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# Implementation of Waste Segregation Protocols Across Laboratory and Imaging Department

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**Abstract**

Healthcare generates a wide variety of waste that poses risks to human health and the environment. Robust waste segregation protocols facilitate safe waste disposal and promote sustainability. Guidelines for implementing waste segregation measures across laboratory, imaging, and pharmacy departments are described, considering policy, infrastructure, training, and compliance issues. Laboratory departments produce hazardous chemical and pharmaceutical waste, as well as biological material and sharps. Imaging departments generate medical devices, hazardous materials, and radiologic waste, while pharmacy departments handle expired medications and cytotoxic drugs. A systematic approach involving coordinated stakeholder engagement, adequate infrastructure, staff training, and periodic auditing supports effective segregation and mitigates associated risks (Lahoti et al., 2024) ; (Lakshmana Kumar et al., 2021).

**Keywords-** Biochemical hazards; contamination; hazardous pharmaceutical stocks; hazardous wastes; limiting exposures; mixed waste; operating procedures; waste management; waste minimization; waste segregation; waste tracking

## 1. Introduction

Hospitals generate huge volumes of waste that can pose serious health risks to healthcare workers, patients, the community, and the environment. Currently, healthcare waste management (HCWM) poses a big challenge to hospitals in Uganda and many other developing countries. Such waste is poorly segregated at source, with most institutions lacking appropriate disposal infrastructures (Kwikiriza et al., 2019). The resulting poor disposal practices continue to pose serious risks to the community, healthcare workers, and the environment, including contamination of water sources and creation of breeding grounds for disease vectors.

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Inadequate segregation of waste at health facilities can lead to generation of huge volumes of hazardous waste that overwhelms available disposal systems; some waste types accumulate over time because they cannot be disposed of without destroying the entire batch/preventing reuse. Facilities that must destroy huge volumes of waste without delay, such as those administering chest X-rays (contaminated contrast materials), are particularly affected by the lack of guidance on acceptable disposal (Derrick. Gabela, 2007).

## 2. Foundations of Waste Segregation in Healthcare

Healthcare waste segregation aims to safeguard healthcare workers and the community from exposure to hazardous materials, to protect the environment and to limit monitoring and management costs (Kwikiriza et al., 2019) ; (L. Ammakiw et al., 2014). Segregation is undertaken by the producer of the waste and is subject to a system of control (monitoring) and an overall governance structure (national policies and programs). Stakeholders include producers (healthcare personnel), the waste management department, regulatory bodies (national environmental and health agencies), and receivers (waste management companies).

Two key principles are general applicability and recognition of the global evolution of healthcare waste and waste management regulations. Regulations are influenced by precedents of green regulations on the management of waste (e-waste, batteries, sulphur paste, etc.) and toxic substances (chemicals, heavy metals, ozone-depleting substances, etc.) and by healthcare human and material resource management. Advisory codes promulgated by international organizations (World Health Organization, Organisation for Economic Co-operation and Development, United Nations Environment Programme, etc.) and provisions of regional and national laws serve as key regulatory drivers.

Waste segregation involves the identification and classification of waste streams, the determination of waste categories relevant to each stream and the inclusion of general applicable standards in waste management procedures. It is systematic, controlled and rigorously practised because of the high stakes involved (risk of imprisonment for the head of the business, possible asphyxia/explosive reaction for chemicals). Waste streams depend on the origin and system of management; in the context of a hospital, wastes are categorized by (i) incoming waste treatment (sanitation and destruction) and (ii) hazardousness. Each department manages the waste produced by its own separate waste streams.

## 3. Waste Streams and Applicable Regulations

Laboratories, imaging services, and pharmacy stores generate, use, and dispose of various products that fall into multiple waste categories. These products—be they chemicals, pharmaceuticals, radioactive materials, or biohazards—evidence the need for appropriate disposal to protect staff and patients from potential exposures and injuries. Until relatively recently, segregating such items by waste type was not prioritized. Yearly walkthroughs

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followed by reports identified waste signs, but departmental actions remained largely unchanged. A similar survey conducted in 2018 confirmed that approximately 75% of all materials were still disposed of inappropriately.

Outdated labels pointed to early 2014 guidance in certain areas. Numerous sectors subsequently established monitoring and reporting activity, resulting in the institution prioritizing regulatory and policy updates in June 2018. Evolving standards under the environmental domain also confined containment options for hazardous chemicals, biologicals, pharmaceuticals, and certain sharps. Standards covering other recyclable items remain in progress. A fresh review exam administered in mid-2019 revealed the number of noncompliant items had increased rather than decreased across all departments (Louis Williams, 2013).

