5.2.2 Recycling

- In laboratory operations, waste minimization and reusing materials are typically preferred over recycling. This preference is mainly due to the significant additional effort required for recycling, such as transporting waste to off-site recycling facilities.
- While plastic syringes are being recycled in some regions of the world⁵, this practice is not universally recommended, particularly in areas where the requisite management procedures, technologies, security measures, and specialized training for handling high-risk items are not available.
- It is essential to carefully consider the potential hazards posed by unauthorized access to laboratory waste. In some instances, the risks associated with such access outweigh any potential benefits of recycling.

5.3 Segregation

In a laboratory, individuals responsible for managing infectious, chemical, radioactive, and non-hazardous general waste must ensure that the waste is segregated correctly at the point of generation by using separate waste containers wherever the work is performed, whether on an open bench, in a biosafety cabinet, or in a room. To enhance safety and minimize the risk of spills, exposures, and injuries, it is recommended that waste bins be readily accessible during laboratory work. It is also advisable to place the bins at a comfortable height for easy access, such as on benches where work is being performed. Additionally, different types of waste containers should be at a reasonable distance to avoid contact between them. It is important to note that housekeeping and other waste-handling staff should not be involved in the segregation process. This principle applies universally in all situations. As waste producers, the responsibility for segregation lies with those generating it, such as laboratory technologists, researchers, and scientists highlighting the importance of personal accountability in maintaining a safe laboratory environment.

5.3.1 Waste Categories

In a Laboratory setting, waste can be broadly categorized into two groups: non-hazardous waste and hazardous waste (Figure 5-2).

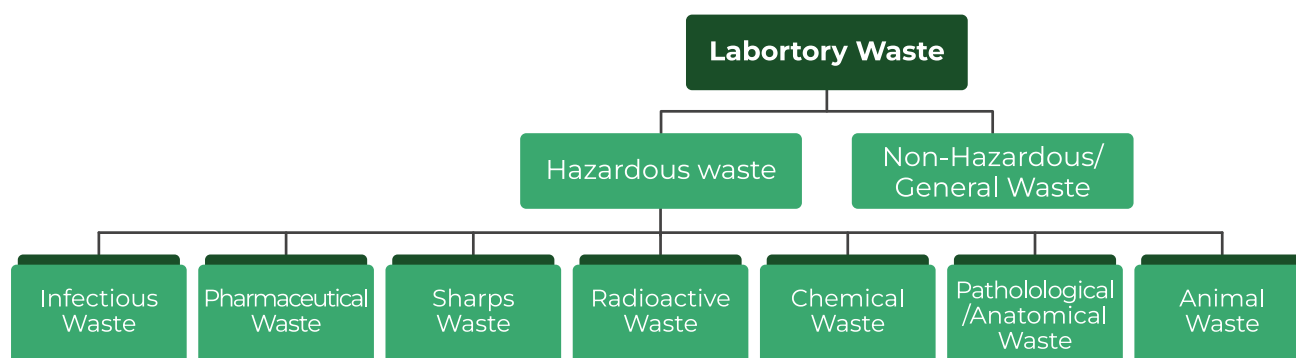


Figure 5-2. Categories of Waste

5.3.1.1 Non-hazardous Waste

The non-hazardous waste category generally includes waste from the facility's administrative, housekeeping, packaging, and maintenance operations. Separating this waste as general or municipal waste is essential. Certain pharmaceuticals, such as fluids containing vitamins, salts, and amino salts, are also non-risk and can be disposed of with non-hazardous municipal waste. When dealing with non-risk/general waste, it must be placed in a container lined with a white waste bag. The waste bin should be fully sealed with a lid to contain its contents. The container should be designed for ergonomic handling and be resistant to acids and oils. The color coding can be adjusted if the waste is further segregated into recyclable, non-recyclable, and biodegradable parts.

5.3.1.2 Hazardous Waste

The second category is hazardous waste, which includes several subcategories such as infectious, pathological/anatomical, sharps, pharmaceutical, radioactive, chemical, and multi-hazardous waste.

Infectious Waste

- It is contaminated or is reasonably suspected to be contaminated with pathogens like bacteria, viruses, parasites, or fungi and poses a risk of disease transmission to humans or animals.
- Infectious waste includes blood and other bodily fluids, microbiological cultures, stocks, carcasses of infected animals, cell lines and cultures, and diagnostic laboratory samples.
- This type of waste should be placed in a rigid plastic or metal container lined with a yellow waste bag, marked with a biohazard sign, and with rounded edges for easy cleaning.
- It is recommended to use chlorine-free, plastic biohazardous waste bags with a thickness of 70 µm.
- Yellow waste bags should be autoclavable (polyethylene or polypropylene) and resistant to heat up to 121°C.
- A waste bag's average capacity to withhold waste should be pre-assessed to avoid ruptures.
- Biohazardous liquid waste should be collected in non-breakable and leak-proof rigid plastic containers with a closable lid and labeled with a biohazard symbol.

Pathological/Anatomical Waste

- It is considered potentially infectious and includes human/animal body parts, organs, tissues, unused blood or blood products, and foetal material.
- This waste should be placed in containers lined with yellow waste bags.
- Recognizable body parts or fetuses can be segregated, labeled, and packaged for authorized burial, separate from the infectious waste stream.

Sharps Waste

- Sharps are objects that can potentially inflict cuts or puncture wounds. Examples of sharps include needles, blades, hypodermic needles, and broken glass.
- Sharp containers should be puncture-resistant and leak-proof, with a narrow opening and a sealable lid, and labeled with a "DANGER! SHARPS" mark. For big sharp items, such as broken glassware, large, wide-mouth, sharp containers with a proper lid should be used.
- Small, sharp containers can be placed into a yellow waste bag with the lid closed adequately for further treatment and disposal.
- Sharp containers can be made with plasticized cardboard, plastic, or metal, and should be autoclavable, if possible.

Pharmaceutical Waste

- Pharmaceutical waste includes heavy metal-containing pharmaceuticals (such as mercury thermometers), controlled drugs (such as opioids), and antibiotics (such as amoxicillin).
- Pharmaceutical waste is placed in metal or rigid plastic containers with a foot-operated lid, such as stainless-steel bins or High-Density Polyethylene (HDPE) drums.
- Line the inside of containers with a good-quality yellow waste bag for easy identification and downstream segregation.

- Label the container with the name of the significant waste item, such as 'Expired Medications' or 'Chemotherapy Drugs,' and any other necessary hazard label, along with labelling specifics mentioned in the labelling section of this document.
- Small quantities can be placed into yellow waste bags after being crushed if compatible with other items in the bag and the downstream treatment method.
- Incompatible pharmaceuticals should be placed in different containers or bags in dry conditions to prevent any adverse reactions.
- Large quantities of pharmaceuticals can be returned to their suppliers for safe disposal (per institutional policy).
- Genotoxic or cytotoxic waste capable of causing genetic mutations should be collected separately in solid and leak-proof containers with the "cytotoxic waste" label and stored securely.

Radioactive Waste

- Radioactive waste comprises radionuclides and objects contaminated with radioactive materials and is classified as low-level, medium-level, or high-level waste. This classification is based on its half-life, activity, radionuclide content, physical form, and seal status.
- Low-level radioactive waste can be placed in yellow leak-proof bags made of Polyethylene (PE), Polyurethane (PU), or Polyvinyl Chloride (PVC), and liquid radioactive waste can be collected in polythene carboys.
- The waste bags should be labeled with specific information, including the radiation symbol, name/type of radioactive material, radionuclide activity, and storage information.
- Waste should be placed in yellow or white bags based on hazard type and level after decay.
- High-level radioactive waste should be handled following the supplier's packaging and storage instructions and returned to the supplier for disposal.^{6,7}

Chemical Waste

- Chemical waste includes discarded chemicals from disinfecting and cleaning procedures, laboratory reagents, solvents, waste contaminated with heavy metals, and waste generated during molecular biology experiments.
- Chemical waste should be collected in yellow-colored substantial containers labeled with the primary chemical name and relevant hazard symbol(s).
- Incompatible chemicals should be placed in separate containers.
- Waste for different treatments should be collected in separate containers per the waste management committee's guidance.
- Ethidium bromide (EB) and its contaminated materials should be collected in yellow plastic bags labeled "Chemical Waste" or "Ethidium Bromide Waste (EBW)".
- Liquid solutions containing less than ten µg/ml EB can be drained down the drain, but EB waste should not be collected in biohazardous waste bags and sharps containers.

Multi-Hazardous/Mixed Waste

- The waste management plan specifies segregation, labelling, packaging, and storage protocols per risk assessment to ensure effective hazardous waste management practices. However, if not followed in true spirit, it can result in the generation of multi-hazardous waste containing radioactive, chemical, or infectious waste, and mixed waste that contains chemical and radioactive waste.
- It requires meticulous management and prevention due to its expensive and limited treatment options.

5.3.2 Color Coding

Packaging is crucial for the proper management of biological waste. It securely contains and transports potentially hazardous materials, ensuring the safety of the environment and individuals involved in the process. It includes the following types of measures:

- Different types of waste should be placed in different color-coded containers. An example of a color-coding scheme, as per the Hospital Waste Management Rules 2005, is shown in Figure 5-3.
- If solid waste containers of a specific waste category are reused in the laboratory, they should be lined with the same-colored waste bag.
- Using the same color-coding scheme across different institutions and regional laboratories is recommended. This methodology will avoid downstream mishandling, improper treatment, and disposal by third-party contractors due to improper visualization of the waste bags.
- This document endorses the color-coding scheme adopted in the Hospital Waste Management Rules 2005 or the World Health Organization's Handbook on the Safe Management of Wastes from Healthcare Activities 2014.^{5,8}

Category	Waste Container	Examples
INFECTIOUS/PATHOLOGICAL WASTE (yellow container lined with a yellow waste bag)		Microbiological cultures and stocks Carcasses of infected or potentially infected animals All sorts of cell lines and cell cultures Contaminated PPE Human/animal body parts, organs, and tissues Unused blood or blood products
NON-HAZARDOUS WASTE (white container lined with a white waste bag)		Empty IV bag Cotton swab with little alcohol Packaging of consumables and kits
SHARPS WASTE (yellow puncture-resistant container)		Needles Blades Hypodermic needles Broken glass

Figure 5-3. An Example of a Color Coding Scheme

5.4 Labelling

Different waste types, including chemical and radioactive, have specific labelling requirements. Properly labeled waste containers and storage areas ensure that different types of waste are correctly identified and handled. Precise and accurate labelling also helps prevent cross-contamination and ensures that waste is disposed of following regulations and safety protocols. The international hazard symbols that may be required to be pasted on different types of wastes are reproduced in Figure 5-4. Additionally, labelling provides essential information for waste management personnel, emergency responders, and anyone else who may come in contact with the waste, promoting safe and efficient waste management practices. These practices become even more essential when commercial services are hired by healthcare facilities to treat and dispose of waste. The following points should be followed for efficient labelling of waste:

- A waste container or bag should be labeled in a way that enables it to be traced back to its place of generation when needed. This will allow waste handlers to track problems with waste segregation and obtain important information about the waste in case of an accident.
- An international hazard symbol should be placed on waste containers or bags along with the type of waste, date of packaging, department, and laboratory/facility name, contact information, and initials of the person packing the bag (Figure 5-5).
- Weight can also be mentioned on waste containers/bags.

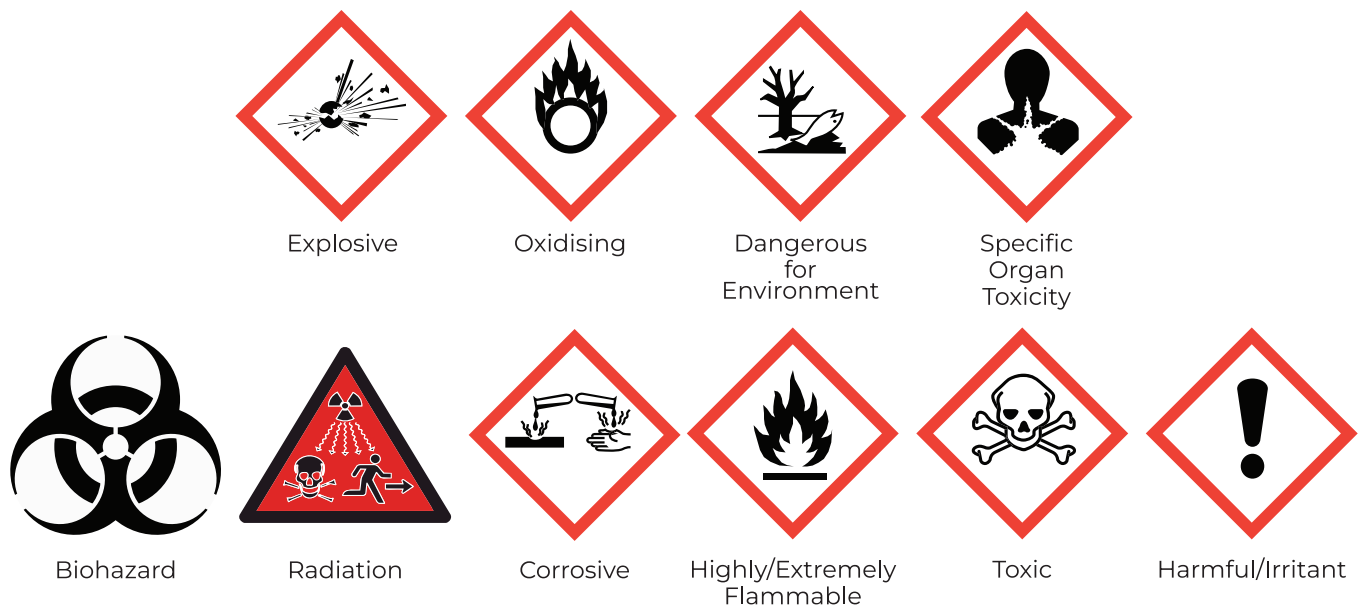


Figure 5-4. Hazardous Waste Symbols⁹

 BIOHAZARD	Infectious Waste _____
	Date of Packaging _____
	Phone No. _____
	Weight _____
	Laboratory Name and Address _____ _____

Figure 5-5. An Example of an Infectious Waste Bag Label

5.5 Collection and Packaging

Waste bags and containers should be appropriately collected and packed for effective waste management. The following points should be followed to ensure it:

- The capacity of containers or bags should be enough to contain waste produced between two consecutive collection times, or the collection frequency should be matched with the quantity of waste produced and the container capacity.
- Pack waste bags properly to avoid spills and leaks during storage and transportation. For downstream autoclaving, the waste bags should not be air-tight.
- Use self-locking plastic sealing tags, simple knots, or the gooseneck method to pack waste bags.
- Do not reopen waste bags once packed. Wipe the outer surface of packed waste bags or containers with an appropriate disinfectant.
- Streamline waste collection according to the laboratory's operating timings and document routes in the waste management plan.
- Use data-collecting forms to track daily waste collection.
- Avoid waste collection during tea and lunch breaks and duty on/off timings.
- Schedule waste collection after procedures that generate the most waste.

Table No. 5-3 lists best practices for waste collection from different sections or departments of a laboratory.

Table 5-3. Best Practices for the Collection of Waste
Best Practices for the Collection of Waste
Use separate waste collection equipment (such as trollies) for risk and non-risk waste.
Develop a waste collection plan in consultation with different stakeholders.
Collect waste regularly at fixed times and at least once a day.
Ensure the availability of sufficient staff for the collection of waste.
Schedule separate collection timings for risk and non-risk waste.
Ensure uninterrupted supply of waste bags/containers, PPE, and waste collection equipment such as trollies.
Immediately place a new waste bag into the container after collecting a filled bag.
Thoroughly clean waste containers between the replacement of waste bags.
Supervise waste collection staff to monitor adherence to the best waste collection practices.
Develop a contingency plan for emergencies, such as an event that can delay waste collection.
Document quantities of waste generated daily or weekly for data analysis, especially when handing waste over to a third-party contractor for treatment and disposal.

Daily Waste Collection Record															
Name of the Lab: _____ Week: _____ Month: _____ Year: _____															
Waste Collection Point (Name of the Section) Hematology / Histopathology / Cytology / Microbiology / Molecular biology, etc.	Waste Category (Please Specify)	Quantity of waste generated per day (Weight and Volume)													
		Mon		Tue		Wed		Thu		Fri		Sat		Sun	
		kg	L	kg	L	kg	L	kg	L	kg	L	kg	L	kg	L

Figure 5-6. Waste Collection Form Template

5.6 Storage

Waste storage can be interim/short-term, with waste temporarily stored on-site immediately after collection (primary waste storage area), or in a central storage area (secondary waste storage area), where it is stored for off-site transport or for on-site final treatment and disposal. In both cases, it should be a secure, enclosed space with restricted access, located away from food preparation areas. Different types of waste should be stored in separate areas, or at least, in different sections within a storage area. A waste storage area should be labeled with the relevant hazard symbol and the restricted access sign (Figure 5-7). Liquid waste should be placed in secondary containers such as deep trays to prevent leakage. Secondary containers should also be labeled with a biohazard symbol. Liquid containers should be secured during storage to prevent tipping over. This area should have the following provisions:

- A compartmentalized space for the organized storage of waste
- A room layout allowing easy access to vehicles and authorized collection staff
- Sufficient supply of personal protective equipment (PPE), including face masks, industrial aprons, industrial boots, disposable or heavy-duty gloves (as required), waste bags/containers, spill kit, and cleaning equipment
- Sufficient capacity for the amount of waste produced in a defined period, with extra space to handle an emergency that can delay the collection of stored waste
- Good drainage, lighting, passive ventilation, a hand-washing sink, and a good water supply for cleaning
- Inaccessible to animals, birds, and insects/rodents
- An impermeable, easy to clean and disinfect, hard-standing floor
- Temperature preferably below 16°C
- Storage for only up to 24 hours
- Regular cleaning of the waste storage area with proper PPE⁵

Additionally, backup waste storage locations should be identified as part of a contingency plan. A hazardous waste inventory should be maintained for all hazardous waste types. Appropriate physical, personnel, and inventory controls should be implemented to ensure security. Biosecurity risk mitigation decisions should be based on risk assessment. For the cleaning of the waste storage area, waste containers should be relocated to another restricted area or to extra space within the same area. After that, the surfaces should be pre-cleaned, followed by disinfection, and the used PPE should be disposed of properly.¹⁰ Additional requirements for the central storage zones for different types of hazardous waste are given in Table 5-4.



No Entry for
Unauthorized Person



Biohazard Sign for
Infections & Sharps Waste Items



Toxic Sign for Chemical &
Hazardous Pharmaceutical Waste



No Eating or Drinking



No Smoking

Signs outside the storage facility

Figure 5-7. Common Signs for Waste Storage Facilities⁴

Table 5-4. Additional Requirements for the Central Waste Storage Areas for Different Types of Hazardous Waste

Type of Waste	Best Practices for the Collection of Waste
Infectious waste	In temperate regions, storage should be at most 72 hours in winter and 48 hours in summer. In warm regions, storage should be at most 48 hours in winter and 24 hours in summer. Exceeding this time requires storage at 3-8°C.
Anatomical waste	Proper temperature control is crucial in anatomical waste storage rooms. The temperature needs to be maintained at the same level as infectious waste due to the potential growth of pathogens and gas formation. Failure to do so can pose serious safety risks to the facility and its occupants.
Pharmaceutical waste	It is crucial to separate non-hazardous pharmaceutical waste from hazardous waste. Non-hazardous waste should be stored with other non-hazardous waste, while hazardous pharmaceutical waste demands durable containers compatible with its contents to prevent chemical reactions. Genotoxic waste can be stored in the same manner as toxic chemical waste, ensuring proper segregation for safe storage.
Chemical waste	When storing chemicals, consider their hazard characteristics and label waste according to its type. Use secondary containers for liquid chemicals to contain leaks. Store liquid and solid chemicals separately and consult Safety Data Sheets (SDS) to take additional precautions. Storage duration varies by chemicals and applicable regulations.
Radioactive waste	Radioactive waste can be stored temporarily for decay, pretreatment/treatment, or before returning it to a vendor. It should be collected in leakproof polyethylene containers. It is not recommended to store them in glass containers. Waste with a decay time of less than 90 days can be stored within the facility, but waste that requires more than 90 days to decay should be handed over to specialized off-site facilities.

5.7 Transportation

There are two types of waste transportation: off-site and on-site. On-site transport refers to moving lab waste to a storage location within the facility or to an on-site treatment site. Off-site transportation involves moving waste from a facility storage location to another off-site location for treatment or disposal.

5.7.1 On-Site Transportation

The following best practices should be followed for the safe on-site transportation of waste:

- Waste containers or bags should never be transported by hand; instead, waste collection trollies or carts should be used.¹¹
- Use separate trollies for different types of waste; these should be painted the same color and labeled with the categories of waste they are intended to transport.
- Choose stable trollies that are easy to load and unload, easy to clean, and appropriate for the volume of waste generated.
- Clean trollies and vehicles regularly, using appropriate cleaning/disinfecting solutions and following written procedures.
- For ease of handling and to avoid spills and their subsequent management, it is preferable to transport liquids in adequately closed and sealed small containers (up to 10 L per load), along with a secondary container.
- Schedule transport during less crowded hours and define routes using the clean-to-dirty principle, i.e., from the least to the most hazardous waste.

- Routes should be fixed, short, and preferably separate from regular human traffic routes (Figure 5-8).
- All involved in transportation and associated tasks, such as maintaining trolleys and other waste-transportation equipment, should clearly define, document, and communicate their roles and responsibilities.