A targeted waste act in the laboratory department announced the complete removal of recyclable materials such as paper, boxes, glass, bottles, and others, in line with the regulations. Imaging sections also fully complied with a directive mandating the installation of segregated management systems, ensuring all previous iterations had been accounted for. Three diverse inquiries concerning the pharmacy domain received little attention, prompting examination of the topic. Subsequent feedback afterward prompted immediate activities steered toward waste types and corresponding containers. The current disposal process for non-hazardous and hazardous content in sectors that remained unanswered witnessed widespread implementation. Embedding accompanying waste types and spatial considerations completed and implemented all associated activities within one department (G Towle et al., 2016).

**4. Waste Segregation in Laboratory Departments**

Laboratory wastes are classified into hazardous chemical wastes, hazardous biological wastes, general waste, and recyclables. Regulations concerning hazardous chemical wastes, biological wastes, and general waste from laboratories fall under various national and international guidelines (Louis Williams, 2013). Hazardous chemical wastes should be segregated according to the chemical compatibility chart found in institution's Safety Data Sheet. Hazardous chemical waste storing cannot exceed 1 month after generation and must be released to a registered hazardous waste collecting agency. Waste spill response procedure and chemical classification can be found in the institution's Laboratory Chemical Safety Guideline. All laboratory chemical wastes along with the container must be labelled with the proper hazardous chemical waste stickers, and designation labels that indicate compatibility group and content descriptions, respectively. Hazardous biological wastes must be incinerated in designated laboratory after autoclaving or retained in tightly sealed container in a secondary containment box following the institution's guidelines for supportive containment of wastes and hazardous biological incident response. A colour code system

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with specific restrictions is implemented for general and recycled wastes. General waste includes contaminated or unrecognizable materials from laboratory workbench whereas recyclable waste comprises of clean and unrecognizable materials (Kwikiriza et al., 2019).

The laboratory wastes generated include hazardous chemical wastes, hazardous biological wastes, general wastes, and recyclable wastes. Regulations governing hazardous chemical wastes, biological wastes, and general wastes remain comprehensive across various national and international guidelines. Hazardous chemical wastes must be managed in accordance with the chemical compatibility chart presented in the institution's Safety Data Sheet. Storage duration of hazardous chemical wastes must not exceed 1 month after generation, and wastes must subsequently be transferred to a registered hazardous waste collection agency. Chemical classification information and waste spill response protocols are outlined in the institution's Laboratory Chemical Safety Guideline. At every stage prior to disposal, all laboratory chemicals and their respective containers must be clearly labelled with the appropriate hazardous chemical waste stickers, as well as designation labels indicating the relevant compatibility group and content descriptions. Hazardous biological wastes may be either incinerated in designated laboratories subsequent to autoclaving or retained in tightly sealed containers placed within a secondary containment box, strictly following the institution's guidelines for safe containment of wastes and protocols pertaining to hazardous biological incidents. A colour code scheme stipulating specific restrictions governs the segregation of general and recyclable wastes. General waste encompasses contaminated or unidentifiable materials originating from the laboratory workbench, whereas recyclable waste consists solely of clean and unidentifiable materials.

### 4.1. Hazardous Chemical Waste

Hazardous chemical wastes are defined as the substances that are engineered or manufactured in laboratories, chemicals that show toxic effects on both human health and the ecosystem when in contact (Louis Williams, 2013). There are different classifications of hazardous chemicals determined on the basis of the Chemical Disposal Codes with reference to British standards. The core idea in controlling hazardous chemical waste is to collect all hazardous chemicals segregated by the Chemical Disposal Codes and then properly store them at designated waste collection points within the laboratory to ensure that the waste will not be tampered and minimising the risk of a catastrophic spill. All hazardous chemicals (i.e., waste) must also be in container system that is adequate for the chemical composition and are not expired (i.e., has not reached its shelf-life duration). Hence, the concept of Secondary Containment comes in, where the outer containment must have a capacity of at least 110% of the original container and also non-reactive or compatible on the outer to ensure that no external disasters will cause a chain reaction (Pourzamani et al., 2019). Apart from proper collection of chemicals, it is also crucial to have knowledge of the types of hazardous

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chemicals stored at the waste collection point so that quick remediation action can be applied in case of a chemical spill.

### 4.2. Biological and Sharps Waste

Biological waste corresponds to materials contaminated with infectious agents or identified as potentially containing pathogens, such as fresh human tissue, culture materials, body fluids, and contaminated blood. Sharps comprise any device or object that can puncture the skin, including blades, needles, and glass. Such items must be managed in accordance with applicable health and safety guidelines. The university has established a waste handling protocol in each laboratory that includes a requirement for all biological and sharp waste to be placed in designated containers that are labelled to indicate the type of waste that they may hold. Such containers must be correctly separated to ensure compliance with the relevant control measures specified in the safety documentation, which includes segregation requirements.