5.7.2 Off-site Transportation

The following best practices should be followed for the safe and secure off-site transportation of waste:

- Waste producers are responsible for ensuring that an authorized third-party transporter/contractor carries out the transportation and that all laws and regulations are followed meticulously.
- International regulations, such as the Basel Convention, are vital in regulating waste movement between countries.¹²
- Likewise, the International Civil Aviation Organization's (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air and the International Air Transport Association's (IATA's) Dangerous Goods Regulations, both based on UN recommendations, must be meticulously followed when transporting biohazardous waste by air.¹³
- It is important to note that the regulations of both the transporting and receiving countries also apply to off-site transportation.
- According to Pakistan's National Hazardous Waste Management Policy 2022, waste transporters must register and obtain a license to transport hazardous waste along designated routes and at designated times. This policy also prioritizes safety by requiring secure, closed vehicles to prevent the dispersal of waste or the emission of unpleasant odors.
- Pakistan's National Hazardous Waste Management Policy 2022¹⁴ mandates that:
 - > Individuals transporting hazardous waste must be provided with the necessary equipment to load and unload the waste.
 - > Drivers must be vaccinated against tetanus, Hepatitis A and B, and deemed medically fit.
 - > Vehicles transporting hazardous waste must not be used to transport other materials for other purposes.
 - > They must display the appropriate hazard sign, emergency contact information, and the waste transporter's name and address.
 - > The vehicle must be fully enclosed, easily cleanable, lockable, and equipped to secure waste containers during transport to prevent spills.
 - > It should contain a spill kit, a first aid kit, an effective disinfectant, empty waste bags, and PPE.
 - > When transporting hazardous waste, it is essential to ensure that the vehicle's drivers are trained.
 - > Drivers should know how to handle, load, and unload waste containers, manage spills, respond to emergencies, and use PPE where necessary.
 - > Emergency response plans and instructions should be available in transport vehicles, along with Emergency Response Intervention (ERI) Cards that provide details on the type of waste, associated risks, and emergency procedures.
 - > A consignment note with the driver must include information about the waste being transported, the driver's name, pick-up and destination details, the number of containers, estimated volume and weight, and a receipt confirming delivery at the destination.
 - > A documented chain of custody shall be maintained throughout the transport of waste to ensure traceability, accountability, and secure transfer from the point of generation to its final treatment or disposal.

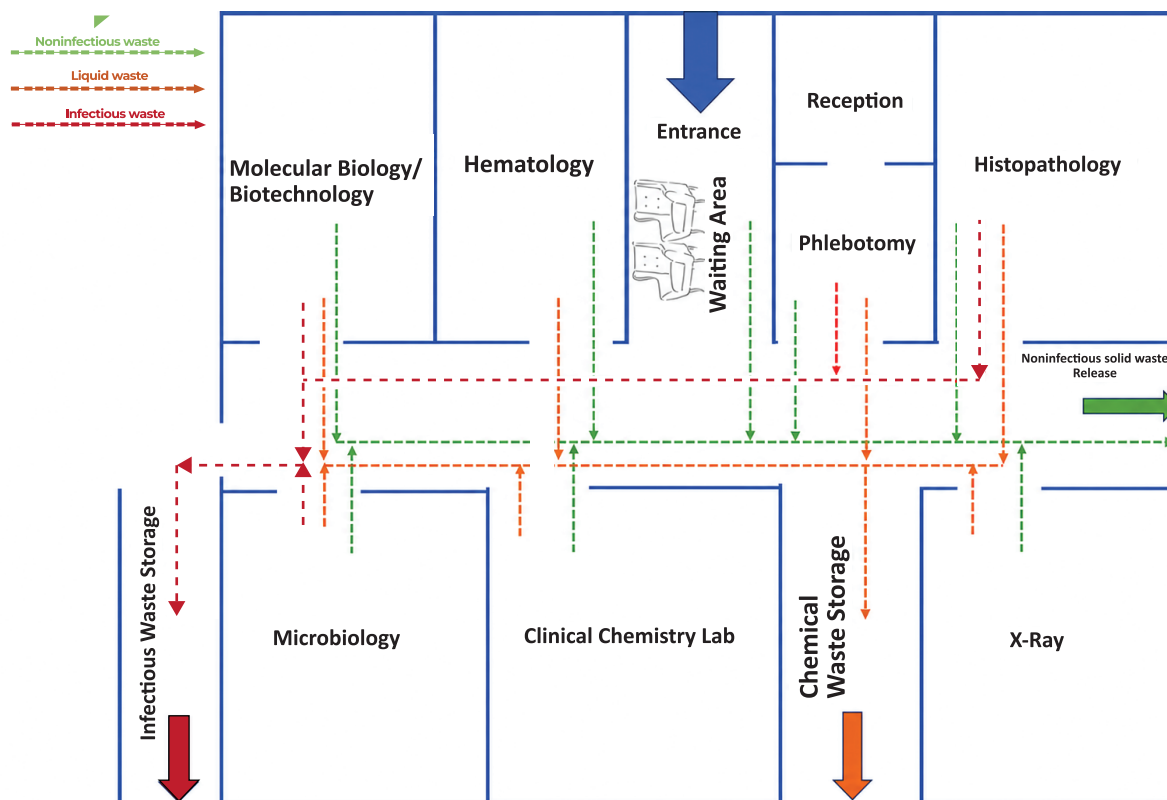


Figure 5-8. An Example of a Route for the On-site Transportation of Waste

5.8 Personal Protection during Waste Management Processes

Staff handling waste should wear appropriate PPE during various waste-handling processes per risk assessment. For heavy duty tasks in waste management, personnel may need to wear heavy-duty gloves, splash-resistant aprons, rubber gumboots, and helmets as required (Figure 5-9). Train staff annually or after significant changes to procedures, protocols, or equipment, and upon working with new agents. Refreshers increase compliance with standard operating procedures.^{4,15}



Figure 5-9. Personal Protective Equipment (PPE) for Heavy-Duty Work in Waste Management

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Checklist - Risk Assessment

Sr. No.	Description	Yes	No	N/A
1.	Waste management processes, including segregation, packaging, labeling, collection, and storage, have been established and documented.			
2.	Green procurement and environmentally preferable purchasing (EPP) have been implemented.			
3.	A waste minimization process is in operation.			
4.	A strategy for the reuse and recycling of waste is in place.			
5.	All applicable regulatory requirements have been fulfilled.			
6.	A facility for on-site and off-site waste transportation is available.			
7.	A training plan for individuals engaged in any of the waste management processes has been established.			
8.	Communication protocols are firmly established.			
9.	Continual improvement of the processes is planned and documented.			

SECTION 06

Treatment and Disposal Methods

Javed Muhammad, Luis Alberto Ochoa Carrera

Biomedical and research laboratories generate liquid, solid, and sharps waste, each requiring appropriate and specific treatment before final disposal to reduce potential environmental, community, and public health risks. Different treatment options, including thermal, chemical, irradiative, and biological, are selected based on waste characteristics, the availability and suitability of technology, and environmental safety considerations. Non-infectious waste can be disposed of as general waste if appropriately segregated at the point of generation and may be suitable for recycling and composting. Materials such as cardboard, metals, and plastics, in particular, offer significant potential for recycling, contributing to more sustainable waste management practices.

6.1 Waste Streams

6.1.1 Solid Waste

- Solid waste, which includes culture plates, tubes, loops, plastic wares, personal protective equipment, paper towels, and animal carcasses, can be categorized as infectious and non-infectious waste.
- Infectious waste must be treated using an autoclave, incinerator, or another suitable method. The autoclave temperature and cycle time should be adjusted based on the type and volume of waste, in accordance with the manufacturer's instructions.
- Waste containing highly infectious agents, i.e., Biosafety Level 3 (BSL-3) waste, must be pre-treated at the generation site before leaving the facility for central storage or final disposal. Waste from BSL-1 and BSL-2 laboratories can be treated off-site or in accordance with institutional policies.
- BSL-4 laboratories must have a dedicated Effluent Decontamination System (EDS) for liquids and a double-door autoclave for solid waste.¹
- In an emergency, such as an autoclave breakdown, a contingency plan should be established that, based on risk assessment, can provide an alternate on-site or off-site treatment option.

6.1.2 Sharps Waste

Sharps include syringes, scalpels, knives, broken vials and ampules, infusion sets, sharp metals, broken glassware, pipettes, and so on.² To dispose of them safely, follow these recommendations:

- Sharps container reuse is not advised; it should be permanently closed and sealed once it is 3/4th filled. These containers can be autoclaved, followed by burial in a secure landfill.
- Dedicated disposable cardboard safety boxes or puncture-resistant containers can be incinerated.
- Avoid shredding or grinding sharps before treating them with a disinfectant to prevent exposure of workers to infectious aerosols.
- Safety devices that automatically retract, blunt, or disable the sharp can be used to minimize needle stick injuries.

6.1.3 Radioactive Waste

Radiological waste comprises materials contaminated with radionuclides and is generated during procedures such as in vitro analysis of body tissues and fluids, in vivo imaging, tumor localization, and various diagnostic and therapeutic applications. While radionuclides are essential for many laboratory and clinical procedures, their use requires strict control in handling, storage, and disposal to ensure the safety of personnel and the environment.

This waste poses significant health risks due to its genotoxic nature, with higher radiation doses capable of damaging genetic material. The low-activity radioactive waste generated in hospitals and healthcare laboratories poses health risks due to contamination of container external surfaces or improper storage mode or duration. Those at greatest risk of exposure include laboratory personnel, waste handlers, and cleaning staff who may come into contact with radioactive materials. There are two types of radioactive molecules:

- Short half-life molecules that decay in hours to days
- Long half-life molecules that degrade in months to years

Recommendations for the disposal of radiological waste generated in laboratories and hospitals are given below:

- Treatment of radiological waste in a microwave, autoclave, or incinerator is not recommended.
- To dispose of radiological waste, decay it in an on-site storage facility, return it to the original supplier, or store it long-term in an authorized and controlled radioactive waste disposal site.³
- After the half-life of radioactive materials has passed, the radioactivity of the substance decreases to half of its original value. The radioactivity of the substance can be measured through a Geiger-Muller or scintillation counter.
- Storage of radiological waste for the required period, until its radioactivity is reduced to safe levels, is a crucial step for safe disposal. At this stage, it can be disposed of as regular waste.
- When handling chemicals mixed with radioactive materials or in an emergency, consulting Safety Data Sheets (SDS) is essential. This will ensure safe disposal of waste in complex situations. Additional information about SDS can be found in Appendix B.
- For treatment in an incinerator, the facility must meet the requirements of the Pakistan Nuclear Regulatory Authority Ordinance 2001 (III of 2001) and be approved by the Federal or Provincial Agency.⁴
- High-risk radiological waste should be treated and disposed of in accordance with national regulations and policies in a centralized site under the supervision of a government agency or an expert contractor.

Table 6-1. Characterization of Radionuclides Used in Laboratory Research

Radionuclide	Half Life	Principle Application	Waste Characterization and Management
Carbon-14 (¹⁴ C)	5730 years	Used in radiocarbon dating, labelling biological molecules in metabolic studies, and tracing carbon pathways in biochemical reactions	Low to medium level waste, encapsulation, and burial disposal
Sodium-22 (²² Na)	2.6 years	Used as a tracer in biochemical and physiological studies, particularly in research related to sodium transport and metabolism	Low to medium-level radioactive waste, handled and disposed of with caution to prevent environmental contamination
Phosphorus-32 (³² P)	14.3 days	Used as a radioactive label in molecular biology, biochemistry, and genetics experiments, such as DNA sequencing and labelling	Medium-level radioactive waste, requires proper shielding and handling procedures, encapsulation, and burial in licensed radioactive waste facilities
Sulfur-35 (³⁵ S)	87.4 days	Used as a tracer in biochemical and molecular biology research, such as protein labelling, nucleic acid labelling, and metabolic studies	Medium-level radioactive waste, requires appropriate storage and disposal

Iodine-125 (^{125}I)	59.4 days	Widely used in radioimmunoassays (RIA), radioactively labelling proteins and peptides, and in autoradiography	Medium-level radioactive waste, proper storage, handling, and disposal protocols to minimize radiation exposure risks
Chromium-51 (^{51}Cr)	27.7 days	Used in immunological and cellular studies, red blood cell labelling for blood volume determination, and in vitro cytotoxicity assays	Medium-level radioactive waste, requires appropriate containment and disposal methods to prevent environmental and health hazards
Iron-59 (^{59}Fe)	44.5 days	Utilized in iron metabolism studies, erythrocyte survival studies, and in vitro labelling of cells for tracking and tracing purposes	Medium-level radioactive waste, necessitates careful handling and disposal to mitigate radiation risks
Tritium (^3H)	12.3 years	Used as a radioactive label in biochemical assays, DNA labelling, and autoradiography	Low to medium-level radioactive waste, requires proper containment and disposal measures to prevent radiation exposure
Cesium-137 (^{137}Cs)	30.17 years	Commonly used as a gamma-ray source in laboratory instrumentation calibration, environmental monitoring, and radiation therapy	Medium to high-level radioactive waste, requires stringent containment and disposal measures due to its long half-life and gamma radiation emission
Nickel-63 (^{63}Ni)	100.1 years	Utilized in tracer studies, electroplating, and as a radiation source in certain laboratory instruments	Low to medium-level radioactive waste, encapsulation, and appropriate disposal methods to prevent environmental contamination

6.2 Waste Treatment Methods

Waste treatment can be achieved by physical or chemical means. The physical methods can be divided into two major types (Figure 6-1):

- Heat/Thermal Treatment
- Irradiation Treatment

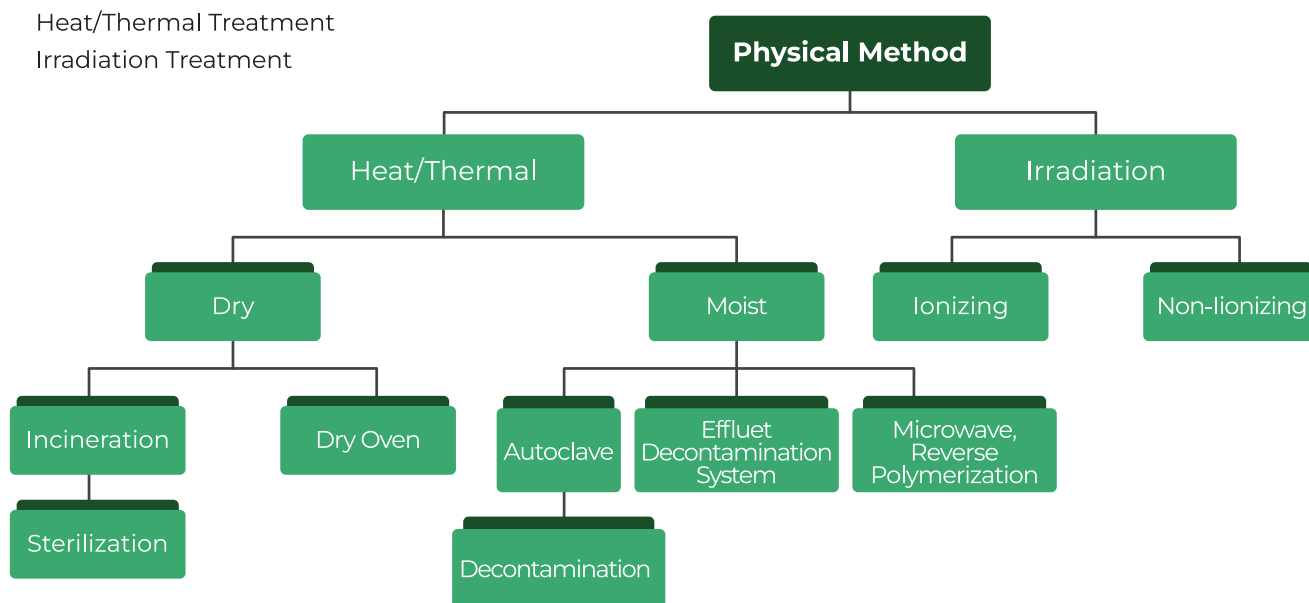


Figure 6-1. Different Types of Laboratory Waste Treatment Methods

6.2.1 Heat/Thermal Treatment

Heat/thermal treatment is categorized as:

- Dry heat treatment (incineration, dry oven, etc.)
- Moist heat treatment (autoclave, microwave, and reverse polymerization)

6.2.1.1 Dry Heat Treatment

Incineration

Incineration uses dry oxidation to convert organic waste into inorganic waste (Figure 6-2) through combustion, pyrolysis, and gasification. It is used for waste that cannot be reused, recycled, or landfilled. It does not require waste pre-treatment, significantly reduces waste volume, and eliminates pathogens in healthcare waste. There are three major types of incinerators:

- a. Starved air/pyrolytic/controlled air incinerator
- b. Multiple chamber incinerator
- c. Rotary kiln incinerator

Each type has its pros and cons based on its cost, temperature range, and waste capacity. When purchasing and installing an incinerator, regulatory compliance, cost, suitability for waste types and capacity, emission control, energy efficiency, maintenance requirements, the supplier's reputation, training needs, and potential future expansion should be considered.^{5,6}



Figure 6-2. Incineration Facilities for Waste Treatment (Pakistan)

a. Starved Air/Pyrolytic/Controlled Air Incinerator

This incinerator can burn over 20 tons of infectious biological waste, including sharp objects, daily. It operates (Figure 6-3) without oxygen and reaches temperatures of 800°C to 900°C in the primary chamber and 1100-1600°C in the secondary chamber. The incinerator is automated, simple to use, and operates continuously. However, it should not be used to treat waste containing chlorinated compounds or bags, which can release dioxins in these incinerators. It can be installed either on-site or off-site, provided that the installation complies with the regulations of the regional Environmental Protection Agency.

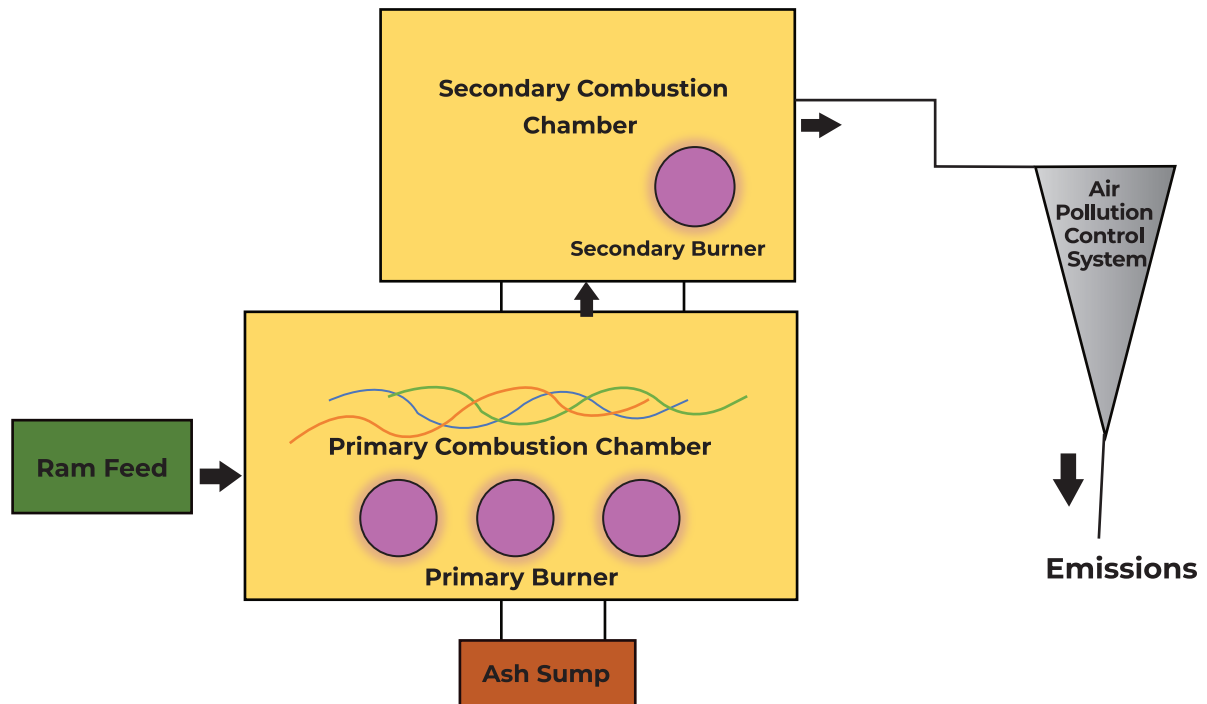


Figure 6-3. Schematic Diagram of a Starved Air/Pyrolytic/Controlled Air Incinerator

b. Multiple Chamber Incinerator

A multiple-chamber incinerator was designed to handle pathological waste (Figure 6-4). Its primary chamber has an oxygen-rich environment, with a temperature range between 800°C and 1000°C. This type of incinerator effectively removes volatile organic compounds and particulate matter.

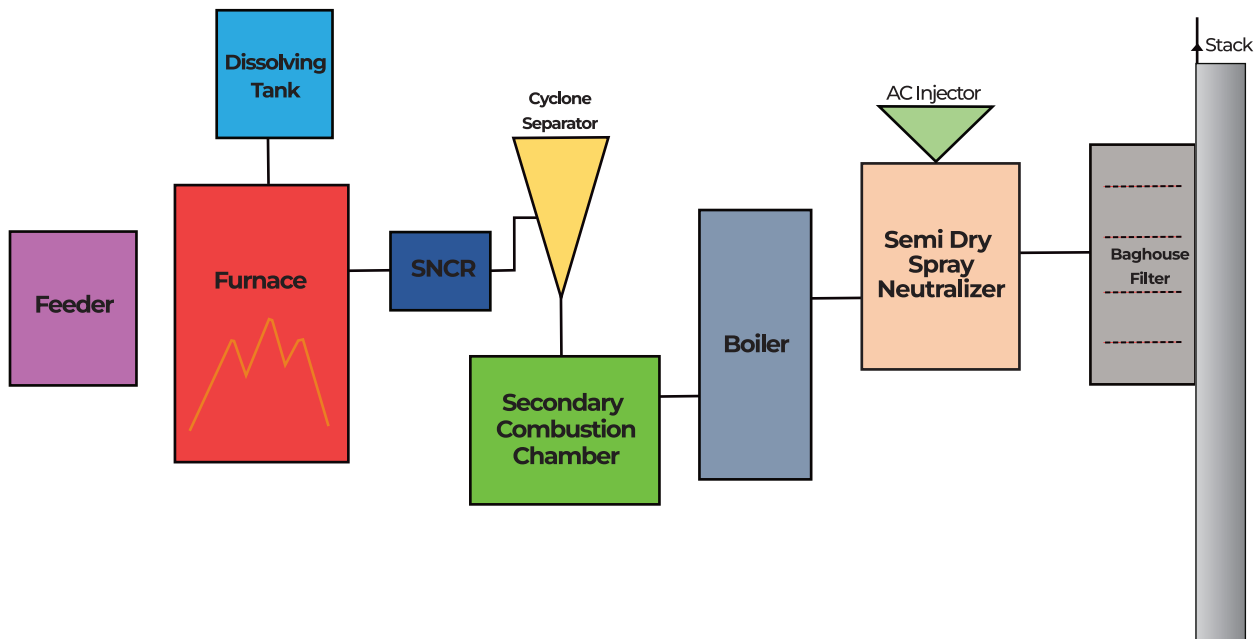


Figure 6-4. Schematic diagram of a multiple-chamber incineration system showing the operational flow from waste feeding into the furnace, where primary combustion occurs, followed by secondary combustion to ensure complete oxidation of gases. The treated flue gas then passes through emission control units, including SNCR, cyclone separator, boiler, semi-dry spray neutralizer, activated carbon injection, and baghouse filter, before being released through the stack.

c. Rotary Kiln Incinerator

A Rotary Kiln Incinerator is a versatile solution for effective disposal of medical waste, genotoxic substances, pharmaceutical waste, and heat-resistant chemicals (Figure 6-5). This incinerator can process large amounts of waste, up to 10 tons per hour, with enhanced efficiency. However, it has some limitations, such as high cost, high-energy combustion, and operational complexity.

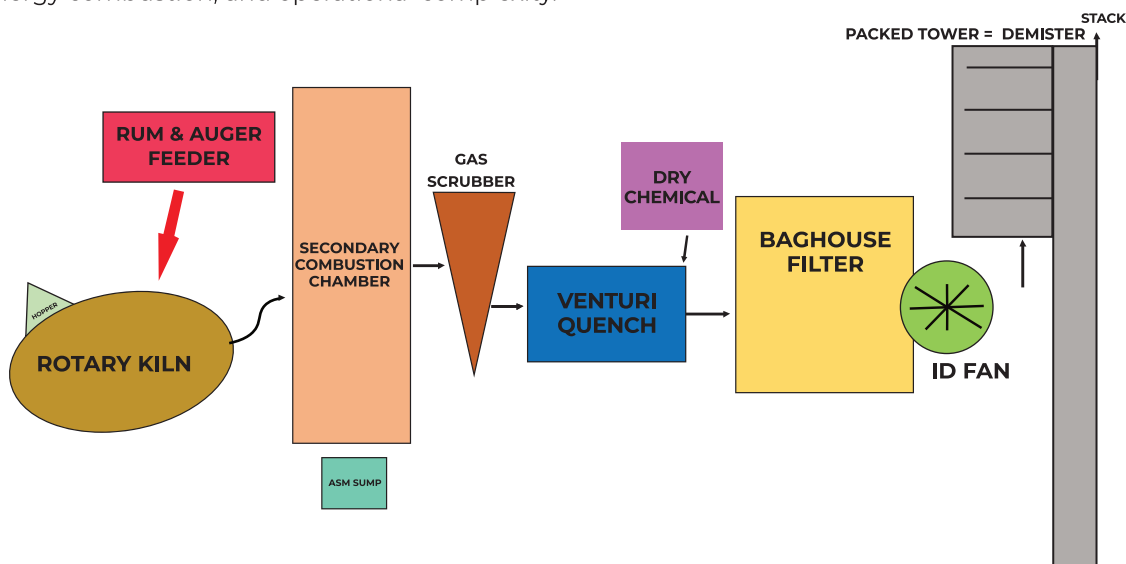


Figure 6-5. Schematic diagram of a rotary kiln incineration system showing the operational flow from waste feeding through the rotary kiln, where primary combustion occurs, followed by secondary combustion for complete oxidation of combustible gases. The resulting flue gas passes through gas cleaning and treatment units, including a gas scrubber, venturi quench, dry chemical injection, baghouse filter, and demister/packed tower, with an induced draft fan controlling gas flow before final discharge through the stack.

Precautions

- Certain materials must not be treated in incinerators, including pressurized gas containers, reactive chemicals, halogenated plastics, and heavy metals.⁷
- When processing waste in an incinerator, appropriate precautions should be followed, including regular equipment maintenance, proper staff training, minimizing or avoiding manual waste loading, and ensuring that ash or treated residues are transported to and disposed of in an approved landfill.
- Staff operating incinerators should wear appropriate PPE such as face shields and masks.
- A contingency plan should be in place for emergencies that could delay waste treatment.

Dry Oven

Dry-heat ovens use conduction to kill pathogens through oxidation. The most common temperature and time combinations for sterilization in a dry oven are 150°C for 150 minutes, 160°C for 120 minutes, and 170°C for 60 minutes. *Bacillus atrophaeus* is used to validate this treatment method due to its resistance to dry heat. Dry-heat ovens can sterilize glassware, powders, and metal equipment non-corrosively with low operating costs, but plastics, surgical dressings, and rubber cannot be treated or sterilized in a dry oven due to their potential deterioration at 160-170°C.

Two types of dry heat ovens are:

- Static air: Generates slow, uneven heat distribution.
- Forced air: Uses a motor-driven blower to provide uniform heat distribution (Figure 6-6).



Figure 6-6. A Forced-Air Hot Air Oven
(Source: University of Haripur, Hazara, KP)

6.2.1.2 Moist Heat Treatment

Autoclave

An autoclave is the safest way to decontaminate laboratory materials. It is a tightly sealed pressure vessel used to treat waste in healthcare facilities (Figure 6-7). It utilizes pressurized water vapors to inactivate biological agents. This moist heat works better for sterilization (121°C for 15 minutes or 134°C for three minutes at 15 lbs of pressure) than dry heat (oven), which requires higher temperatures and longer exposure times (160°C for 80-120 minutes or 200°C for 60-120 minutes). Autoclaves can disinfect glassware, used personal protective equipment, materials contaminated with blood or other body fluids, culture plates, and so on. Autoclaves are unsuitable for large anatomical waste because steam cannot effectively penetrate dense tissues and organs. Autoclaves function by replacing air, which acts as a significant insulator, with steam, enabling heat to reach and sterilize the interior of waste. However, in bulky anatomical material, this penetration is often insufficient.⁷



Figure 6-7. A Standard Autoclave Unit Used in Waste Treatment
(Source: University of Haripur, Hazara, KP)

The three common types of autoclaves are:

- Gravity-displacement autoclaves
- Pre-vacuum or high-vacuum autoclaves
- Steam flush pressure pulse autoclaves (SFPP)

a. Gravity Displacement Autoclave

A gravity-displacement autoclave introduces steam under pressure into the chamber, forcing air downwards into an outlet port (Figure 6-8). The drain valve closes automatically once the steam completely displaces air, and pressure builds up in the chamber. This autoclave supports multiple treatment cycles for different types of waste and has a 0.2 µm membrane filter on its vent. It is highly effective across a range of waste loads and can operate at elevated temperatures to shorten treatment time. However, a limitation is that air may become trapped within dense or complex waste, reducing steam penetration and increasing the risk of incomplete sterilization.

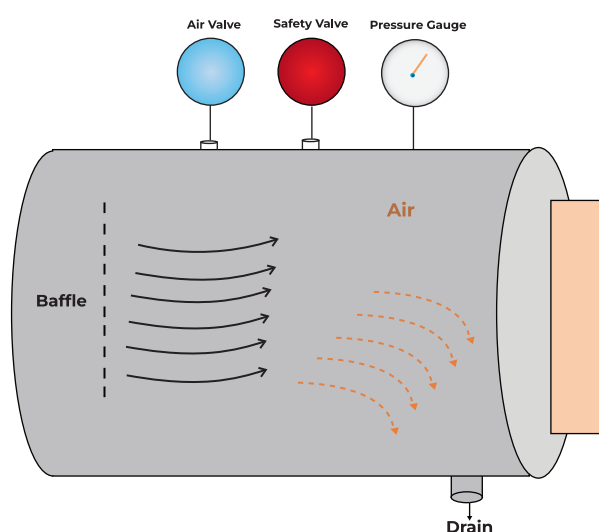


Figure 6-8. Steam Removal in a Gravity Displacement Autoclave

b. Pre-Vacuum Autoclave

A pre-vacuum autoclave is used when air inside an autoclave chamber cannot be easily displaced in a complex load of waste, such as animal cages, bedding, wrapped surgical kits, and other porous materials. At the beginning of the cycle, this autoclave uses a powerful pump to evacuate air from the sterilization chamber. By creating a vacuum, steam penetration can occur effectively under high negative pressure. This type of autoclave is highly effective, even for complex loads, and it can work at a high temperature of 135°C in shorter cycles. For safety, it also has a 0.2 µm membrane filter on its vent.

c. Steam Flush Pressure Pulse Autoclave (SFPP)

It uses repeated steam flushes and pressure pulses to remove air from the autoclave chamber. Unlike a pre-vacuum autoclave, this autoclave does not produce a vacuum to remove air, and the pressure does not drop below atmospheric during operation. This type of autoclave saves both time and cost because it is not susceptible to air leaks and requires no Bowie-Dick test. The risk of recontamination of the autoclave load is minimal, as the chamber operates at a pressure higher than ambient, preventing the ingress of external air. In 1988, the Association for the Advancement of Medical Instrumentation (AAMI) recognized both vacuum and pressure-pulse autoclaves as dynamic air-removal-type autoclaves. In the sterilization phase, exposure times in SFPP are 132°C for 3 minutes and 135°C for 4 minutes at 15- 30 psi. The steam sterilization cycles recognized by the Association for the Advancement of Medical Instrumentation (AAMI)⁸ are shown in Figure 6-9.

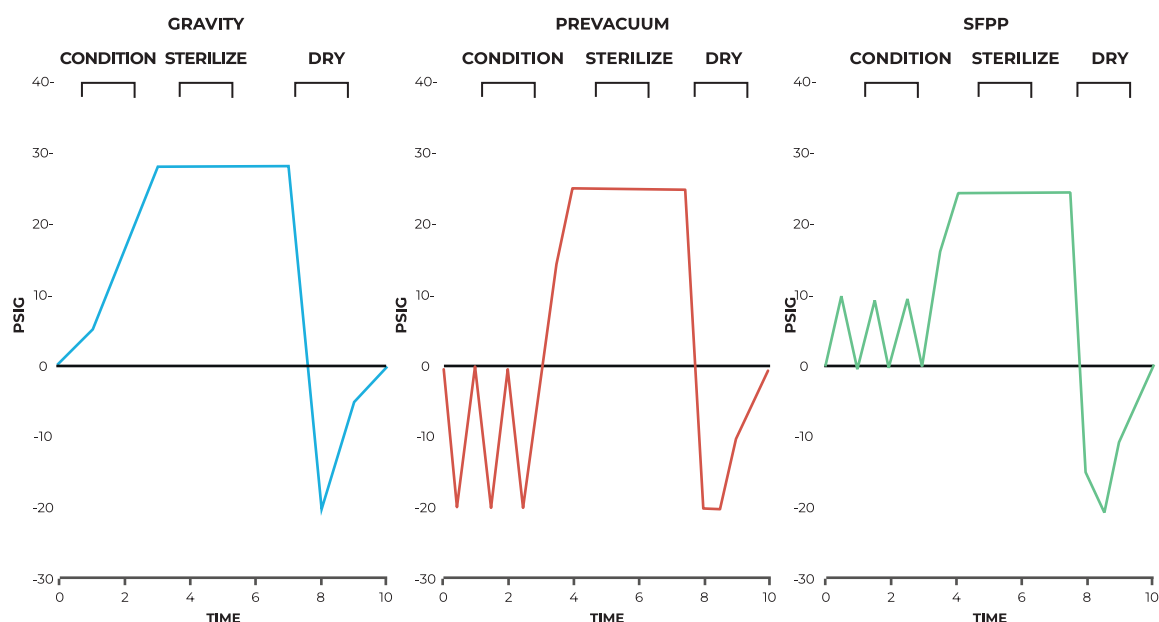


Figure 6-9. Three Steam Sterilization Cycles Recognized by the Association for the Advancement of Medical Instrumentation (AAMI)

Here are some precautions to follow when using an autoclave:

- Ensure the autoclave area is well-ventilated to avoid vapor buildup.
- Pack materials loosely to allow easy steam penetration and use autoclave-compatible bags made of polypropylene or polycarbonate.
- Fill bags to $\frac{3}{4}$ of their total volume.
- Put waste materials for treatment in a secondary leak-proof container to prevent spills and melting of low-quality plastics into the autoclave's drain.
- Add a small amount of water to the waste bag before packing to enhance heat transfer in the packed waste.
- Use a rack or secondary container for materials placement to avoid contact with the autoclave's interior surfaces.

- Wear appropriate PPE when operating autoclaves.
- Perform routine in-house maintenance of autoclaves and, if possible, shred autoclave-treated materials to reduce the volume of waste for final disposal. Record each batch of waste being treated.
- Do not overfill bags or waste containers, and do not autoclave corrosive, radioactive, volatile, or flammable materials.
- Validate and verify autoclave sterilization cycles with chemical indicators, thermocouples, and biological indicators.

Biological Indicators

Biological Indicators (BI) validate and verify autoclave sterilization cycles, providing a direct measure of the effectiveness of microbial kill. By challenging autoclave processes with highly resistant spores, these indicators provide a robust method for assessing sterilization performance and ensuring regulatory compliance.⁹ Biological indicators are available in many different forms, including biological indicator test strips and vials containing *Bacillus stearothermophilus* spores (Figure 6-10).

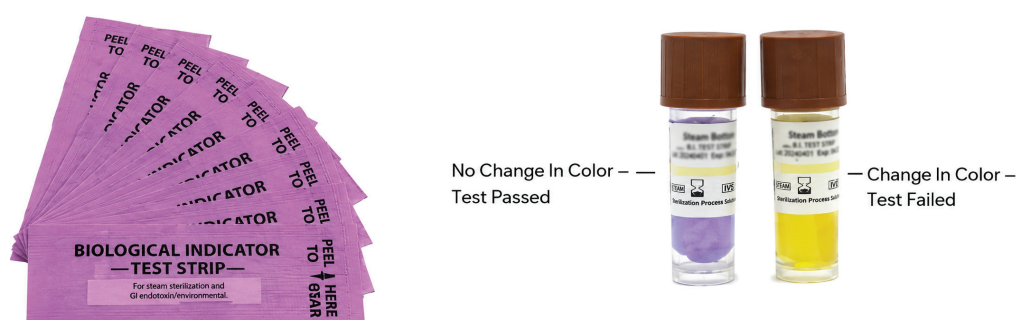


Figure 6-10. Biological Indicator Test Strips and Rapid Biological Indicator Vials

Chemical Indicators

Chemical indicators provide a practical and cost-effective method for verifying that the required sterilization parameters have been achieved during an autoclave cycle. They are classified into six categories, each designed with specific performance characteristics and monitoring capabilities (Table 6-2).

Table 6-2. Categories of Chemical Indicators

Class	Name	What does it monitor?	Accuracy	Visuals
1	Process Indicator	Shows if a unit has been exposed to sterilization (distinguishes processed vs unprocessed items). Does not confirm steam penetration to the center of the waste and does not measure specific parameters (only exposure). Examples include indicator tapes.	Low	
2	Specific-Use Indicator	Tests specific functions (e.g., air removal in a pre-vacuum autoclave). Examples include a Bowie-Dick test.	Moderate	 UNPROCESSED PASS FAIL
3	Single-Variable Indicator	Monitors one critical parameter only, such as temperature in a steam sterilization cycle	Moderate	

4	Multi-Variable Indicator	Assesses if multiple parameters are met, like temperature over a specific duration in a sterilization chamber	Higher than class 3	Multivariable CI  Accept if magenta circle turns orange/yellow or lighter yellow
5	Integrating Indicator	Monitors all critical parameters throughout sterilization and works across a range of cycles. Examples include moving front indicators.	High	
6	Emulating Indicator	Evaluates parameters of a specific cycle only. Examples include cycle-specific indicators.	Very high	

Thermocouples

Thermocouples, versatile temperature sensors, are widely used in various industries, including medicine, food, and manufacturing. These instruments are strategically positioned within an autoclave chamber to provide highly accurate temperature readings at various points during sterilization. By providing real-time temperature data, thermocouples ensure that the autoclave operates within the specified temperature range, guaranteeing effective sterilization while preventing overheating or underheating. Moreover, these temperature sensors play a crucial role in maintaining consistent, reliable autoclave performance, thereby contributing significantly to the safety and quality of sterilized items and instilling confidence in the process.

Microwave Oven

Microwave technology treats biomedical waste using electromagnetic energy at 2450 MHz (wavelength 12.24 cm), generated by a magnetron, to effectively disinfect the waste (Figure 6-11). These systems are available in different configurations, with small units treating approximately 30–100 liters per cycle, while semi-continuous systems can achieve throughputs of up to about 250 kg/hour depending on waste composition and operating conditions. In a typical semi-continuous process, biomedical waste, including microbial cultures, sharps, blood- and body-fluid-contaminated materials, pathological waste, and routine laboratory waste, is fed into a loading hopper. The waste is then conveyed into a shredder to reduce particle size and improve heat penetration. Within the treatment chamber, water is injected and converted into saturated steam (approximately 95–100 °C), while microwave energy from multiple magnetrons (commonly four to six units, depending on system design) ensures rapid and uniform heating. Air displaced from the chamber is typically vented through a high-efficiency particulate air (HEPA) filtration system to prevent microbial release. In some configurations, a secondary shredder may be installed downstream of the microwave treatment stage, particularly to further reduce volume or to enhance material handling of treated sharps and residual solids.¹⁰

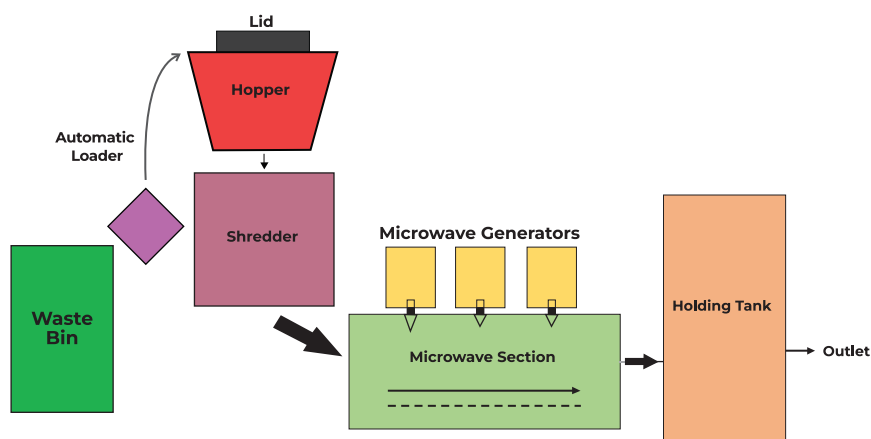


Figure 6-11. Schematic Diagram of Semicontinuous Microwave Technology

Reverse Polymerization/Thermal Depolymerization

Reverse polymerization is a thermal process that uses medium heat ranging from 177-370°C, high-intensity microwave energy, and high pressure. The process involves breaking down organic materials in nitrogen-rich and oxygen-depleted environments. This nitrogen-rich atmosphere helps reduce oxygen levels, preventing combustion at high temperatures. This microwave-based technology differs from incineration, where waste oxidation occurs at high temperatures. One disadvantage of this technology is that it produces gaseous emissions that require control.¹¹

The system operates in three stages: loading, weighing, and purging; microwave-assisted depolymerization; and cooling and grinding. This technology can effectively treat biological and anatomical waste, plastics, sharps, and glass, with a daily capacity of 1,225 Kg. This method achieves 6-log¹⁰ pathogen inactivation and an 80% final volume reduction. NaOH is used as a scrubber to control emissions, which generate wastewater that needs to be treated.

6.2.2 Irradiation

Waste can be treated using two types of irradiations: ionizing and non-ionizing.

Ionizing radiation, such as gamma rays or electron beams, disrupts molecular structures and damages cellular components. This method sterilizes waste by eliminating pathogens and microorganisms, making it safe for reuse or disposal. Ionizing radiation is highly energetic and can effectively penetrate waste materials, ensuring comprehensive treatment.

Non-ionizing radiation, such as ultraviolet (UV) light and infrared radiation, treats waste by altering chemical bonds and affecting biological processes in microorganisms. UV light damages microorganisms' DNA, inhibiting their ability to reproduce and, as a result, disinfects the waste. This method is helpful for the surface disinfection and decontamination of waste materials. Additionally, infrared radiation can be used to dry or thermally treat waste, reduce moisture content, and destroy organic matter.

Both ionizing and non-ionizing radiation methods offer efficient, environmentally sustainable solutions for waste management, each with distinct advantages in waste treatment.^{11,12}

6.3 Disposal

One method of disposing of treated waste is burial in a secure, monitored landfill site. Treated waste must never be dumped into general landfills; instead, engineered sites designed specifically for hazardous waste must be used for its safe burial.² These engineered landfills (Figure 6-12) are constructed with engineering-based controlled measures to minimize soil, surface, and groundwater contamination, block rodent access, and prevent public exposure.

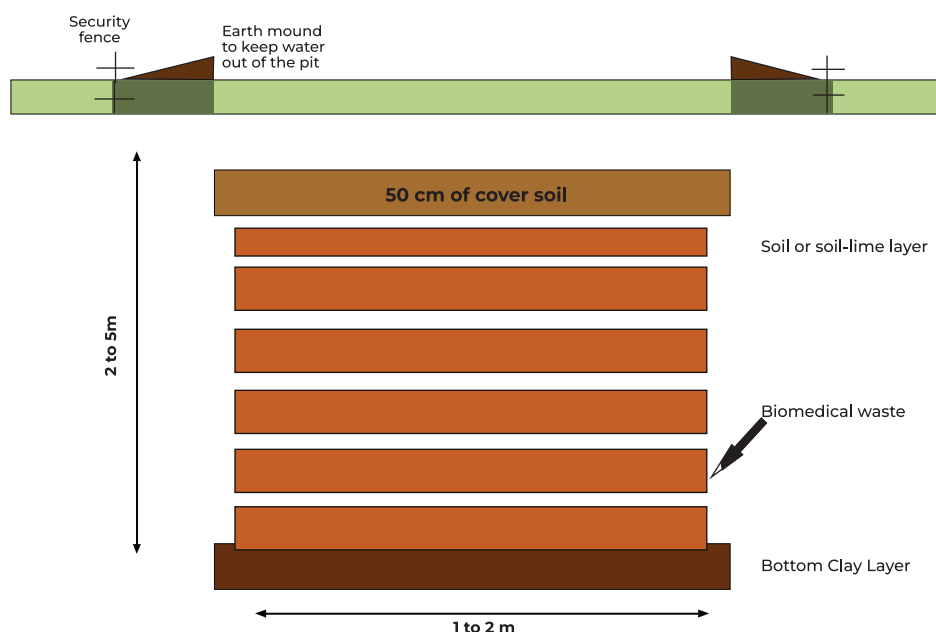


Figure 6-12. Structure of an Engineered Landfill

To ensure safe and secure waste disposal, it is imperative to prioritize the following points for the final disposal of biohazardous waste:

- Restrict access to disposal sites exclusively to authorized personnel, including designated waste transporters.
- Inform and engage the public regarding hazardous waste disposal and any necessary safety precautions.
- Adequately cover waste materials to prevent odors and pests.
- Avoid locating water wells near disposal sites.
- Reserve burial for biohazardous waste only.
- Adhere to local Environmental Protection Agency guidelines for burying different types of wastes.