Biological waste must be either steam-sterilized in an autoclave or collected by a specialized external third-party service provider as designated under the university's Integrated Waste Management Plan. Authorized laboratory staff who have successfully completed the training on biological waste handling, including the university's risk assessment format, can sign the Waste Collection Request Form (as indicated in the Integrated Waste Management Plan) and access a collection service for biological waste that is deemed as too hazardous for autoclaving. This service is operated by an external waste management company that holds an appropriate permit to treat biological waste. Sharps must be retained in 'Secure Sharp' containers that are specifically designed to hold this type of waste stream. When these 'Secure Sharp' containers are full, laboratory staff who have attended the appropriate training course can submit the Waste Collection Request Form to arrange for a collection by the same external company mentioned above.

### 4.3. General and Recycling Waste

General and recycling waste must be handled according to general waste and recycling definitions established by several agencies (Louis Williams, 2013). Colour codes of yellow for general waste and blue for recyclable waste correspond to the department colour coding systems (Elgitait, 1970). Each department maintains yellow waste bins for paper, card, plastic, and general waste from ordinary activities such as form completion and packaging. These bins should be used only for waste that has not come into contact with hazardous chemicals or biological agents. Paper towels used for cleaning chemical spills should be placed into regulated waste colour-coded bags or containers.

As part of a coordinated effort to reduce the amount of general waste produced, a Kitchen Left-Overs Recycling initiative was introduced in July 2011. To further conserve resources, it

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is recommended that staff obtain only the amount of paper necessary for completion of the task as recyclable paper waste can originate from other sources, such as used office sheets and laboratory papers. The use of printing and photocopying paper must be minimized, especially when any form of double-sided printing is effective. Printing jobs should also be checked thoroughly before execution to avoid the imminent disposal of unused pages. All source waste that originates from the imaging department must not be disposed of in general waste bins to avoid undue contamination of sorting facilities.

## 5. Waste Segregation in Imaging Departments

Imaging departments generate various types of waste, including sharps, liquid chemicals, contrast materials, lead-containing materials, electronic equipment, and generator waste. To ensure safe disposal and minimize environmental impact, these wastes must be managed appropriately (Chezian Sengodan, 2014).

Regulatory guidelines stipulate that imaging facilities containing hazardous materials, such as lead, or using toxic materials, such as X-ray contrast agents and developing solvents, must adhere to specific segregation protocols. Effective waste management in imaging departments requires waste separation at the source, along with the use of designated containerization and labeling practices; secondary containment measures may also be needed outside the imaging area.

Imaging departments must implement waste segregation according to established policies to protect the health of patients, personnel, the general public, and the environment.

### 5.1. Radiologic and Electronic Waste

The radiological waste generated during medical imaging involves imaging devices and lead-containing materials while the electronic waste comprises non-functional electronic materials, batteries, broken electronic devices such as computers, monitors, printers, and various electronic accessories, and their disposal is regulated by the Ministry of Environment, India, as E-Waste (Management) Rules, 2016. E-waste is reused or recycled through the purchase of unwanted devices from contractors for reconditioning and resale to authorized agencies. Radiological and electronic waste is segregated at the source itself and packed appropriately into containers identified with respective labels to avoid secondary contamination. The radiological waste is collected and treated appropriately according to the Department of Atomic Energy (DAE) guidelines on good radiological practices and the waste is either packed into approved containers or returned back to the supplier. Segregation is to be done on the basis of wasted materials to achieve maximum separation and treatment as per regulation. Waste from various modalities of imaging is categorized into neutron generators and chemicals, lead-based materials, radioactive waste, used x-ray processing solutions, e-waste and Li batteries, cathode ray tube (CRT) monitors, and the guidelines for each are provided.

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To ensure proper management of radiologic waste originating from imaging and radiotherapy, all waste including patient swabs, used clothing, paper, plastic, rigid waste (plans, containers, instruments), and waste from generators such as chromatographic paper, eluting, and contaminated gels needs to be collected, packed, and sent for disposal according to the recommendation of the Department of Atomic Energy. Imaging services across laboratories, hospitals, health centers, and universities emit significant medical waste, hence ensuring the implementation of adequate waste disposal protocols are of pivotal need. (Sharma et al., 2018)

### 5.2. Hazardous Materials from Imaging Procedures

An important goal of radiology departments is to minimize the generation of hazardous waste from the preparation and administration of contrast agents and solvents while eliminating the risk of direct human exposure to contrast and solvent components. All waste from imaging procedures must be considered hazardous even when generated in very small volumes. Procedures must therefore ensure that contaminated materials are contained and properly disposed of. Special attention must also be directed to spills of hazardous or potentially hazardous materials. Proper waste containers must be immediately on hand for both normal waste generation and for spills. Radiologists are also well positioned to minimize the use of hazardous materials with specific imaging techniques and therefore waste generation at the same time.