6.4 Decontamination, Disinfection, and Sterilization

6.4.1 Decontamination

Decontamination is the process of cleaning, disinfecting, or sterilizing surfaces, equipment, spaces, or materials to reduce microbial contamination to safe levels, thereby protecting laboratory personnel, the environment, and the integrity of research outcomes. It aims to achieve a safe and hygienic environment and prevent the transmission of infection.¹³ Decontamination protocols vary depending on the level of decontamination required and include fumigation, disinfection, autoclaving, or incineration. These are critical for maintaining laboratory quality and safety standards and compliance with regulatory guidelines.¹⁴

6.4.1.1 Disinfection

Disinfection, the process of destroying (inactivating) vegetative microorganisms, is not merely a routine part of laboratory operations but a vital one. It is primarily carried out using chemical disinfectants (Table 6-3). It is crucial for maintaining a safe laboratory environment to include routine disinfection of surfaces such as laboratory workbenches and equipment, and the treatment of biomedical waste.

Different disinfectant characteristics should be considered before selecting them for specific purposes, such as:

- Proven efficacy
- Quick action - a short contact time
- Wide spectrum with bactericidal, virucidal, fungicidal, and sporicidal actions, as per the intended use
- Polyvalent – suitable for many different applications
- Easy to use
- Not toxic or harmful to the environment
- Long shelf life
- Not toxic or harmful to the user
- Economic and cost-effective¹⁵

Table 6-3. Different Types of Disinfectants Commonly Used in Laboratories

Disinfectants	Examples of Commonly Used Products
Iodophors	Betadine, Povidine
Chlorine releasers	Bleach (Sodium hypochlorite)
Oxidizing agents	Hydrogen peroxide (H ₂ O ₂), Peracetic acid
Biguanides	Chlorhexidine
Alcohols	70% Ethanol, 70% Isopropanol (IPA)
Aldehydes	Formaldehyde, Glutaraldehyde
Phenolic compounds	Triclosan, Environ
Quaternary Ammonium Compounds (QACs)	Benzalkonium chloride

Each disinfectant has its mode of action, conditions for use (e.g., form, concentration, and contact time), and physical and chemical characteristics, including toxicity and potential for harm.¹⁶ The efficacy of disinfectants against different categories of microorganisms is shown in Table 6-4.¹⁷ The two most commonly used disinfectants are detailed below.

Sodium Hypochlorite/Bleach (NaOCl)

This chemical is a widely used disinfectant recognized for its efficacy, affordability, and high efficiency. It is used for surface cleaning, disinfecting instruments, glassware, managing liquid waste, and handling infectious spills. When purchasing a commercial product, requesting a test report or certificate from the vendor is essential to determine the concentration and time required to achieve the specified log reductions. It is mandatory to adopt validated procedures for liquid waste treatment using bleach or to perform in-house validation for new/unvalidated procedures. Bleach has some limitations, such as a short half-life, especially when diluted; skin, eye, and respiratory irritation; discoloration of fabrics; reactivity with some chemicals; and detrimental effects on the environment. Diluted sodium hypochlorite solution remains active for a maximum of 1 week. In contrast, undiluted solutions have a shelf life of 6 months to 1 year, after which they degrade at 20% each year.

Alcohol

Alcohol, specifically Ethanol or Isopropanol, is commonly used as a disinfectant. They work effectively against vegetative bacteria, fungi, and enveloped viruses. The cidal activity of alcohol is at its best at a concentration of 60-90%, but it sharply drops if the concentration falls below 50%. These disinfectants are easy to use and are less corrosive than chlorine, leaving no surface residue. They are used to disinfect the outer surfaces of waste bags and containers before handling and transport. However, they are not ideal for treating large amounts of solid infectious waste due to their flammability, rapid evaporation, high cost, poor penetration, and limited activity against non-enveloped viruses. They may also cause eye irritation and toxicity if ingested or inhaled.

Table 6-4. Efficacy of Commonly Used Disinfectants

Products/Compounds	Vegetative Bacteria	Mycobacteria	Bacterial spores	Fungi	Lipidic viruses	Hydrophilic viruses
Chlorine releasers	+	+	+	+	+	+
Hydrogen peroxide	+	+	+	+	+	+
Chlorhexidine	+	-	-	+	+	+
70% alcohol (ethyl-propyl)	+	+	-	+	+	+/-
Aldehydes	+	+	+/-	+	+	+
Phenolic compounds	+	+	-	+	+	+
Quaternary Ammonium Compounds (QACs)	+	-	-	+/-	+	+/-

+ effective, - non effective

6.4.1.2 Sterilization

Sterilization is a process in which the probability of all living organisms, including spores, surviving is 1:1,000,000, which is one in one million or 10^{-6} . Sterilization methods include high-level disinfectants and physical treatments such as heat, gamma irradiation, and plasma sterilization.

6.4.1.3 Fumigation

Formaldehyde

Formaldehyde is widely used for fumigating enclosed areas, biosafety cabinets, and equipment before maintenance, service, or disposal. It causes an irreversible denaturation of proteins and damages bacterial DNA. It is very effective in controlling microbial contamination. The market offers different sources of formaldehyde, including paraformaldehyde tablets, formalin solutions, and formaldehyde gas generators. The fumigation technique involves releasing formaldehyde gas from these sources that can reach every part of the enclosed space or equipment. Before fumigation, the area or equipment is sealed off to prevent formalin from escaping outside. The maximum exposure limit of formaldehyde is 2 parts per million (ppm) to ensure safety. After 24 hrs. of fumigation, formaldehyde is dissipated completely with proper ventilation. In one of the methods for fumigation, 35 ml of liquid formalin (40%) is added to 17.5 g of potassium permanganate (KMnO_4), which is a ratio of 2:1 (v/w) to fumigate one cubic meter of space. When potassium permanganate is added to formaldehyde, a reaction occurs that generates fumes. Generated fumes kill bacteria, fungus, and their spores. It is important to validate fumigation methods for the subsequent safe disposal or use of equipment.¹⁵

Vaporous Hydrogen Peroxide (VHP)

Vaporous Hydrogen Peroxide (VHP), a gaseous form of hydrogen peroxide, is used for pre-disposal decontamination of glove boxes, walk-in incubators, and other high-risk equipment. VHP is effective at concentrations of 0.5 to less than 10 milligrams per liter (mg/l) with an optimal concentration of 2.4 mg/l, and a contact time of at least one hour. VHP releases water and oxygen as its end products and therefore has a better safety profile than formaldehyde. However, concentration, exposure time, and conditions of use should be clearly defined and validated before adopting it as the method of choice for equipment decontamination.

Chlorine Dioxide

Due to its strong oxidizing properties, chlorine dioxide gas can decontaminate various spaces, HVAC systems, and equipment before disposal. For fumigation, the concentration should be approximately 10 mg/l with a contact time of 1-2 hours. Chlorine dioxide doses are safer than formaldehyde and do not produce toxic by-products such as chloramines during treatment.

Dry Fogging System

A dry fogging system is a technology used to disperse disinfectants, sanitizers, or other chemical agents as extremely fine droplets, typically smaller than 10 μm in diameter. This method produces a dry mist that can uniformly coat surfaces and penetrate inaccessible areas without causing excess moisture buildup. Dry fogging is employed in various environments, including laboratories, healthcare facilities, and waste storage areas, to achieve thorough decontamination and disinfection. The active ingredients used for decontamination or disinfection are peracetic acid and the equipment that converts the liquid disinfectant into dry fog. This machine typically uses ultrasonic technology, high-pressure nozzles, or thermal energy to create fine droplets. The dry fogging system efficiently and effectively delivers disinfectants to all targeted areas, achieving comprehensive decontamination. Fumigation techniques are not ideal for treating solid waste due to their poor penetration and safety risks.

6.4.2 Treatment of Waste Containing Prions

- The Robert Koch Institute recommends treating prions in an autoclave at 134°C for 60 minutes. However, each institute should validate its parameters using sample waste that represents the actual waste to determine the minimum pressure, exposure time, and temperature required to inactivate prions.
- Incineration at 1000°C is an effective method for destroying prions in animal carcasses and liquid and tissue waste. However, combustion at temperatures below 600°C may reduce prion infectivity, but it cannot guarantee destruction.
- Alkaline hydrolysis is a technology that has been approved for treating solid waste containing prions. It can effectively destroy prions within six hours. Moreover, it can be used as an alternative to incineration. It involves exposing tissues and carcasses to a solution of 1 N NaOH or KOH in a pressure vessel at 150°C.
- According to BMBL protocols for handling waste containing prions, reusable instruments can be pretreated with 1N NaOH or bleach at 20,000 ppm for 1 hour in a fume hood, then autoclaved at 134-138°C for 18 minutes or at 121°C for 1 hour.¹
- During sample processing, liquid waste can be collected in a vessel with a one-liter capacity containing 150 ml of 6 N NaOH.

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Checklist – Waste Treatment and Disposal

Sr. No.	Description	Yes	No	N/A	Remarks
1.	A solid waste treatment and disposal plan is in place.				
2.	A sharps waste treatment and disposal plan is in place.				
3.	A liquid waste treatment and disposal plan is in place.				
4.	Radiological waste treatment and disposal have been planned.				
5.	Waste Treatment Methods in Use (select all that apply)				
	a. Moist Heat (Autoclave)				
	b. Incinerator				
	c. Dry Oven				
	d. Microwave				
	e. Reverse Polymerization				
	f. Ionizing Radiation				
	g. Non-Ionizing Radiation				
6.	For the outsourcing of waste, an MOU/contract has been developed and signed.				
7.	Autoclave validation for waste treatment has been done.				
8.	Biological indicators are used as planned.				
9.	Chemical indicators/thermocouples are used with every load.				
10.	Suitable methods of decontamination, sterilization, and disinfection have been defined and implemented.				
11.	The organization has organized disposal in compliance with local regulations and guidelines.				
12.	Personnel engaged in waste treatment and disposal have received appropriate training, and a refresher training plan is in place.				
13.	Corrective and preventive measures are developed and implemented.				
14.	Records of laboratory waste treatment and disposal are maintained and retained for data analysis.				

SECTION 07

Liquid Waste Management

Asad Ullah, Saeed Khan

Improper handling and disposal of liquid waste/effluent threaten human and animal health and the environment by polluting watersheds and groundwater.¹ Therefore, it must be stored and disposed of properly to ensure safety and compliance with applicable regulations. Gathering comprehensive information on environmental, health, and safety requirements in accordance with local and national regulations is crucial before setting SOPs for its final disposal. If needed, an experienced and qualified person, such as a biosafety officer, a subject-matter expert, the institutional biosafety committee (IBC), or other relevant stakeholders, must be consulted to ensure proper decontamination and disposal of liquid waste.

7.1 Classification of Liquid Waste

Risk assessment aids in determining an optimal approach for decontaminating liquid waste.² Therefore, it is important to identify and classify biological agents and other hazardous substances that can be potentially present in liquid waste. Per local and national regulations, this helps categorize it as wastewater or special infectious liquid waste. Infectious waste includes:

- a. Bulk quantities of blood, blood products, and body fluids from human and animal origin
- b. Laboratory wastes (microbiological broth cultures of infectious agents, etc.)

7.2 Processes of Liquid Waste Management

- Waste segregation is key to successful waste management in a laboratory. Separate waste containers must be used for different types of liquid waste, such as infectious, chemical, and radioactive waste.
- During handling, dripping, spillage, and aerosol formation must be minimized to avoid exposure to hazardous substances.
- Waste collection bottles should not be filled more than 75% of their total volume. When collecting waste, the contents inside the bottle may interact, producing gas and pressure. Since air is much more compressible than liquids, the 25% air volume within the collection bottle reduces the risk of explosion.³
- If the liquid is stored in a glass bottle or in large quantities, use a secondary container to carry it to the waste collection area.
- Correct labelling of waste containers is essential to inform others about potential hazards and shorten the response time in case of an emergency.
- Labelling includes waste category along with corresponding pictogram, data about the date and location of waste generation, and the responsible person. Regular training on correct labelling practices is recommended for every laboratory.
- Liquid waste must be transported in shatterproof containers. Shatterproof containers prevent the leakage of hazardous liquids in case they are accidentally dropped.
- When handling liquids in a laboratory, the formation of droplets and aerosols can be prevented by using aspiration tools that match the labware to be aspirated, such as tubes, dishes, bottles, T-flasks, and 96-well plates.
- Pharmaceutical liquid waste (discarded, unused, or expired medicines) and photographic and X-ray chemicals (fixer and developer) are disposed of as per the chemical safety plan.

7.3 Selecting the Proper Decontamination Method

- It is important to never flush antimicrobial, anticarcinogenic, antineoplastic, or controlled drugs into sewer systems. However, harmless solutions like salts, glucose, amino acids, and vitamins can be flushed into sewers; though, this should be avoided in stagnant or slow-moving water.
- Transforming active substances into neutral products helps reduce associated risks. It may reduce the volume of waste that must be sent to third parties for special treatment. Therefore, it is important to deactivate infectious and other hazardous substances before further treatment or handling.
- Choose a deactivation method according to the nature of the hazard and the level of risk. Local and national regulations must be complied with in this regard.
- Evaluate the method's compatibility with other substances in the waste.
- Check compatibility with the instruments and materials used for deactivation.

Note: Understand the hazards and toxicity of the materials by consulting Safety Data Sheets (SDSs) and safe disposal methods. SDS is an important component of the Workplace Hazardous Materials Information System (WHMIS)⁴ and is intended to supplement alert information provided on labels. SDS contains chemical composition, hazardous ingredients, concentration levels, physical characteristics, stability, health effects, safe storage guidelines, handling procedures, and disposal methods (see Appendix 3).

7.4 Treatment of Liquid Waste

7.4.1 Chemical Treatment

- A primary consideration when choosing a chemical disinfectant for treating liquid waste is its effectiveness against biological agents handled in the laboratory or potentially present in the waste. An example of a suitable disinfectant for chemical treatment is 5.25% bleach in a 1:10 dilution. However, it's crucial to validate procedures for treating liquid waste to confirm their effectiveness under specific conditions. For example, organic load, which represents the amount of organic matter in a solution, may affect a disinfectant's efficacy against the same pathogens across different liquid wastes. Similarly, some pathogens may be more resistant to disinfectants than others.
- Spores and prions necessitate a more thorough decontamination before disposal.
- It is important to note that not all liquid disinfectants can be drained down the drain after disinfection and should be handled as chemical waste.
- Never autoclave chemically treated liquid waste, as it can generate dangerous chemical byproducts; instead, handle it according to the handling instructions for the disinfectant being used.⁵

7.4.2 Thermal Treatment

- Containers of human blood and Other Potentially Infectious Materials (OPIM) can be autoclaved for further disposal as autoclaved waste or via drainage as per risk assessment and existing regulations.^{6,7} For disinfection, steam must come into direct contact with the liquid being treated; therefore, containers holding liquid waste should not be air-tight during treatment.
- Certain types of liquid wastes can be safely disposed of through high-temperature incineration or cement kilns. For this, liquid waste can be placed in biohazard waste bags in predefined quantities per bag.
- Containers maintaining a vacuum, where opening may create splash hazards, should not be opened for on-site treatment. Such containers should be disposed of in biohazard waste bags and transferred for further treatment in accordance with established protocols.
- Disposal of certain liquid drugs may require the presence of absorbent materials in waste containers if encapsulation and land filling are the only options available for disposal.^{8,9}
- Liquid waste can be solidified using solidifiers, which convert it into solid waste for further treatment and disposal.

7.4.3 Effluent Decontamination System (EDS)

Maximum containment laboratories should have an Effluent Decontamination System (EDS) to safely treat and dispose of effluents from their research and diagnostic activities. These systems can use physical, chemical, and biological treatment processes to eliminate contaminants from the liquid waste. The objective is to produce a treated effluent suitable for discharge back into the sewerage system. Sodium hypochlorite, phenols, and Quaternary Ammonium Compounds (QACs) are a preferred choice of chemicals for decontaminating liquid waste.¹⁰ The US EPA's Registered Antimicrobials for the treatment of medical waste are listed as List J, and can be found in Appendix C.

7.4.4 Treatment of Mixed Waste

Biological liquid waste containing radioactive substances or hazardous chemicals must be treated with special care and after a thorough risk assessment.

- Liquid waste containing biohazardous and radioactive materials should be segregated and stored in a secure location until radioactivity levels have decreased to a safe level, then chemically disinfected to eliminate biological agents.
- Liquid waste containing chemical and biological hazards must be treated with a suitable and compatible disinfectant, followed by the neutralization of the chemicals or handing over to a dedicated chemical waste treatment facility.
- Biological liquid waste containing both chemical and radioactive hazards should be handed over to a designated waste treatment facility after proper labelling.¹¹

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Checklist – Liquid Waste Management

Sr. No.	Description	Yes	No	N/A	Remarks
1.	All sources of liquid waste within the facility have been identified.				
2.	The types and quantities of liquid waste produced, including its hazardous components, have been determined.				
3.	A system to segregate different types of liquid waste is available.				
4.	Suitable containers are available for the collection and storage of liquid waste.				
5.	Containers have been labeled with the type of waste and any hazards associated.				
6.	Liquid waste is disposed of as per regulations.				
7.	Records of liquid waste generation, collection, and disposal are being maintained as per regulatory requirements.				
8.	Compliance with waste management procedures is monitored.				
9.	Regular inspections of storage areas and containers for leaks, deterioration, or overfilling are regularly done.				
10.	Training on proper handling, storage, and disposal of liquid waste has been provided and documented.				
11.	Procedures are developed to respond to liquid waste spills to minimize environmental impact.				
12.	An Effluent Decontamination System (EDS) is available.				

SECTION 08

Chemical Waste Management

Qamar Abbas, Habib Ullah Jan

Proper handling and disposal of chemicals is essential to ensure the safety of people and the environment. Harmless chemicals can usually be disposed of through the sanitary system, but hazardous chemicals such as mercury, certain acids, and bases require special care. These hazardous chemicals are potentially harmful due to their toxic, flammable, corrosive, or reactive properties. Some other compounds, such as those on the “Red List,” should never be drained into the regular sanitary system due to associated health and safety risks. These include chloroform, formaldehyde, benzene, phenol, chromium VI chemicals, and phthalates.¹ Regulatory bodies like the Pakistan Environmental Protection Agency (EPA) monitor chemical waste disposal to ensure the safety of the environment. Similar regulatory bodies operate worldwide, including the United States Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA). The Pakistan National Hazardous Waste Management Policy, 2022, also clarifies institutional responsibilities, strengthens management, and protects environmental safety.²

8.1 Chemical Life Cycle

The concept of the chemical life cycle involves considering both the origin and final disposition of chemicals. It is essential to evaluate potential hazards at every stage of their use, rather than focusing only on the moment a container is opened. This approach ensures comprehensive risk management throughout the entire process.³ The chemical life cycle can be divided into four key stages:

1. Procurement
2. Storage
3. Handling
4. Disposal

8.2 Potential Hazards of Chemical Waste

Safe management of hazardous chemical waste must be done according to its identity, constituents, and hazards. Table 8-1 shows labels for flammable, corrosive, and reactive chemicals as per the Standard Globally Harmonized System (GHS) and the United Nations (UN) Recommendations on the Transport of Dangerous Goods (TDG).^{4,5} Chemical waste is evaluated for its potential hazards based on the following four characteristics:

- a. Flammability
- b. Corrosion
- c. Reactivity
- d. Toxicity

a. Flammability Characteristics

Flammable waste includes liquids with a flashpoint below 140° F (60° C), oxidizing materials, ignitable compressed gases, and solids that are combustible through reaction or friction. Examples of flammable waste are petroleum products, aerosol cans, solids, oxidizers, and organic peroxides.

b. Corrosive Characteristics

Chemicals with a pH below two or above 12.5 can initiate corrosion in particular steel grades. Acids and bases are examples of typical corrosives. Strong acids include hydrochloric acid, acetic acid, sulfuric acid, muriatic acid, etc. Bases include caustic substances such as sodium hydroxide, ammonia, potassium hydroxide, bleach, cleaners, etc.

c. Reactivity (Oxidizers) Characteristics

Reactive waste is generally unstable and readily undergoes violent changes. It reacts violently with water, forms potentially explosive mixtures, and emits toxic gases, vapors, or fumes when water is added. Examples of reactive waste are explosives, common reactive materials, oxidizers, and materials that emit ionizing radiation.

d. Toxicity Characteristics

Unlike many other chemicals, toxic materials are dangerous because of their chemical reactions inside the body. For instance, flammables and explosives cause uncontrolled reactions outside the body, whereas toxic chemicals disrupt the intracellular metabolism of an exposed individual. Exposure to toxic chemicals can cause severe health issues or death. Examples of typical toxic materials are pharmaceuticals, heavy metals, and polychlorinated biphenyls (PCBs). When concentrations of metals and organic chemicals in solid waste exceed regulatory thresholds, the waste becomes toxic. The EPA's Toxicity Characteristic Leaching Procedure (TCLP) determines these thresholds by measuring the ability of certain toxic substances to leach from waste materials in a landfill. Hazardous waste, which includes heavy metals, solvents, and pharmaceuticals, must be carefully managed to prevent harm and reduce contamination.

Table 8-1. Labels for flammables, corrosives, and oxidizing agents as per the Globally Harmonized System and the United Nations (UN) Recommendations on the Transport of Dangerous Goods (TDG)		
	Globally Harmonized System (GHS)	United Nations (UN) Transport of Dangerous Goods (TDG)
Flammables		
Corrosives		
Oxidizing Substances		
Toxic Substances		

8.3 Waste Minimization and Pollution Prevention

Minimizing waste is an effective way to save chemical usage and disposal costs. There are several ways to achieve waste minimization in a laboratory:

- Order only the minimum quantity of chemical materials required or use digital inventory management systems that enable real-time tracking of stock, storage duration, and expiration dates. It also generates automated alerts for chemicals approaching their expiry, supporting timely review, testing, or disposal. This is particularly important for the safe management of Class A and Class B peroxide-forming chemicals, where prolonged storage increases the risk of hazardous peroxide formation.
- Share surplus chemicals with other labs.
- Purchase mercury-free instruments.
- Whenever possible, try to substitute hazardous chemicals with non-hazardous ones.
- Reduce the scale of laboratory experiments, wherever possible, to minimize the volume of waste produced.
- Dispose of chemicals as soon as their shelf life expires.
- Maintain an inventory of chemicals in the laboratory.

Effective management and regular inspection of chemical inventories can reduce the quantity of hazardous waste and costs associated with its disposal.⁶ By effectively managing and consuming chemical stocks, a manager can prevent unwanted occurrences such as "unknown" chemicals, duplicate purchases, expired chemicals, and excessive inventory.

The use of digital inventory management systems can enhance chemical safety by enabling real-time tracking of stock, storage duration, and expiration dates. These systems can generate automated alerts for chemicals approaching their expiry, supporting timely review, testing, or disposal. This is particularly important for the safe management of Class A and Class B peroxide-forming chemicals, where prolonged storage increases the risk of hazardous peroxide formation.

8.4 Labelling of Waste Containers

Chemical waste containers should be sealable, leak-proof, and compatible with the chemicals to be collected. The containers and waste bags used for solid chemical waste should be labeled with the primary hazard name, chemical composition of the waste, and the percentage of each component in it, along with the department and facility name from which this waste was generated, and the name and phone number of the contact person from that department, as shown in Figure 8-1.⁷ Additional labelling can provide supplementary information on hazards, for example, the hazard diamond. Unlike the initial label, the hazard diamond is not included in the Globally Harmonized System (GHS), yet it remains widely employed and significant. Its use remains optional worldwide except in a few countries, where existing regulations mandate it. In hazard diamond, the higher the number within the squares on a scale of 0 to 4, the greater the compound's hazard in the container. Explanation of the colors on a hazard diamond is elaborated in Figure 8-2.⁸ The empty chemical containers should be marked "EMPTY" and should be disposed of like regular trash. Any unidentified waste material will be treated as hazardous until its actual status is determined through appropriate testing. It is essential to mark it as "unknown" before testing and affix a designated label card for identification.

HAZARDOUS WASTE

PRIMARY HAZARD

TOXIC

Facility Name: _____

Department Name: _____

Laboratory Name: _____

Contact Name: _____

Phone Number: _____

Chemical Composition	%

Figure 8-1. An Example of a Chemical Waste Label

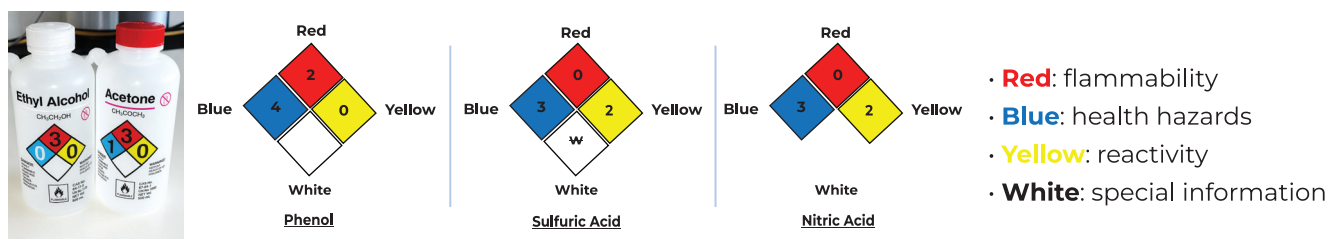


Figure 8-2. The Hazard Diamond Developed by the National Fire Protection Association (NFPA), USA

8.5 Storage of Chemical Waste

Chemical waste should be collected and stored in a central waste storage facility. The following precautions should be taken for waste storage:

- Store chemicals based on compatibility, with incompatible materials separated by impermeable barriers.
- Properly label storage locations for different chemical wastes. Storage locations should be compatible and appropriate for the relevant type of chemical waste.
- Do not store chemical waste containers on the floor.
- Do not overcrowd the storage area.
- Do not accumulate waste for an extended period.
- Use a temperature-controlled, dry area to store chemical waste containers and ensure the labels are legible and facing outward.
- Store chemicals at the proper temperature.
- Routinely inspect the storage area to ensure there are no spills, leaks, or broken containers.

A chemical compatibility matrix can serve as a quick reference to guide safe storage practices by highlighting which classes of chemicals must be kept separate. Table 8-2 provides a few examples of chemicals that must never be stored together.

Table 8-2 Chemical Compatibility Matrix for the Safe Storage of Chemicals

Chemical Class	Keep Away From	Reason/Hazard
Oxidizers	Flammables, organic materials	Can intensify fire or cause combustion
Flammable liquids	Oxidizers, ignition sources	Fire and explosion risk
Acids	Bases, cyanides, sulfides	Toxic gas release, heat generation
Peroxide-forming chemicals	Heat, light, oxidizers, prolonged storage	Formation of explosive peroxides
Water-reactive chemicals	Water, moisture	Release of flammable/toxic gases, heat
Toxic chemicals	Incompatible substances (varies)	Release of harmful vapors or reactions
Compressed gases	Heat, physical damage, incompatible gases	Explosion or leakage risk

8.6 Treatment and Disposal of Chemical Waste

8.6.1 Acids and Bases

- Each waste material necessitates specific management. Adherence to waste management processes is crucial, as it has a significant role in overall waste management.
- When handling concentrated acids and bases, it's essential to collect them in their original containers, which should be tightly closed before collection.
- Diluted acid and base solutions should be disposed of down the lab sink with ample water, provided their concentrations are below 10% (V/V), and their pH is between 6 and 9. Draining any material with a pH below 6 or above 9 is prohibited to prevent environmental contamination and potential legal issues.
- Neutralization of acids and bases is very common and widely accepted. Corrosive waste can be neutralized if the materials have no other associated hazards. However, if a material is classified as 'hazardous' due to its toxicity, ignitability, or reactivity, or contains any other hazardous wastes, it cannot be neutralized. Corrosive waste that can not be neutralized must be collected as regulated hazardous waste.
- The neutralization procedure must be done in small batches, and the waste may not be transported between areas for batch neutralization.

8.6.2 Ethidium Bromide

- Ethidium bromide (EtBr) waste is commonly generated in laboratories conducting research in the biological and biotechnological sciences.
- Its mutagenic properties may present a hazard if disposed of down the drain or in the regular trash.
- EtBr-containing solutions should either be treated on-site or collected for off-site treatment and disposal. EtBr can be removed using activated charcoal by mixing 100 mg of charcoal powder with 100mL of solution containing up to 0.5 ug/mL EtBr, then storing the mixture at room temperature for one hour and filtering it through a Whatman#1 filter. The filter paper is then disposed of as hazardous waste. Alternatively, EtBr can be neutralized with a chemical such as hypophosphorous acid, sodium nitrate, sodium bicarbonate, potassium permanganate, hydrochloric acid, or sodium hydroxide.⁹
- Test tubes, gloves, papers, and other items contaminated with EtBr should also be disposed of as hazardous waste.

8.6.3 Gas-Producing Waste Streams

- Certain chemicals tend to produce gas and must be handled carefully to prevent explosions.
- Such waste should be stored in poly containers with special vented caps. Plastic containers are highly recommended in these situations, as glass containers pose a higher risk of explosion.
- Aqua regia is an example of gas-producing waste and is a mixture of concentrated Nitric Acid (HNO₃) and Hydrochloric Acid (HCl).

8.6.4 Peroxide-Forming Chemicals

These are special types of chemicals that can generate shock-sensitive and explosive compounds. Mishandling them can lead to explosions. These chemicals exist in all three states of matter, and appropriate SOPs must be adopted for their safe handling. Peroxides can be eliminated using activated alumina columns, by shaking with acidic ferrous sulfate, or through treatment with suitable reducing agents. However, aged, crystallized, or highly concentrated peroxides must be handled as hazardous waste and disposed of via specialized procedures.¹⁰ They are categorized into four hazard classes.

Class A

- These peroxide-forming chemicals can form explosive levels of peroxides while sitting on the shelf. Examples of such chemicals are ethyl ether, used for lipid extraction, or dioxane, used as a solvent for RNA and DNA precipitation.
- These chemicals should be tested before use or disposed of through a dedicated chemical waste disposal system three months after opening or at the expiration date on the container if unopened.

Class B

- These peroxide formers are only a hazard if peroxides are concentrated, which may happen upon evaporation or distillation of the solvent. Examples of such chemicals include 2-propanol, used as a disinfectant and solvent in research and diagnostic laboratories.
- These materials should be disposed of one year after opening or at the expiration date on the container if unopened.

Class C

- These peroxide formers may auto-polymerize as a result of peroxide formation. Such as acrylic acid, used in some bioengineering and materials science experiments.
- These materials should be disposed of 1 year after opening or at the expiration date on the container if unopened.

Class D

- These compounds can form peroxides; therefore, they should be handled with care when stored in large quantities for extended periods. An example of this category is polyethylene glycol (PEG), which is used in various laboratory procedures.

8.7 Chemical Spill Management

An appropriate response to a chemical spill depends on the chemical's hazard classification and the quantity spilled. For instance, neutralization is recommended for acids and bases, while organic solvents can be handled with appropriate absorbent materials. However, large spills require a specialized team and equipment for a safe cleanup.¹¹ It is essential to consult the Safety Data Sheet (SDS) and exercise caution when responding to such incidents.

A spill can be managed safely by following these steps:

1. In the event of a chemical spill, always call for help or notify lab management before attempting to clean it up.
2. Quickly assess the size and severity of the spill. Determine if it's safe to approach the spill area without risking personal safety.
3. If dealing with a liquid spill, attempt clean up only if the volume is 4 liters or less.
4. For larger spills, call your safety officer or a designated official for assistance.
5. If the spill involves volatile or toxic chemicals, ensure adequate ventilation by opening windows, turning on exhaust fans, or using fume hoods to remove harmful fumes and vapors from the area.
6. If the spill is significant or poses immediate danger, alert others by activating alarms or verbally informing them to evacuate the area.
7. Always wear appropriate personal protective equipment (PPE) when cleaning up, including goggles, gloves, respirators, and shoe cover as needed. Ensure that the PPE is compatible with the chemicals involved in the spill.
8. Create a perimeter around the spill to prevent further contamination.
9. Clean up the spill from the outer edges and work your way inwards.
10. If it's safe to do so, attempt to contain the spill by using absorbent materials (such as spill pads or granules) or sandbags to prevent the spread of the chemical.
11. Depending on the nature of the spilled chemical, neutralize it using appropriate neutralizing agents or dilute it with water to reduce its concentration and mitigate its effects.
12. For flammables, immediately absorb spilled liquid and place it in sealed containers. If the spill is large (e.g., greater than 1 liter), immediately evacuate. Call for help.
13. Follow the instructions in the spill kit or consult Safety Data Sheets (SDS) for guidance on proper cleanup methods and disposal of contaminated materials.
14. Label and segregate waste containers to prevent accidental exposure.

15. Decontaminate any surfaces or equipment that may have been exposed to the spilled chemical using appropriate cleaning agents and procedures.
16. Dispose of contaminated materials, absorbents, and cleaning agents in accordance with local regulations and hazardous waste disposal guidelines.
17. Report the spill to appropriate authorities, such as the laboratory supervisor, safety officer, or environmental health and safety department.
18. Document the incident by completing an incident report detailing the nature of the spill, response actions taken, and any injuries or exposures that occurred.
19. Conduct a post-incident review to identify the root causes of the spill and opportunities for improvement in spill prevention, response procedures, and emergency preparedness.
20. Update safety protocols and provide additional training as needed to prevent future incidents.

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Checklist – Chemical Waste Management

Sr. No.	Description	Yes	No	N/A	Remarks
1.	Pollution prevention techniques, such as reduction, reuse, and recycling (3R), have already been put into practice.				
2.	Proper labelling of ex-stock chemicals and chemical waste containers is ensured.				
3.	Waste containers are kept closed, allowing them to be opened only for waste addition.				
4.	Instructions are in place to avoid mixing incompatible waste items.				
5.	Secondary containment for liquid chemical waste is ensured.				
6.	Waste is stored in sturdy, compatible, and chemical-resistant containers.				
7.	SOPs are in place to limit hazardous waste storage in the lab to a maximum of 10 gallons.				
8.	Regular waste pick-ups to minimize waste storage have been scheduled.				
9.	Proper signage restricting smoking, eating, and drinking in chemical storage areas is displayed properly.				
10.	PPE suitable for the level of exposure, such as a lab coat, gloves, eye protection, booties, and an apron, is being utilized to handle chemical waste.				
11.	A protocol is established to avoid storing strong acids and organic materials together.				
12.	Periodic checks are in place to observe container rust, corrosion, and leakage.				
13.	Measures to prevent the disposal of hazardous waste through evaporation, sewer, or regular trash are implemented.				
14.	Unlabeled, expired, and substandard chemicals are segregated and disposed of.				
15.	Intentional smelling, inhaling, and tasting of chemicals is restricted and communicated.				
16.	Reporting procedures for exposures, spills, or injuries have been established.				

SECTION 09

Occupational Health and Medical Surveillance

Zia Ashraf, Faheem Shahzad

An occupational health and safety program is essential for protecting workers' health and well-being and promoting productivity in biomedical, clinical, and microbiological laboratory environments. It protects staff who handle hazardous substances, including infectious agents and toxins, and manage hazardous waste from generation to disposal. This includes laboratory professionals, individuals involved in collecting, storing, transporting, treating, and disposing of waste, and any other staff associated with laboratory waste management processes. When managing Occupational Health (OH) services for its employees, a laboratory or institution must carefully consider all available resources and options.

9.1 Framework for Occupational Health (OH)

Occupational Health (OH) services for individuals handling hazardous waste should be based on a thorough risk assessment. The designated OH provider should work closely with institutional health and safety staff, e.g., biosafety officer (BSO), health and safety officer (HSO), occupational physician, principal investigator (PI), and infectious diseases experts, to ensure the best possible work-related healthcare for laboratory personnel and personnel responsible for hazardous waste management. Continuous collaboration among stakeholders and Subject Matter Experts (SMEs) is crucial to protect staff handling hazardous waste.¹

Waste handlers must be trained in the use of relevant engineering controls, standard operating procedures (SOPs), and personal protective equipment (PPE) to maintain a safe and healthy work environment.² To enhance the effectiveness of an OH program, medical services should be tailored to individual staff needs and guided by a risk-based approach informed by comprehensive risk assessments.

9.2 Components of an Occupational Health (OH) and Medical Surveillance Program

A medical surveillance program, as a component of a broader occupational health and safety system, provides support in the event of potential exposure to hazards during waste management.³ Any change in a staff member's health status that may indicate a potential laboratory-acquired infection (LAI) should prompt an interdisciplinary investigation into possible workplace exposure. Various OH and medical surveillance program components are implemented at different stages of employment, from proactive risk management (e.g., pre-placement evaluations or vaccinations) to incident-based medical interventions (e.g., post-exposure immunizations or medications).⁴ These interventions prioritize reducing adverse health effects from exposure to hazards in a workplace as per standards and guidelines established by OSHA⁵, WHO⁶, CDC⁷, and local or national authorities.

9.2.1 Preplacement Medical Evaluation

A medical surveillance program should include a pre-placement medical assessment of newly hired staff. This evaluation must consider an individual's personal and occupational health history, including medical condition, past treatments, medication usage, allergies, and immunization history. This evaluation may include:

- Pre-immunization serology: Guidelines established in the local context should be followed to inform OH decisions for individuals.
- Serum banking: It has limited utility, so routine offering is not recommended. Exceptions may be considered based on risk assessment. Proper storage, accurate retrieval, disposal, patient privacy, and ethical standards must be ensured if it is implemented. Serum sampling and storage may also be managed on a case-by-case basis, contingent upon the establishment of well-designed post-incident screening and investigation procedures.⁸

9.2.2 Immunization

The Advisory Committee on Immunization Practices (ACIP) advises on immunization strategies to prevent vaccine-preventable diseases (VPDs). Additionally, the Expanded Program on Immunization (EPI) in Pakistan includes vaccines for adolescents and older age groups. An occupational health program should administer necessary vaccines in accordance with ACIP and EPI guidelines.^{9,10} It should also consider administering additional vaccines as per risk assessment. However, it must be noted that medical interventions such as vaccines or medicines can reduce the risk, but don't eliminate it; therefore, they should not be considered a replacement for other risk control measures.

9.2.3 Periodic Medical Evaluation

Periodic medical evaluations are essential for safeguarding the health of laboratory and waste management staff. These evaluations should be tailored to the specific risks identified through laboratory risk assessments. Institutions may implement routine medical evaluations for designated work groups when there is a significant and justifiable risk of exposure to hazards, based on the nature of the work and applicable regulatory requirements. The components of such evaluations should be clearly defined. They may include a physical examination, review of medical history, assessment of immunization status, and any additional tests or screenings as deemed necessary. Periodic testing to identify unrecognized occupational exposures should generally be avoided unless there are factors that could delay the detection of a laboratory-acquired infection. Staff working with high-consequence biological agents or in high-containment facilities may require additional assessments or tests.

9.2.4 Support for Workplace Injuries and Potential Exposures

Staff handling laboratory waste should receive appropriate post-incident care in the event of exposure to infectious agents or other hazards. It is imperative for laboratory waste management staff to promptly contact the designated OH provider if they experience symptoms suggestive of a laboratory-acquired infection (LAI). In the event of an injury, it should be reported to the OH provider after first aid administration. The OH provider should perform a comprehensive risk assessment of the affected staff member, in coordination with laboratory supervisors, management, and biosafety experts, incorporating workplace evaluation, targeted environmental testing, and contact tracing to identify potential exposures. When developing a post-exposure management plan, key factors to consider include existing exposure control measures, the mechanism and route of exposure, the nature of the hazard, the characteristics of the suspected agent (e.g., infectivity, pathogenicity, and transmissibility), and the first aid measures administered. To reduce risk, any affected area should be cleansed, any waste spillage should be managed effectively, and post-exposure prophylaxis (PEP) should be started immediately. The team must assess the possibility of onward transmission and estimate the risk of disease and exposure (RoD/RoE) to potential biological agents or specific pathogens of concern (POC).¹¹ Clear communication of the post-exposure plan, including testing procedures, interpretation of results, and treatment options, is essential. Reportable LAIs should be reported to public health authorities.

9.2.5 Occupational Health Assistance to Personnel Working in High and Maximum Containment Settings

When disposing of laboratory waste containing dangerous pathogens, such as in high-containment (HC) and maximum-containment (MC) laboratories, it is crucial to exercise caution. If staff members handling such waste experience unexplained acute illnesses, they should seek medical attention immediately. The OH and medical service providers should establish connections with relevant stakeholders to provide advanced care for staff members infected with high-consequence pathogens.¹²

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Checklist - Occupational Health (OH) and Medical Surveillance

Sr. No.	Description	Yes	No	N/A	Remarks
1.	There is a system in place to identify, monitor, and manage occupational health risks.				
2.	Regulatory OH requirements have been fulfilled.				
3.	OH services are available and provided through a risk-based approach, including support for occupational injuries and potential exposure incidents.				
4.	Preplacement medical evaluations and immunizations are in place.				
5.	Waste handlers undergo regular medical check-ups.				
6.	Waste handlers are trained to recognize early signs of health issues related to their work.				
7.	Waste handlers are educated on the risks of waste and ways to prevent exposure to hazards, including the proper donning and doffing of PPE.				
8.	Waste handlers receive training on bloodborne pathogen exposure control measures and hazardous waste management.				
9.	The training records are maintained.				
10.	The waste handling areas are well-ventilated.				
11.	There is easy access to handwashing facilities, emergency showers, and eye wash stations.				
12.	Spill kits are readily available and properly stocked.				
13.	Hazardous waste containers are clearly labeled and sealed.				
14.	Waste handlers are provided with appropriate gloves, goggles, and masks.				
15.	PPE items are regularly inspected for wear and tear.				
16.	Protocols for handling contaminated PPE are in place.				
17.	Ergonomic assessments are conducted regularly.				
18.	The work environment is designed to minimize physical strain, including the design of waste trolleys.				
19.	There is a system to report and address ergonomic concerns promptly.				

SECTION 10

Advancements in Technologies for Laboratory Waste Management

Ali Ahmad Sheikh, Ramesh Kumar

Safe handling and disposal of laboratory waste are essential to prevent both accidental release and intentional misuse of hazardous substances. The primary objective of laboratory waste management is to neutralize or eliminate hazardous components and minimize overall waste volume. In addition to conventional waste management approaches, a range of methods and technologies has emerged or is being explored to make waste management more environmentally sustainable, cost-effective, practical, and efficient. As outlined in Table 10-1, many of these approaches focus on the principles of reuse, recycling, and reprocessing.

Table 10-1. Emerging Technologies in Laboratory Waste Management

Technology
Data Analytics and Artificial Intelligence (AI)
Waste-to-Energy-(WtE) Technologies
Plasma Treatment
Decentralized Composting Units and Bioremediation
Waste Shredder
Hydroclave Technology
Microwave-Based Waste Treatment
Solar Disinfection
Solidification and Encapsulation
Inertization

10.1 Data Analytics and Artificial Intelligence (AI)

AI has revolutionized laboratory waste management through data-driven decision-making. It makes waste management efficient by predicting waste flows, optimizing treatment operations, improving segregation accuracy, enabling real-time monitoring, and reducing logistical inefficiencies, including downtime.^{1,2}

10.2 Waste-to-Energy (WtE) Technologies

Waste-to-energy (WtE) processes offer a dual benefit by generating energy while significantly reducing waste volume. These technologies convert waste into usable fuels that can subsequently be used to generate electricity. However, strict emission control measures are essential to mitigate potential environmental and public health impacts.

Among conventional approaches, incineration remains a widely used WtE technology. In addition, advanced or emerging methods such as gasification and pyrolysis can further reduce waste volume by converting it into gaseous and liquid fuels. These technologies are energy-intensive and require skilled personnel, as they rely on high-temperature processes and precise operational control.³

Their application to infectious waste is possible but typically limited to specialized settings, where waste undergoes appropriate pre-treatment and is managed within highly controlled, validated, and strictly regulated systems to ensure safety and effectiveness.

10.3 Plasma Treatment

Plasma treatment decomposes infectious waste at high temperatures using an ionized gas called plasma, reducing it to its constituent elements. While it is an effective method, it is costly and requires skilled maintenance.⁴

10.4 Decentralized Composting Units and Bioremediation

Decentralized composting units and bioremediation use microorganisms to break down and detoxify hazardous waste. These eco-friendly methods produce nutrient-rich compost that can be used as fertilizer. However, they require careful management to ensure microorganisms work efficiently and do not escape into the environment.⁵

10.5 Waste Shredder

An efficient and cost-effective crusher machine can shred items such as used syringes, needles, blood bags, dialyzers, and plastic and glass items. It allows better steam penetration and chemical disinfection, leading to superior sterilization. This machine can significantly reduce waste volume by an impressive 85%, making it a valuable tool in waste management.

10.6 Hydroclave Technology

Hydroclave technology is a unique approach to treating biological waste. It combines steam sterilization with continuous mixing or shredding of waste within a rotating chamber, resulting in a significant reduction in waste volume. This environmentally friendly technology ensures the complete elimination of pathogens, making it a safe and effective method for waste management.⁶

10.7 Microwave-based Waste Treatment

Microwaving is an effective method for treating waste, producing an environmentally safe end product. This method uses microwave energy (primarily at 2450 MHz) to heat the waste, breaking it down into a sterile, harmless solid.⁷

10.8 Solar Disinfection

Solar disinfection is a cost-effective method for regions with limited access to electricity. This method involves exposing waste to sunlight by placing it inside a transparent container with a solar cooker for several hours on a sunny day. It is reported to achieve a 7-log reduction in microbial counts.⁸

10.9 Solidification and Encapsulation

Solidification involves transforming and immobilizing infectious waste into a stable, durable form that is easier to store, reuse, or dispose of in a landfill. This process may involve chemical reactions and uses cement, lime, or polymers to solidify waste. The primary purpose of solidification is to create a barrier between the environment and the waste, thus preventing seepage or leakage into the soil by reducing permeability. Encapsulation entails coating the openings of waste containers, such as metal drums or HDPE bins, with a chemically inert substance, thereby stabilizing waste and reducing biodegradation. This method is suitable for sharps, pharmaceutical, and hazardous laboratory waste.⁹

10.10 Inertization

The main aim of the process is to reduce risks associated with toxic and hazardous substances. The waste is mixed with cement to solidify and stabilize it. After this treatment, the waste becomes less soluble, almost immovable, and less reactive. Pharmaceutical waste and ash from incinerators are typically inertized.¹⁰ This method is inexpensive and does not require special equipment or expertise. It differs from solidification, which is a physical process that converts waste into a solid, monolithic block. Whereas inertization alters the chemical state of waste, making it less soluble and toxic, then locks it into a solid matrix.

The selection of an appropriate technology for the treatment of laboratory waste depends on many factors, including the availability of skills and required resources, the long-term maintenance of the equipment involved, and the technology's sustainability. It also depends on the awareness and acceptance of new technologies locally, and the required infrastructure and support for the downstream processes involved in the treatment and disposal. The advantages and disadvantages of different treatment methods are mentioned in Table 10-2.

Table 10-2. Emerging Waste Treatment Methods with Advantages and Disadvantages

Technology	Advantages	Disadvantages
Data Analytics and AI	Efficient resource allocation Recycling cost reduction through optimized routes Enhanced safety for workers Environmental impact reduction Higher accuracy in waste sorting Improved public health outcomes	Reliance on accurate data for predictions Initial high implementation costs Privacy concerns with data collection Dependency on technology infrastructure Vulnerability to cyberattacks
Gasification/Pyrolysis	Greater volume reduction in waste Self-sustaining process	High energy consumption Requires specialized facilities and highly skilled personnel
Microwave-Based Waste Treatment	Efficient system Rapid processing Reduced environmental impact	Safety concerns Technical challenges High initial investment Limited application
Plasma Treatment	Conversion of waste to glass, rock, ferrous metal, or inert gas	High energy consumption Expensive operation Need for refractory materials Limited lifespan of the plasma torch with electrodes
Solar Disinfection	Viable and eco-friendly	Extensive treatment time
Decentralized Composting Units	Reduces transportation costs and carbon emissions Produces high-quality compost for landscaping, agriculture, and soil improvement	May not efficiently handle large waste volumes Requires significant upfront investment in equipment and infrastructure
Bioremediation	Uses natural processes to break down pollutants, reducing harsh chemical usage	Can take weeks to years to achieve desired results, depending on the contamination
Waste Shredder	Fully automated	High operational cost
Hydroclave Technology	Reduction in waste volume and weight Faster with more even penetration of heat and volume	High operational cost
Inertization	Converts hazardous substances into stable, non-reactive forms, reducing their mobility and potential for leaching into the environment	May not eliminate all hazardous properties of the treated materials, leading to residual risks or the potential for recontamination over time

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SECTION 11

Emergency Preparedness in Waste Management

Saima Mohsin, Samreen Sarwar

Laboratory waste endangers public health during emergencies or may itself give rise to them. Therefore, emergency preparedness is critical for clinical and research laboratories. These facilities can face various emergencies, such as disease outbreaks, fires, natural disasters, needle-stick injuries, medical emergencies, water and leaks, civil unrest, waste spills, and slips and falls caused by heavy waste bags, especially on wet floors. Improper labelling of chemical waste containers and mixing of incompatible chemicals can also lead to emergencies.¹ The key to handling them is to have an emergency response plan that can adapt to different situations and is well-structured and transparent in its execution. Visual aids such as signs and posters can help convey emergency response and evacuation procedures, which can be particularly useful for overcoming language barriers and illiteracy.

11.1 Emergency Response Plan and Documentation

An emergency response plan is a component of proactive risk management systems. It involves identifying all potential emergencies, developing strategies to handle them, and preventing or minimizing their impact. Developing safety manuals that outline emergency response procedures is essential. Regular meetings should be held to review these procedures and reinforce the importance of teamwork. All accidents, incidents, and near misses must be recorded and investigated to implement preventive and corrective measures. Stakeholders' engagement to successfully develop and execute emergency response plans is essential for the following reasons:

- Lab safety is everyone's responsibility.
- It encourages staff to report safety concerns without fear of retaliation.
- All stakeholders, including support staff, work together as a unit in emergencies.
- Every person in an organization has a clearly defined role in an emergency response plan.
- All relevant persons should be trained to handle specific emergencies.
- A list of emergency responders' contact numbers should be available and visibly posted in a lab.
- A training plan to enhance personnel preparedness and emergency response effectiveness (section 3.6).²

11.2 Major Laboratory Emergencies in Laboratory Waste Management

Laboratory-acquired infections can occur due to waste spills, injuries from needle sticks or other sharp objects during waste handling, eye exposure from improper personal protective equipment (PPE), and aerosolization of infectious agents. Below are some details about a few emergencies:

11.2.1 Waste Spills

By implementing a comprehensive and effective spill response plan, organizations can minimize the risks associated with infectious waste spills. This proactive approach ensures compliance with regulatory requirements and protects the health and safety of waste handlers, other employees, and the environment.³ Infectious waste spills can be classified as major (>10 ml) and minor (<10 ml) depending on the amount of waste spilled. Minor spills can be managed by following these steps:

- Alert people and remove contaminated PPE. Seek immediate help if an exposure or injury occurs.
- Evacuate the lab and allow aerosols to settle down (max 30 minutes), if required.
- Post a 'DO NOT ENTER' sign on the door (Figure 11-1).
- Wear proper PPE and get a spill kit.
- Cordon off the area.
- Collect sharps/broken glass with tongs or forceps.

- Cover the spill with absorbents.
- Apply appropriate disinfectant (for an appropriate length of contact time).
- Wipe down the area again with a suitable disinfectant.
- Discard the contaminated absorbent materials in a biohazard waste bag.
- Wash your hands after removing PPE.
- In case of injury to an individual, refer to an occupational health physician.
- Log and report the incident. An example of an incident reporting form is given in Appendix A.

DO NOT ENTER:
BIOLOGICAL SPILL HAS JUST OCCURRED



For more information
NAME: _____
PHONE NUMBER: _____
Spill Date: ____ Spill Time: ____

Figure 11-1. Biohazard Signage for Spills

For large liquid and solid waste spills, organizations should use modified spill management procedures, as flooding large quantities of liquid or solid waste with a disinfectant can spread the spill with additional exposure risks. A good strategy in this case is to pick up solid waste with a wiper and dustpan and dispose of it in a biohazard bag, then use absorbents and disinfectants to decontaminate the area. Infectious spills on trolley surfaces can be cleaned by using the following method:

- Don PPE.
- Identify the spilled area.
- Use disinfectant-soaked paper towels.
- Keep disinfectant paper towels on the spilled area for proper contact time.
- Wash the trolley with detergent at the designated trolley-cleaning station if it can be transported there safely without spreading contamination. Otherwise, adequately disinfect the trolley with disinfectant-soaked paper towels before taking it to the cleaning station.
- Discard contaminated PPE in a biohazard bag.
- Wash your hands.
- Report and log to the laboratory supervisor.

A list of spill kit items is given in Appendix D.

11.2.2 Medical Emergency

In the event of a severe medical emergency, prompt action is critical. This includes personal injuries involving extensive blood loss, third-degree burns, or a heart attack.

- A designated emergency response team in the facility should be contacted in these cases, or the facility's emergency response procedures may direct laboratory personnel to directly call general emergency contact numbers, such as 1122 in Pakistan. These responders are trained and authorized to carry out life-saving measures, such as cardiopulmonary resuscitation (CPR). These emergency contact numbers should be displayed on all important locations. A sample template is included as Appendix E. It is important to protect emergency responders from hazards present inside the laboratory. Therefore, it is essential to establish communication with them well ahead of time and develop emergency response procedures considering their safety.⁴
- If an incident is minor, such as splashes in the eyes or spills on the body, first-aid resources should be available, such as an eyewash station or a safety shower.

11.2.3 Needle Stick/Sharps Injury

Needle stick injury is a significant hazard for waste handlers, especially when handling biohazard waste bags and sharps containers containing needles and other sharps.⁵ A few simple steps can help mitigate risks associated with these incidents and ensure an appropriate response.

- Expose wound: Identify and uncover the affected area by tearing gloves or PPE.
- Express wound: Encourage any bleeding.
- Flush the wound: Rinse it thoroughly under tap water for 5 minutes.
- Cover wound: Cover the wound and apply an initial dressing.
- Doff Normally: Remove gloves/PPE from the affected area.
- Seek medical assistance.
- Report to the designated official.

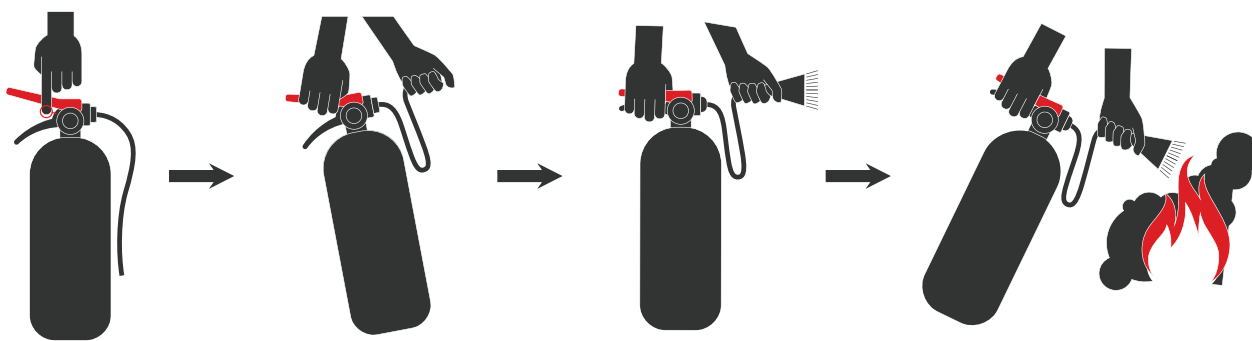
However, for deeper cuts, do not allow bleeding to continue profusely. Do not suck the wound, and refrain from scrubbing it.

11.2.4 Fire Hazard in Waste Storage Areas

Laboratory staff must know the location of safety equipment, including fire alarms, extinguishers (Table 11-1), egress stairs, and emergency exits. In the event of a fire, they must immediately activate or respond to the alarm. Trained staff members can help prevent small fires from escalating into larger ones. To ensure everyone's safety, evacuate the building through the nearest marked exit using stairs only and keep the exits clear. Once outside, gather at the designated assembly areas and provide information about missing persons. It is crucial to report the incident to a designated official. Figure 11-2 explains the protocol for using a fire extinguisher.⁶

Table 11-1. Classification of Fire Extinguishers

Sr. No.	Classes of Fire	Type of Extinguisher	Symbol	Suitable for the Types of Fire
1	Class A	Water Based		Fires including ordinary combustibles, e.g., paper, wood, cloth, and plastics
2	Class B	Carbon Dioxide or Dry Chemical		Flammable liquids, gases, oil, and paints
3	Class C	Dry Powder or Dry Chemical		Live electrical equipment, e.g., motors, appliances, power tools, and wiring
4	Class D	Met-L-X and other Class D with Special Granular Formations or Dry Powder		Combustible metals, e.g., magnesium, titanium, etc.
5	Class K	Wet Chemical		Combustible cooking oils or fats in cooking appliances



Here are the steps to use a fire extinguisher through the **PASS** method:

- **Pull** the pin.
- **Aim** the nozzle of the fire extinguisher at the base of the fire, maintaining a distance of approximately 8 feet.
- **Squeeze** or press the handle to activate the discharge.
- **Sweep** the nozzle slowly from side to side, directing the stream at the base of the fire.
- **Continue** discharging the extinguisher until the fire is completely extinguished or the extinguisher is empty.

Figure 11-2. Protocol to Use a Fire Extinguisher

11.3 Emergency Response Equipment

Laboratory emergency preparedness ensures that essential resources such as personal protective equipment, spill kits, and emergency safety equipment, including eyewash stations, safety showers, fire extinguishers, medical supplies (First Aid), and fire blankets (Figure 11-3), are always available and properly maintained. Proper inventory of all emergency equipment should be maintained to ensure its availability during an emergency. Maintaining a log sheet to keep track of the maintenance schedule is also essential.^{7,8} Inspecting alarms, fire detectors, and other critical emergency response systems is required to ensure their functionality at all times.



Eye wash station



Fire detector



Safety shower



Fire extinguisher



Fire Alarm

Loudspeaker



Figure 11-3. Examples of Emergency and Fire Safety Equipment

11.4 Emergency Evacuation Planning

All personnel should exit the building immediately in certain emergencies, such as toxic chemical releases (compressed gases and cryogenic gases), large flammable chemical spills, fires, explosions, earthquakes, or flooding. The safety of everyone in the laboratory and emergency responders should be the top priority in such cases.⁹ A designated team/staff is responsible for making decisions during emergencies and coordinating emergency evacuations. The laboratory personnel must evacuate the building by using stairs only and must not use elevators. There are three categories of emergency evacuation depending on the situation:

a. Critical Evacuation

This signals an urgent need to evacuate when life is threatened, such as during a massive fire. Cease all processes and immediately evacuate the laboratory without maintaining containment.

b. Modified Evacuation

This evacuation is necessary in the event of medical emergencies. Laboratory personnel must promptly evacuate the laboratory while following modified decontamination procedures.

c. Standard Evacuation

When there is no life-threatening event, such as an alarm indicating improper directional air flow, personnel should secure their work area first. This includes sealing all containers, unplugging nonessential electrical equipment, and locking the doors of important locations, such as the waste storage area. Finally, personnel must vacate the laboratory zone, inform emergency services, and report the incident to designated officials.

11.5 Contingency Planning

A well-structured contingency plan and a well-trained emergency response team help identify potential emergencies and handle them systematically to prevent or minimize their impact. Contingencies should be planned for all waste management processes, including segregation, handling, storage, transport, and treatment/disposal. Any event, such as a shortage of PPE, waste bags, containers, and trolleys, a shortage of space in the waste storage area, breakdown of autoclave, incinerator, or other waste treatment equipment, pests' infestation, rodents' outbreak, staff shortage, or inability to dispose of waste in a landfill, should not disrupt routine waste management. Conducting a comprehensive assessment of factors that may affect proper waste management during emergencies and training of individuals on contingency plans is crucial. This ensures that all planning aligns with a deep understanding of potential risks and vulnerabilities.

11.5.1 Alternative Segregation, Storage, and Transport Options

During emergencies, several backup segregation, storage, and transport options can be explored and adopted, such as:

- Segregation: Use of containers and bags, with manual labeling, that are not meant to contain waste, but have a similar structure or characteristics
- Storage: Formulation of backup storage strategies within the facility premises, with restricted access and proper signage, to mitigate challenges arising from waste accumulation and landfill closures
- Transport: Use of back-up trollies, limiting waste movement until a trolley is available, or using other leak-proof and secure trollies or containers to carry waste

11.5.2 Alternative Disposal Methods

During emergencies, several alternative treatment and disposal options can be used, including:

- Utilization of on-site treatment facilities
- Establishment of contingency agreements with certified waste disposal facilities^{10,11}
- Engagement in collaborative efforts with affiliated facilities via Memoranda of Understanding (MoUs)
- Installation of standby autoclave units to address potential breakdowns

11.5.3 Communication Protocols

Developing clear communication protocols and channels for reporting hazardous waste incidents and coordinating the implementation of contingency measures, such as:

- Notifying relevant authorities
- Coordinating response and recovery efforts internally and externally
- Facilitating prompt and effective crisis management

11.5.4 Regular Review and Update of Contingency Plans

Periodically reviewing and updating contingency plans is essential, considering factors such as:

- Insights garnered from previous incidents
- Regulatory modifications
- Technological innovations
- Evolving risk evaluations, thereby ensuring the enduring resilience and efficacy of laboratory waste management approaches

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Checklist - Emergency Preparedness in Waste Management

Sr. No.	Description	Yes	No	N/A	Remarks
1.	A protocol for incident reporting to the responsible authorities is established.				
2.	Emergency contact details have been disseminated and posted in visible locations.				
3.	Emergency response measures are in place as per the established protocols.				
4.	Spill kits and first aid kits are available and are inspected regularly.				
5.	Emergency response training/drills are conducted regularly.				
6.	Emergency exits are marked, and passageways are unobstructed.				
7.	Standby Generator and UPS are available.				
8.	Standby autoclaves are available in the facility.				
9.	Accessible and well-maintained fire extinguishers are in place, and the personnel are trained to use them.				
10.	Additional containers/buckets are available, e.g., for major spills.				
11.	Additional biohazard waste bags are available.				
12.	The clean-up and decontamination protocols are established.				

SECTION 12

Roles and Responsibilities in Laboratory Waste Management

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Clearly articulating roles and responsibilities in a Laboratory Waste Management Plan is essential for risk mitigation, resource efficiency, environmental protection, training, legal compliance, and continual improvement. The plan establishes a framework for accountability, communication, and continual improvement in a waste management system. The following individuals can be entrusted with the responsibility of effectively managing laboratory waste:

- Facility Director
- Principal Investigator
- Laboratory Manager
- Section Heads
- Biosafety Officer
- Store In-Charge Member
- Senior Laboratory Technologist
- Sanitation In-Charge/Waste Management Officer
- Co-opted Members
- Senior Management Representative
- Accounts Officer/Financial Representative
- Infection Prevention and Control (IPC) Representative
- Others as necessary

12.1 Waste Management Committee

A laboratory waste-management committee (WMC) shall be responsible for the preparation, periodic review, revision, and updating of the institutional waste-management guidelines, plan, and/or procedures. This committee can serve as a subcommittee of IBC. The WMC shall meet at a predefined frequency, and the laboratory manager/biosafety officer/waste management officer will follow up on the minutes of previous and current meetings to ensure compliance. The Terms of Reference (TOR) of a waste management committee shall include the following:

- Endorse a plan/layout of a laboratory facility, delineating waste-disposal zones for infectious and non-infectious waste for each department.
- Plan and arrange a site for the central storage of hazardous and non-hazardous waste at the facility.
- Finalize and document comprehensive details regarding container types, quantities, waste bag specifications, and transport trolley requirements.¹
- Devise strategies for minimizing laboratory waste, encompassing inventory management, recycling methodologies, waste segregation, and microscale techniques to save costs and promote sustainable practices.
- Formulate a timetable that includes waste collection times and frequencies for each section and designated area.
- Estimate the required number of staff for waste handling and management.
- Determine, document, and communicate the duties and responsibilities of all facility staff involved in waste generation, segregation, transport, treatment, and disposal.
- Establish procedures for managing waste necessitating treatment, such as autoclaving or chemical disinfection, before final transport or disposal.
- Develop and supervise the selection, design, and operational management of on-site and off-site healthcare waste disposal facilities and methodologies.

- Continually improve its waste management system by adopting sustainable treatment and disposal methodologies and looking for new technologies to manage waste.
- Optimize options for more cost-effective methods in laboratory waste management.
- Lead the development of emergency response procedures and the preparation of comprehensive documentation for implementation.
- Prepare contingency plans for all waste management processes and associated potential emergencies, such as incinerator or autoclave breakdowns.
- Investigate, record, and review all incident reports regarding hazardous waste management.
- Design training courses and programs on laboratory waste management for all relevant team members and staff, equipping them with the necessary knowledge and skills to handle hazardous waste safely and securely.
- Deliberate on whether to engage the services of waste disposal contractors, recognizing their critical role in enhancing laboratory waste management through specialized services encompassing proper collection, transportation, treatment, and disposal.

A Waste Management Committee facilitates waste reduction and recycling through meticulous strategic planning, comprehensive policy implementation, and active community engagement. These concerted efforts can foster environmental sustainability and contribute to ecosystem preservation. The integrated approach of these initiatives will lead to a more efficient and environmentally conscious waste management system, ultimately benefiting both the community and the environment.

12.2 Waste Management Team

A waste management team is responsible for the execution and on-ground implementation of the lab waste management plan developed by the waste management committee. This team should include people who handle waste and supervisors who oversee this work. The following responsibilities should be fulfilled by the waste management team:

- Coordinate, execute, and monitor all waste management operations.
- Ensure that waste bags, containers, protective clothing, collection trolleys, and other supplies are always available in adequate supply, restocked promptly, regularly inspected for potential damage, and properly maintained.
- Ensure the central storage facility is used correctly and secured against unauthorized access.
- Conduct a risk assessment to identify potential risks associated with waste management.
- Train housekeeping and sanitary staff to maintain adequate sanitation.
- Supervise housekeeping and sanitary staff to ensure proper hygiene and cleanliness.
- Ensure that the established waste transportation methods are used on-site to transport waste to the central storage facility or incinerator (if installed) and off-site by the local municipality.
- Communicate emergency response procedures and ensure that all staff members are confident in their actions during emergencies.
- Record the quantities of waste generated by each section every week.
- Regularly report on waste management operations, including incidents and other relevant issues, to the designated authorities on time.

12.3 Laboratory Director

The laboratory director, the facility's top management, is ultimately responsible for the effective management of laboratory waste. They must:

- Establish required committees and assign roles and responsibilities.
- Allocate resources for effective management of laboratory waste.
- Formulate and approve a waste management policy.²

12.4 Principal Investigator

The principal investigators should:

- Participate in/lead risk assessment for waste management.
- Provide training and technical guidance on hazardous agents, including pathogens and toxins, and the proper use of Safety Data Sheets (SDS).

12.5 Laboratory Manager

The laboratory manager is responsible for waste management activities within the laboratory premises. Their responsibilities in this regard are outlined below:

- Conduct/participate in risk assessments for waste management.
- Contribute to the development of protocols and guidelines for the safe handling of biological waste generated in the laboratory with the support of the biosafety officer and the waste management officer.
- Keep accurate chemical and material inventory records.
- Regularly review and update inventory to prevent surplus procurement.
- Share excess or unused materials with other laboratories, with proper notification to the relevant authorities.
- Supervise, monitor, and implement the laboratory waste management plan components relevant to their laboratory.
- Prepare the laboratory for waste management audits conducted by an authority designated by the local Health Care Commission (HCC) or any other external auditing agency.
- Develop a budget for the required financial resources and ensure all necessary supplies are made available on time.
- Ensure that the laboratory complies with all applicable local and national regulations for waste management processes relevant to laboratory operations.³

12.6 Section Head

A section head is a managerial role that oversees a specific section within a department or a laboratory and has the following responsibilities:

- Ensure designated waste containers are used for each waste category, and the waste is collected safely and securely in these containers.
- Ensure all staff members are aware of and trained in waste management practices.
- Ensure that the sanitation department adequately supervises sanitary workers to promote compliance with established waste management protocols.
- Maintain effective liaison with laboratory staff, the laboratory manager, the waste management officer (WMO), and the biosafety officer to facilitate the timely identification, communication, and resolution of issues during implementation of the Laboratory Waste Management Plan.
- Ensure and enforce safety protocols to minimize risks, accidents, and cross-contamination.
- Responsible for ongoing monitoring to identify and address any compliance issues or safety hazards.

12.7 Biosafety Officer

The role and responsibilities of a biosafety officer are critical in the proper handling, treatment, and disposal of biological waste from a biosafety and biosecurity perspective. The following will be included in the responsibilities of a Biosafety Officer:

- Lead/review risk assessment conducted by a risk assessment team to handle biological waste generated in a laboratory safely and securely.
- Stay up to date on all relevant local, national, and international regulations and guidelines for biological waste management.
- Identify the need for safety and security training for laboratory and housekeeping staff in accordance with job descriptions.
- Organize relevant courses, training activities, and refresher sessions for laboratory and housekeeping staff who handle laboratory waste according to standard operating procedures, national and international guidelines, and audit requirements.
- Establish safety and security protocols to minimize the risk of accidents, injuries, exposures, and contamination while handling biological waste and ensure their implementation.
- Periodically review the plan and suggest preventative and corrective actions after an incident or an internal audit for the non-conformances identified.
- Liaise with regulatory authorities, promote a culture of responsibility, and ensure compliance with laboratory waste management procedures within the laboratory.

- Provide advice and feedback on biosafety and biosecurity practices, including the use of Engineering, Administrative controls, SOPs, and PPE-related measures.
- Responsible for continual improvement by identifying different cost-effective technologies for waste management and streamlining the processes.⁴

12.8 Store In-Charge

A laboratory store in-charge plays an essential role in the organized, on-time availability of materials. Laboratories work with various materials, some of which can pose risks to human health and the environment if improperly handled. The following will be included in the responsibilities of a laboratory store in-charge:

- Ensure all materials are stored safely and securely by implementing proper storage protocols to prevent spills, contamination, and unauthorized access.
- Maintain an accurate and up-to-date inventory of all laboratory materials, chemicals, and supplies, and communicate with the laboratory manager(s) to anticipate needs. This includes PPE, waste bins, biohazard waste bags, and sharps containers.
- Place orders for all required items and related supplies as per requirements, and coordinate with suppliers to ensure an on-time, sufficient supply of materials used in biological waste management.
- Implement a tracking system to monitor the use, replacement, and disposal of supplies.

12.9 Laboratory Technologist

The role and responsibilities of laboratory technologists include the following:

- Exercise proper segregation of laboratory waste into the appropriate containers for infectious, non-infectious, sharps, and chemical waste.
- Follow all safety and security protocols established for hazardous waste handling.
- Respond to emergencies such as spills, needlestick injuries, and emergency evacuations in accordance with established protocols, and promptly report incidents to the relevant authorities.
- Participate in all relevant training programs related to laboratory waste management to ensure up-to-date knowledge and compliance with established protocols.
- Report non-compliance, unsafe practices, or other issues to the relevant authorities.
- Maintain records as required by the waste management plan.
- Support the audit and inspection process.

12.10 Laboratory/Facility Accounts Officer

A laboratory accounts officer ensures that financial resources are available and efficiently managed to support biological waste management activities. His responsibilities include the timely provision of funds allocated for:

- Personal Protective Equipment (PPE) and other safety equipment
- Maintenance of incinerators (if present) and other waste management equipment
- Training and education of staff
- Emergency safety equipment
- Third parties for the treatment and disposal of waste

In addition, his responsibilities also include:

- Financial planning
- Budgeting, cost analysis, and control
- Financial reporting to management
- Budget monitoring
- Oversight of procurement processes
- Vendor management and contract negotiations, if there are contractual services for waste disposal
- Conducting cost-benefit analyses of waste reduction and recycling initiatives
- Maintaining invoices, contracts, and financial records for audit purposes

12.11 Bio-Medical Engineer/Biomedical Technician

A biomedical engineer or a biomedical technician:

- Manage preventive and corrective maintenance and calibration of equipment used in waste management processes, such as weighing scales, laboratory biosafety equipment, and other laboratory apparatus.
- May contribute to the design of engineering controls, including the upkeep of waste trolleys for infectious waste, temperature regulation in waste storage areas, and the maintenance and validation of autoclaves and on-site incinerators.

12.12 Waste Management Officer/Sanitation In-Charge

The waste management officer/sanitation in-charge plays a critical role in maintaining a safe, clean, and compliant laboratory environment. His responsibilities include monitoring and implementing the waste management plan under the guidance of the biosafety officer and the laboratory manager.^{5,6} The responsibilities of a waste management officer are to:

- a. Waste Collection and Transport
 - Ensure that sanitary workers replace used bags and containers with new ones immediately.
 - Ensure strict adherence to procedures for the transport of waste to the central waste storage facility or incinerator and supervise the laboratory sanitary staff responsible for the collection and transport of waste.
 - Supervise cleaning operations in waste collection areas, storage spaces, and other relevant locations.
 - Ensure that sanitation equipment, such as waste bins, collection vehicles, and cleaning tools, is well-maintained.
- b. Waste Storage and Disposal
 - Ensure proper maintenance and security of the waste storage area.
 - Supervise and ensure that the waste is securely stored in the allocated area in designated containers, bags, and zones to prevent contamination, spills, or accidents.
 - Prevent waste disposal in unauthorized areas, even temporarily.
 - Monitor waste disposal practices.
 - Ensure the waste is kept on the premises only for the duration specified in established guidelines and standard operating procedures (SOPs).
- c. Training and Education of Staff
 - Ensure training for sanitary workers on the risks associated with waste handling; proper collection of hazardous waste; identification of appropriate bags, containers, and labels for hazardous waste; donning and doffing of adequate personal protective equipment; the concept of cleaning and decontamination; and other topics as specified by training need assessment or risk assessment.
- d. Incident Management and Control
 - Ensure emergency supplies are always available and confirm awareness among all staff members.
 - Ensure that the housekeeping staff is adequately trained to respond appropriately to emergencies such as spills, Needle Stick Injuries (NSIs), or inhalation of noxious gases.
 - Participate in the investigation and review of incidents related to waste management processes.

The waste management officer is also responsible for maintaining accurate records of waste generation, storage, and disposal, including manifests and tracking documents required by regulatory agencies.

12.13 Institutional Biosafety Committee (IBC)

The Institutional Biosafety Committee (IBC) in universities, medical and veterinary colleges, and other research institutions reviews research proposals to ensure that the proposed project activities have the least potential for harm to individuals, the community, and the environment. One of the IBC's functions is to oversee and guide the institutional waste management program.^{7,8} In educational and research organizations, in addition to overseeing the facility's overall waste management system, IBC reviews the waste management plan developed by the Principal Investigator (PI) to ensure safe and secure handling and disposal of infectious waste generated during research. The IBC takes the following necessary steps in addition to its standard functions:

- Review and approve waste management policy and plan, and provide advice on their development and revision.

- Ensure compliance with national, regional, statutory, institutional, and international regulations, policies, and guidelines.
- Review the risk assessment and mitigation plan to thoroughly examine the potential risks associated with waste management and the proposed measures to mitigate them.
- Review SOPs for waste management processes and provide advice on improving them.
- Ensure, recommend, and support comprehensive training programs for lab workers and waste handlers to equip them with the knowledge and skills needed to handle hazardous waste safely, thereby strengthening the institution's waste management efforts.
- Ensure that adequate personal protective equipment (PPE) is part of the waste management program for waste handlers and other relevant personnel.
- Prioritize incident/accident reporting, and ensure these occurrences are adequately investigated, and that appropriate corrective and preventive actions are taken on time.
- Ensure issues are promptly addressed and resolved, fostering a culture of responsibility and vigilance.
- Periodically review the facility's waste management plan for efficacy and evaluate resource availability for an effective waste management system.

12.14 Community Members

The inclusion of community members on relevant committees helps address community apprehensions and concerns through dialogue with the laboratory director, biosafety officer, and other committee members, as laboratory-generated waste may harm the local community and the environment.

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SECTION 13

Veterinary Waste Management

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Veterinary facilities generate hazardous and non-hazardous waste from diagnostic, vaccine production, research, and treatment activities (Figure 13-1). Animal confinement operations and abattoirs may also produce waste containing high-consequence pathogens. Therefore, safe waste disposal in these facilities is essential and must be ensured through adherence to established waste management principles. Improper waste management can lead to health risks for people, animals, and the environment.¹

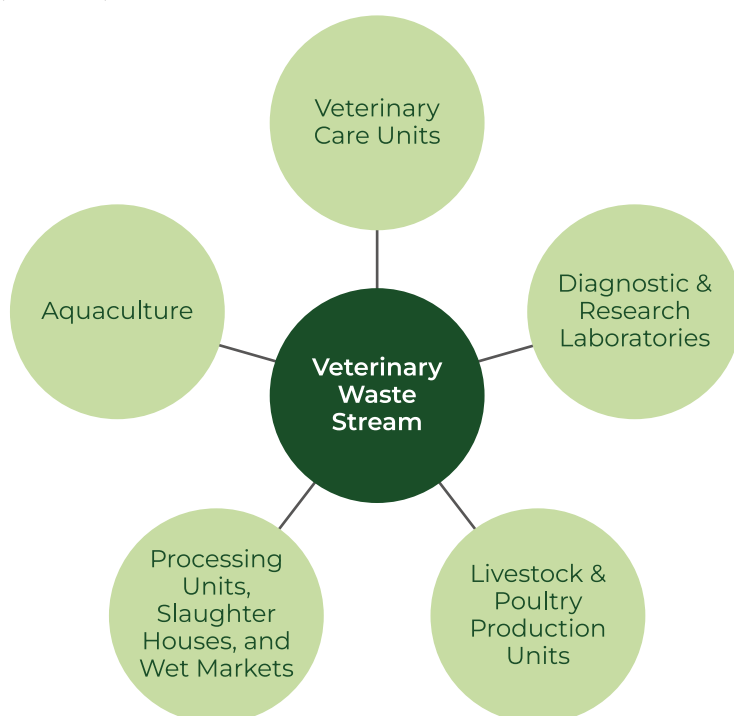


Figure 13-1. Sources of Waste Generation in Veterinary Practices

13.1 Veterinary Diagnostic and Research Laboratory Waste

Veterinary diagnostic and research laboratories help identify and prevent the spread of zoonotic diseases. These laboratories use animal samples for research purposes, but do not necessarily experiment on live animals. Waste generated in veterinary diagnostic and research laboratories includes animal, infectious, chemical, cytotoxic, and radioactive waste. These wastes may be managed using approaches analogous to those used in human clinical laboratories, taking into account the efficacy of available treatment technologies for specific waste streams, including large animal carcasses.² Animal waste is biological waste of animal origin, which may or may not be infectious, and contains animal carcasses, body parts, tissues, fluids, feed, litter, etc. Careful planning when formulating a waste management program is crucial for prioritizing environmental protection, human and animal health, and safety.

13.2 Animal Research Facilities

Animal research facilities are used to conduct controlled scientific experiments on live animals to study diseases, biological processes, and evaluate the safety and efficacy of drugs and vaccines. They also support biomedical research and development by providing reliable animal models for advancing medical and

veterinary science. The waste generated in these facilities may contain pathogens, toxins, and hazardous chemicals, demanding careful handling and disposal.

13.2.1 Management of Research Animal Waste

- It must be ensured that laboratory personnel handling carcasses are not exposed to biological hazards and toxic chemicals.
- The death of animals must be ensured after euthanasia to avoid any accidents.³
- All carcasses should be placed in sealed, double-bagged plastic bags, labeled appropriately, and stored in the designated carcass refrigerator or freezer before disposal.
- Carcasses for diagnostic purposes should be labeled as “necropsy,” while carcasses of euthanized animals should be labeled as “euthanized.”
- Other information, such as animal species, method of euthanasia, date, and the initials of responsible personnel, should be available.
- Animal carcasses contaminated with radioactive agents must be handled with care and disposed of according to the regulations and guidelines for the radioactive agents present inside the carcass.

13.3 Veterinary Hospitals/Clinics Waste

Animal health facilities generate waste, including body fluids, tissues, animal excrement, litter, bedding, and excess feed. These facilities also generate waste containing expired medicines, empty medicine vials, swabs, bandages, sharps, and disinfectants. As with other facilities, it is important to classify the waste generated in these facilities into appropriate categories, such as infectious, anatomical, non-infectious, and so on, and handle them accordingly.⁴ Appropriate and compliant disposal of this waste is critical to preventing environmental contamination and safeguarding public health and the environment.⁵

13.3.1 Waste Management in Veterinary Health Care Units

- Animal health facilities should keep records of the waste generated, its origin, and potential risks, including the risk of spreading infections.
- Infectious waste should be securely stored and promptly disposed of, as in human clinical laboratories.
- Chemical waste, including disinfectants, should not be disposed of in the sewer system. Instead, lab supervisors or safety officers should be consulted for proper disposal procedures (see section 8 on chemical waste management).
- Pharmaceutical waste not disposed of correctly can pollute surface and groundwater supplies, posing a significant threat to public health. It can be in a solid/semi-solid or liquid state. Special precautions must be taken when transferring solids, semisolids, and powders from their outer packaging into pharmaceutical waste bags. The outer packaging, devoid of any drug residues, is considered non-drug waste and can be appropriately disposed of or recycled with non-medical waste. In cases where the outer packaging contains residual drugs, it should be carefully packed into pharmaceutical waste bags for disposal. For drugs with significant antimicrobial (antibiotics/antiviral/antifungal/antiparasitic) or antineoplastic properties, especially when disposing of large quantities, extra precautions must be taken. It is advisable to consult a pharmacist for safe and responsible disposal of pharmaceutical waste.

13.4 Dairy and Poultry Farms

Livestock and poultry farms generate three types of waste: solid waste, slurry, and wastewater. These include urine, dung, feed, dairy manure, and renderings. Effective farm management involves reducing, collecting, storing, reusing, and treating waste while minimizing environmental impact. Disposing of carcasses safely and promptly is crucial in preventing the spread of diseases and environmental pollution, especially during an outbreak. It is also essential to convert non-hazardous organic waste into valuable resources, with solids repurposed as fertilizers and fuel. The following guidelines should be followed for effective management of waste generated from dairy and poultry farms:

- Record the types of waste generated on a dairy/poultry farm to develop a waste management plan.
- Set waste-reduction targets by estimating the amounts of waste recycled, used for energy generation, or sent to landfills/incineration.
- Separate solid and liquid manure streams for efficient composting and nutrient utilization.
- Implement effective storage practices for livestock manure to prevent degradation and fly production.
- Store animal waste in a cold, well-ventilated area, wear proper PPE when handling dead animals, and thoroughly clean and disinfect instruments and work surfaces with appropriate disinfectants.

13.5 Carcass Disposal Methods

Various methods exist for carcass disposal, each with its own considerations. Before adopting any specific method, it is essential to consult all applicable rules and regulations. Adhering to these requirements ensures that the chosen carcass disposal method aligns with the legal and environmental frameworks, promoting responsible and sustainable practices. The following waste treatment procedures can be used for carcass disposal.

13.5.1 Rendering

- A thermal rendering process involves treating carcasses with high-temperature, pressurized steam (typically around 130 °C or 265 °F), effectively eliminating pathogens and converting the material into safe, usable byproducts such as protein-rich animal feed (Figure 13-2). This process plays a key role in both sanitizing non-infectious animal waste and transforming it into commercially valuable materials.⁶
- However, byproducts from infectious carcasses can only be reused after strict regulatory approval and are often discouraged for high-risk waste.

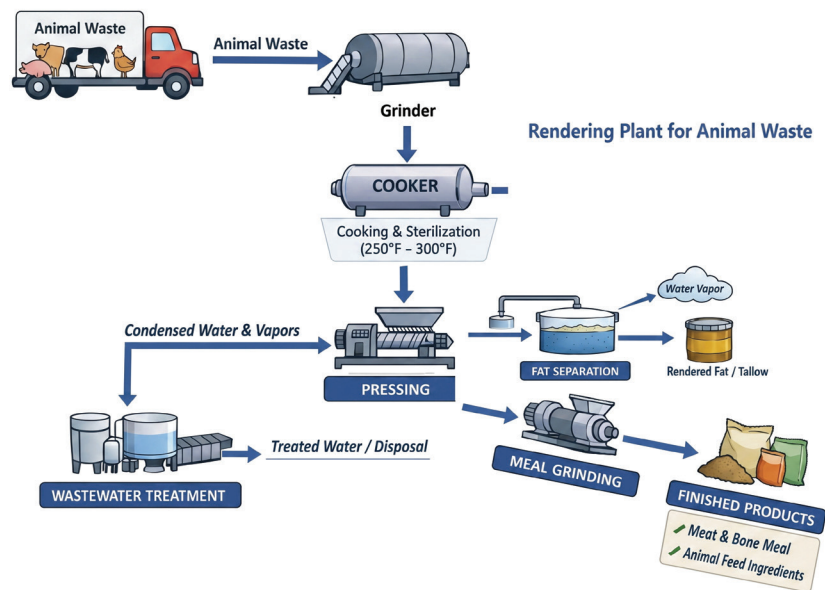


Figure 13-2. Rendering Plant Treating Non-Infectious Animal Waste

13.5.2 Incineration

Incineration is a process in which carcasses are subjected to controlled burning, reducing them to ash. While this method is effective, it is costly due to the need for auxiliary fuel. It is imperative to adhere to proper loading, operating, cleaning, and maintenance procedures for incinerators at regular intervals, following the manufacturer's instructions closely to ensure optimal functionality. Additionally, the strategic placement of incinerators is essential to avoid public complaints about potential odor nuisances generated during incineration. Poorly controlled, emissions-heavy incinerators produce obnoxious gases that are carcinogenic in humans.⁷ Incineration is recommended for the disposal of infectious animal carcasses in several guidelines.

13.5.3 Burial

Burial is a prevalent method of disposing of the remains of the deceased, valued for its viability, cost-effectiveness, and efficiency. Swift burial prevents nuisances such as odors, flies, and scavengers. However, carefully selecting and maintaining a burial site is paramount to mitigating the risk of groundwater pollution.⁷ The burial process should be conducted in an environmentally responsible and safe manner, minimizing potential risks to public health and the ecosystem by following these guidelines:

- The burial site must be situated away from residential areas and receive approval from local environmental protection agencies.
- The chosen site should be distant from drinking water sources, streams, and flood-prone areas to minimize the risk of contamination.
- Sandy or gravelly soil and areas with a shallow groundwater table should be avoided.
- The burial site should be at least 4 feet above the groundwater table.

- The bottom of the trench for carcass disposal should be compacted, and carcasses may be arranged in layers, with a 6 – 12-inch layer of soil between each layer of waste.
- Individuals involved in the burial process, including trench digging, carcass handling, and backfilling, should adhere to proper personal and equipment precautionary measures.
- It is advisable to fence the trenched area, as an open trench may pose safety hazards.
- Burial of infectious carcasses is acceptable only under strict environmental and biosecurity controls and is usually considered a last resort method during infectious disease outbreaks.

13.5.4 Carcass Composting

Carcass composting is a natural and environmentally friendly method for disposing of mortalities. This method, particularly suitable for poultry producers, is prioritized for its cost-effectiveness, ease of piling and windrowing, and minimal risk of environmental pollution. In regions where incineration and burial face restrictions, composting has emerged as the most suitable approach for the safe disposal of carcasses. In certain countries, such as the USA, composting is officially recognized as an effective method for managing routine and emergency mortalities of large animals. In this process, deceased animals undergo decomposition through the activity of microorganisms, effectively neutralizing most disease-causing pathogens.^{8,9} Standard carcass composting methods include composting in a bin or static windrow.

a. Bin Windrow Composting

Bin composting is a suitable method for disposing of small to medium-sized carcasses, offering efficiency and environmental friendliness (Figure 13-3). Here are key aspects of this method:

- A three-sided bin is constructed on a compact clay soil or concrete floor, ensuring stability and containment. Typically, three such bins are built side by side.
- Appropriate carbon sources such as wheat straw, hay, sawdust, or poultry litter are used to create a suitable base. The choice depends on the size and volume of carcasses. The dry absorbent material, such as hay or straw, when strategically placed, prevents liquids from draining during the composting process. Tree trimmings may also be incorporated to enhance porosity and structure within the compost pile.
- Carcasses are arranged in layers within the bin, maintaining a 12-16-inch distance between layers of the composting materials, ensuring no part of the carcass is exposed. This layering serves the dual purpose of preventing predators and controlling odors and flies. Approximately 3-5 cubic yards of composting material is required for every 1000 pounds of carcass.
- Frequent turning of the composting material is crucial, preferably when the pile temperature is below 90°F or above 140°F. Regular turning enhances aeration and accelerates decomposition, contributing to effective carcass disposal.

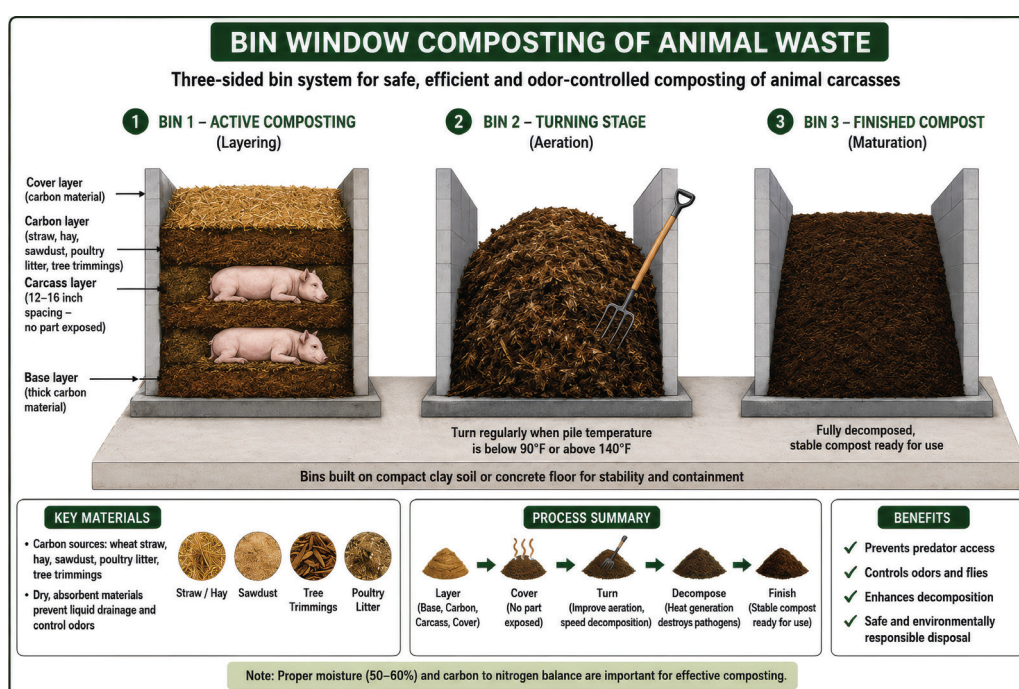


Figure 13-3. Bin Window Composting of Animal Waste

b. Static Windrow Composting

This composting technique proves versatile for both small and large animals, offering simplicity and efficiency in the treatment process (Figure 13-4). Here are the key considerations:

- Piles and windrows are strategically constructed on compacted soil or a concrete floor in an open area without walls and roofs. This design facilitates easy access for the loading and unloading of deceased animals.
- Various materials can be used for substrate preparation, including sawdust, straw, and poultry litter. An 8-12-inch-thick base layer of substrate material is established to provide a solid foundation for composting.
- Achieving the correct carbon, nitrogen, oxygen, and water ratios is crucial for successful composting. For instance, composting 909 kg of poultry carcasses would require approximately 336 kg of sawdust.
- Animals are positioned on the prepared base layer to ensure a well-distributed arrangement.
- The abdominal cavity of each animal is punctured to prevent bloating and potential rupture during composting.
- The animals are covered comprehensively with 24"–36" of substrate material on all sides. This step serves to deter scavengers and effectively contain odors.
- An additional layer of substrate material is applied to cap the entire pile, promoting optimal composting conditions.

By following these steps, producers can implement an efficient composting technique suitable for a range of animal wastes. This approach ensures safe and responsible disposal while supporting environmentally sustainable livestock management practices.



Figure 13-4. Static Windrow Composting

13.6 Slaughterhouses

Slaughterhouses produce a considerable amount of solid, liquid, and gaseous waste that can contaminate air, water, and food, thus posing risks to public health and the environment.¹⁰ Addressing this issue requires adopting appropriate waste management strategies (Table 13-1) such as burning, burying, composting, and rendering.¹¹ These strategies can also help transform this waste into valuable by-products used in agriculture and industry. About 60% of the leftover materials after the slaughter are considered waste and must be disposed of or recycled appropriately.

13.6.1 Solid Waste Management

In slaughterhouses, solid waste should be managed keeping the following things in mind:

- Waste bins made of waterproof, easy-to-clean material should be placed in sufficient numbers in all work areas.
- Dedicated staff for regular waste collection should be available and provided with risk-based protective equipment.
- Solid waste should be collected, identified, segregated, and disposed of immediately.

- Hides and skins should be removed and transported immediately.
- Legs, hooves, heads, and bones should be removed immediately after slaughtering and transported out of the slaughtering area using wheelbarrows or dedicated carts.
- Gut contents, including undigested feed, should be either composted with manure or disposed of as waste by burial or incineration.
- In outbreak situations, waste from slaughterhouses must be handled under enhanced biosecurity controls and in line with applicable WHO/FAO risk management recommendations.¹¹

13.6.2 Wastewater Management

Draining slaughterhouse wastewater (SWW) into water bodies can have serious consequences, including eutrophication, excessive algal growth, and reduced dissolved oxygen levels. Therefore, it must be handled carefully and in accordance with applicable rules and regulations. For its management:

- Bleeding areas and drainage points in a slaughterhouse should be identified, and the blood should be collected immediately in a separate pit/system away from wastewater drainage, to prevent drain blockage from coagulation. The coagulated blood can be added to compost, used as a fertilizer in fields, or buried with other waste material. If these options are not feasible, it can be sent to anaerobic digesters, incinerators, or rendering facilities.^{12,13}
- The liquid waste produced during slaughtering, containing high concentrations of blood, suspended fat particles, and undigested feed particles, should be washed away using a safe, potable, and constant fresh water supply at adequate pressure into a dedicated drainage system. The drains should be made of water-resistant material and be wider and deeper to allow the free flow of wastewater. A covered waste tank with sufficient storage capacity should be constructed away from processing and dirty areas in the slaughterhouse. The tank should be made of a durable, waterproof, and quickly disinfectable material.
- Wastewater should not be allowed to stagnate on the floor of the processing area and should not mix with drainage lines designated for toilets and bathrooms on the premises.
- For treatment and disposal, the slaughterhouse wastewater can be directed to a dedicated septic system, municipal sewer if regulatory bodies allow this drainage (usually done after removing solids and grease), wastewater lagoons, evaporation ponds, or an anaerobic digester. The treatment in a dedicated septic system is a multi-stage process and is outlined in Fig 13-5.¹³
- Liquid waste produced in slaughterhouses during disease outbreaks requires strict management, including effective collection, treatment, and disposal under reinforced biosecurity controls.

Table 13-1. Waste Generation in Various Animal Slaughtering Operations

Operation/Process	Types of Waste Produced
Livestock reception and washing	Manure, urine, odor, and wastewater
Bleeding (slaughtering)	Blood and wastewater
Scalding	Blood, odor, and wastewater
Dehairing/singeing	Hair, tail emission, odor, toenails, and wastewater
Dressing (head/hoof/hide removal)	Head, hoof, and hides
Evisceration	Blood, edible offal, inedible offal, casing, stomach contents, paunch, manure, odor, and wastewater
Chilling	Wastewater, packaging materials, blood, and cleaning effluents
Cutting and boning	Bones, trimmings of meat/fats, and wastewater

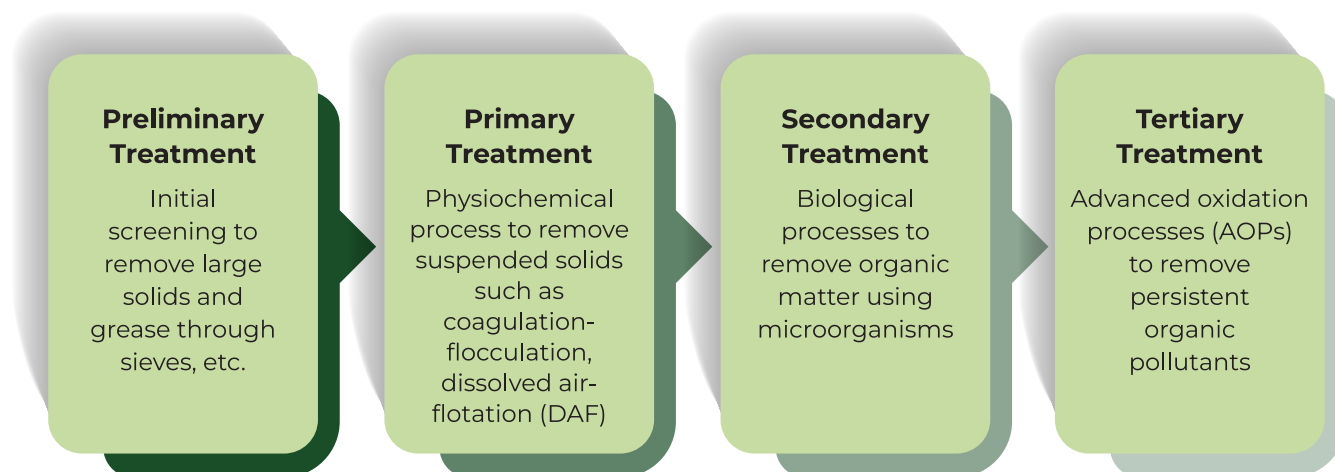


Figure 13-5. Wastewater Treatment Process for Slaughterhouses

13.7 Aquaculture Waste

In recent decades, aquaculture has grown significantly. Its meat production surged to 223.2 million tons in 2022.¹⁴ This industry generates various types of biowaste, including viscera, skin, frames, bones, fins, heads, and shells. The effluents released by these facilities into water bodies can harm the aquatic environment.¹⁵ About 25% of the wastewater released by fish farms contains pathogenic and metabolic waste. Waste management for aquaculture is generally expensive. However, the following guidelines can help reduce the impact of biowaste:

- Feed management tools can be used to minimize waste by reducing the amount of phosphorus the fish release.
- High-energy pellets can be used as feed without reducing growth and with less waste generation.
- Using floating feed improves monitoring and reduces the risk of overfeeding.
- Water released from ponds/fish farms should be controlled by filtering and collecting most solids.
- Round tanks with properly designed inlets, filters, and drains are recommended to remove solid materials with minimum labor. Solid waste must be removed without delay.
- Pathogenic liquid waste can be treated with ultraviolet radiation to disinfect the water after solid waste is removed.¹⁶
- If additional land is available near the aquaculture facility, constructed wetlands or shallow artificial wastewater treatment systems may be established to support natural water purification processes. This approach is cost-effective, as it requires little to no external energy input.
- Aquaculture waste can be utilized in ways akin to agricultural waste. Several valorization techniques are available for fish biowaste, including biogas production, biodiesel generation, biofertilizer production, and the extraction of high-value compounds such as fish collagen, natural pigments, and chitosan (from shellfish waste). However, their adoption is largely dependent on the cost-benefit ratio of the selected technology.¹⁷

13.8 Utilization of Animal Waste as Byproducts

Non-infectious animal waste can be utilized in a variety of ways:

a. Hides and Skins

Hides and skins are used in leather production with two primary methods: air-curing and salt-curing. Air-curing involves fleshing, cleaning, and drying hides in the open air. By contrast, salt-curing involves rubbing hides with salt and storing them in a cold place for 30 days. Both methods are crucial for maintaining the quality and market value of hides and skins, making them valuable in the leather industry. This practice ensures sustainable and efficient use of animals, minimizing waste and maximizing resource efficiency.¹⁸

b. Meat and Bone Meal

- Meat and bone meal is a common and beneficial component of animal feed, made from various animal products, including skin, horns, hoofs, intestinal contents, and blood.
- The production process, known as wet-rendering, involves cooking the material in a specialized steam-rendering tank under pressure, up to 40 psi.

- This process helps break up and soften the tissues, facilitating the release of fats and ensuring the thorough destruction of harmful pathogens.
- These stringent safety measures guarantee the production of high-quality meat and bone meal that is safe and highly beneficial for animal feed.

c. Blood Meal

- Blood meal is a dark brown, high-protein, nutrient-rich by-product, used as an organic fertilizer or animal feed.
- The amount of blood produced in slaughterhouses can vary based on their capacity. Efficient, immediate disposal of blood is essential to prevent sanitation and hygiene issues.
- Blood can attract rodents and insects and coagulates quickly, so it needs to be collected promptly.
- Small-scale slaughterhouses typically coagulate blood by cooking it in a tank, draining off the liquid, breaking up the coagulum, and drying it in a simple solar dryer.
- This process yields about 12 kg of dried blood from 10 cows and three sheep.
- For large-scale production, commercial blood dryers are commonly used.

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Appendix A – Incident Reporting Form (Template)

Institution Name:	
Date of Report:	
Reporter Name and Position:	
Reporter Telephone:	
Reporter Email:	
Reporter Mailing Address:	
Date of Incident:	
Name of Principal Investigator/Lab Manager:	
What was the nature of the incident?	☐ Personnel exposure ☐ Spill ☐ Loss of containment ☐ Loss of PPE ☐ Failure to obtain administrative approval ☐ Failure to follow approved containment conditions ☐ Other - please describe:
Was the proper approval taken for this work?	☐ YES ☐ NO If yes, on what date?
If yes, please provide:	Approval date: Approved biosafety level(s) for the work: Additional approval requirements (if any):
Please provide a narrative of the incident, including a timeline of events. The incident should be described in sufficient detail to allow for an understanding of the nature and consequences of the incident. Include the following information as applicable. A description of: - The incident/violation location (e.g., laboratory biosafety level, non-laboratory space). - Personnel involved in the incident/violation, including others present at the incident location. - Actions taken immediately following the incident/violation, and by whom, to limit any health or environmental consequences of the event. - The training received by the individual(s) involved and the date(s) the training was conducted. - The institutional or laboratory standard operating procedures (SOPs) for the work, and whether there was any deviation from these SOPs at the time of the incident/violation. - The personal protective equipment in use at the time of the incident/violation. - The occupational health requirements for laboratory personnel involved in the research. - Any medical advice/treatment/surveillance provided or recommended after the incident. - Any injury or illness associated with the incident. - Medical surveillance results (if not available at the time of initial report, please indicate when results will be available). - Equipment failures. DESCRIPTION OF INCIDENT: (use additional space as necessary)	
Has the administration reviewed this incident?	☐ YES ☐ NO If yes, please provide a copy of the minutes of the IBC/other meeting in which the incident was reviewed.
Has a root cause for this incident been identified?	☐ YES ☐ NO If yes, please describe:
Describe measures taken by the institution to mitigate any problems identified. For measures identified but not yet taken, please include a timeline for their implementation: (use additional space as necessary)	

Please provide copies of any documents referenced in this report.

Signature:

Reporting Person:

Appendix B – Safety Data Sheets (SDS)

Safety Data Sheets (SDSs) are crucial for ensuring the safe handling, storage, and transportation of materials. These documents provide essential information about materials' properties, hazards, and safety precautions, enabling individuals and organizations to take necessary precautions for a safe working environment.

- Employers and employees must familiarize themselves with the information provided in the SDS to create a safe working environment and respond effectively to potential hazards.
- Regular training on SDS interpretation and implementation is essential to promote a culture of safety and compliance in various industries.

In the following sections, more detailed information is provided for the purposeful use of these sheets:

What is a Safety Data Sheet?

A Safety Data Sheet (SDS) is a comprehensive document that provides detailed information about materials' physical and chemical properties.

Components of a Safety Data Sheet (SDS)

The Hazard Communication Standard (HCS) requires chemical manufacturers, distributors, or importers to provide Safety Data Sheets (SDSs) (formerly known as Material Safety Data Sheets or MSDSs) to communicate the hazards of hazardous chemical products.

Section 1: Identification includes the product identifier; the manufacturer's or distributor's name, address, and phone number; the emergency phone number, the recommended use, and the restrictions on use.

Section 2: Hazard(s) identification includes all hazards associated with the chemical and the required label elements.

Section 3: Composition/information on ingredients includes details on chemical ingredients and trade secret claims.

Section 4: First-aid measures include important symptoms/ effects, acute, delayed, and required treatment.

Section 5: Fire-fighting measures lists suitable extinguishing techniques, equipment, and chemical hazards associated with fire.

Section 6: Accidental release measures lists emergency procedures, protective equipment, and proper methods of containment and cleanup.

Section 7: Handling and storage lists precautions for safe handling and storage, including incompatibilities.

Section 8: Exposure controls/personal protection lists OSHA's Permissible Exposure Limits (PELs), Threshold Limit Values (TLVs), appropriate engineering controls, and personal protective equipment (PPE).

Section 9: Physical and chemical properties lists the chemical's characteristics.

Section 10: Stability and reactivity lists chemical stability and potentially hazardous reactions.

Section 11: Toxicological information includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.

Section 12: Ecological information

Section 13: Disposal considerations

Section 14: Transport information

Section 15: Regulatory information

Section 16: Other information includes the date of preparation or last revision.

Employers must ensure that Safety Data Sheets (SDSs) are readily accessible to all employees. For additional information, visit the Occupational Safety and Health Administration (OSHA): www.osha.gov

Appendix C



US Environmental Protection Agency Office of Pesticide Programs

List J: EPA's Registered Antimicrobial Products for Medical Waste Treatment (Updated January 2026)

Registration Number	Active Ingredient(s)	Product Name	Company	Formulation Type
1677-229	Sodium Dichloro-s-triazinetriene	Isolyser Lts-Plus	Ecolab, Inc	Ready to use
65402-8	Hydrogen Peroxide; Peroxyacetic Acid (Peracetic Acid)	Vigorx 15/23 Antimicrobial Agent	Evonik Active Oxygen, LLC	Ready to use
69681-25	Sodium Dichloroisocyanurate Dihydrate	Clor Mor 56 PG	Allchem Performance Products, Inc	Dilutable
69681-26	Sodium Dichloro-s-triazinetriene	Clor Mor 60 PG	Allchem Performance Products, Inc	Dilutable
70271-10	Sodium Hypochlorite	Purebright 10% Sodium Hypochlorite Solution	kik International, LLC	Ready to use
86042-1	Sodium Dichloro-s-triazinetriene	Super Solid Plus	Disorb Systems, Inc	Ready to use
88346-1	Sodium Dichloroisocyanurate Dihydrate	Pooline Super Dichloe 56	Tianjin Pool & Spa Corpotion	Dilutable
90383-1	Sodium Dichloroisocyanurate Dihydrate	Zap-Out	Stewart Superabsorbents, LLC	Ready to use
935-48	Sodium Dichloroisocyanurate Dihydrate	Oxygchem Mas 56 Alkaline Sanitizer	Occidentall Chemical Corporation	Ready to use

Appendix D – Safety Equipment

Every laboratory should possess fundamental safety gear, along with any specialized equipment necessary to address specific risks and respond to emergencies within the laboratory. Such as:

1. Spill kit
2. First aid box
3. Safety shower
4. Eyewash station
5. Fire extinguishers
6. Fire blanket

Spill Kits Contents			
Sr. No.	Description of Items	Quantity	Date of Expiry (DOE) of Consumable Items
1.	Instructions for the use of the spill kit (SOP) in a plastic covering	One	
2.	Warning or biohazard signs	Four	
3.	pH indicator (pH paper strips)	One	
4.	Absorbents (tissue papers, towels, material pads, or sorbents)	As per the requirement	
5.	Neutralizers (acid or base) Acid: Sodium bicarbonate Base: Citric acid/sodium thiosulfate	One bottle each (2.5 L)	DOE: _____ DOE: _____
6.	Personal Protective Equipment (as per risk assessment) Nitrile gloves Latex gloves Disposable gowns Safety goggles Face masks Face shields Respirators (N95) Shoe covers	One box One box Four Two One box Two Six One box	
7.	Head cover	One box	
8.	Hand sanitizer (250 ml)	One bottle	DOE: _____
9.	Disinfectant bottle plastic	One	
10.	Biohazard waste bags (autoclavable) (small/large)	Twelve	
11.	Long tongs or long forceps (12 inches long)	One each	
12.	Spill pillow for large spills	One	
13.	Dustpan and wiper	One each	
14.	Sharps container (puncture-resistant)	One small	
15.	Germicidal wipes	One pack	DOE: _____
16.	Plastic vinyl booties	Two pairs	
	NOTE: Additional items and PPE (e.g., PAPR, Tyvek suit) can be placed inside a spill kit based on risk assessment.		

CONTENTS OF A SPILL KIT



Biological Spill Response Kit

NOTE:
Use appropriate personal protective equipment (PPE) and follow institutional protocols while handling spills.

Appendix E – Important Contacts Template

Emergency Services		
Contact Type	Contact Number(s)	Additional Information
Main Laboratory		
Lab Manager		Overall laboratory function issues
Principal Investigator (PI)		Contact for any research project issues
Lab Safety Officer		Name: (Insert name)
Fire Department	1122/16	
Ambulance	115	
Police Department	15	
Poison Control Center		Contact for any exposure by ingestion
Emergency Response Team		Contact for any lab-related emergencies
Biosafety Officer		For biological hazards, spills, and other incidents
Health & Safety Office		General safety concerns and incidents
Facility Management		Contact for building-related issues
Radiation Safety Officer		For radiation-related emergencies
Chemical Spill Response		Contact for chemical spill incidents
Security Office		For security concerns and breaches
Electric Supply Company	118	Contact for power issues
Local Hospital/Occupational Physician		Name of hospital/physician's name
Water Supply Company	055-9230200	Contact for water issues
Gas Supply Company	119	Contact for gas issues
IT Support		For IT-related complaints/emergencies
In-Charge Sanitation		For any support for waste management
Environmental Health & Safety (EHS)		Contact for overall EHS issues