Contrast agents and solvents remain key precursor materials in nuclear medicine and diagnostic imaging. Waste generated during the preparation, administration, and cleaning of imaging procedures and devices must therefore be collected and removed from the working environment in a timely manner. Considerable quantities of hazardous waste can thus accumulate in a radiology department or imaging facility. The use of alternative procedures and imaging modalities can mitigate these issues. Nevertheless, where the use of hazardous materials cannot be avoided, the close and immediate management of packaging and disposal remains paramount (Sharma et al., 2018).

### 5.3. Containerization and Labeling Practices

Waste segregation across imaging departments in healthcare involves the management of waste from radiologic imaging devices, hazardous chemicals used during imaging procedures, and electronic waste from imaging-related equipment. Waste management frameworks such as the Globally Harmonized System provide guidance for classifying hazardous materials. Imaging departments must follow the safe disposal pathway outlined in the waste disposal procedure for radiology and imaging departments.

Containerization and labeling practices should be standardized across the institution to facilitate compliance and streamline staff workflows. Segregated waste containers should be

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furnished with appropriate bags or bins corresponding to the specific waste categories. Contaminated bags should be sealed and disposed of immediately after use. All containers and bags must be labeled clearly to identify the type of waste to be disposed of. Waste segregation should commence at the point of care to reduce the likelihood of cross-contamination.

**6. Waste Segregation in Pharmacy Departments**

Pharmacy departments are central to ensuring that pharmaceutical waste generated by other departments is collected and sent for destruction, as indicated by regulatory guidelines for chemical disposal. Expired or unused medications can present a fire hazard; thus, proper disposal is essential. Various provisions accompany the destruction and disposal of pharmaceutical waste, with special requirements for cytotoxic drugs. Compliance with the stipulated standards must be assured after destruction to ensure proper disposal. Chemical waste generated in pharmacies remains a major concern for hospital management.

Pharmacies play a crucial role in managing pharmaceutical waste and are obliged to collect pharmaceuticals from departments that do not have legislative authorization to destroy them. Waste batteries, used containers, and other associated bulky waste must be collected and stored carefully and transported to official channels provided by the management for external disposal. Incoming systems for managing pharmaceutical waste must be implemented, with the collection of all bulky pharmaceutical waste and expired medications for proper disposal. Recycling structures are gradually introduced for the collection of damaged products whose containers are made of recyclable materials and an active collection process for expired medications. Continuous recycling promotion from suppliers is an integral effort of the hospitals to facilitate recycling at the source.

**6.1. Pharmaceutical Waste and Expired Medications**

Safe and effective disposal of pharmaceutical waste, including expired medications, is necessary to minimize potential contamination of the environment or misuse by the general public. Appropriately handling waste such as chemically active compounds or expired medications also decreases concerns with possible adverse effects on patients and the public (Hart, 2018).

To address these concerns and meet federal and state regulations, medications may be returned to the supplier or destroyed via contracted disposal companies. Disposal also can follow the guidelines in Minnesota Rule 7045.0020 of the Minnesota Pollution Control Agency.

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### 6.2. Cytotoxic and Hazardous Drug Waste

Pharmaceutical waste encompasses substances designed for therapeutic use upon completion of a prescribed regimen or when containers have surpassed their manufacturer-designated expiry date. Handling these materials falls under hazardous-waste regulations, governed by the Environmental Quality Act and its associated regulations. A well-defined disposal process aligns waste-generation locations with the latest hazardous-waste-generation analyses and harmonizes with the framework established within departments of Oncology and Hematology and other health institutions (Kennedy et al., 2022).

Cytotoxic and other hazardous drug delivery occurs predominantly through Parenteral routes in hospitals. Such delivery entails the use of Specific syringes, infusion devices, and Technics necessitating explicit health and safety measures from Partner Facilities to day Care Centers. Containment and user-support feedback remain essential. Further, exploration into Mechanical and non-mechanical drench systems along various avenues persists.

### 6.3. Waste Minimization and Return Programs

Standardized waste-mitigation approaches proceed through supplier interventions, including returns of useless materials and collaborative development of innovative, dose-centric formulations that enable effective therapeutic outcomes while minimizing superfluous by-product accumulation (L. Bekker et al., 2018). In conjunction with these programs, institutional policies that mandate and promote insulating regulatory-compliance measures prevent unstewarded assisted departures from the institutional supply-chain, thus underlining enduring financial and environmental (as well as safety) pursuits without compromising operational continuity or patient care.

## 7. Implementation Strategies

Implementation strategies encompass stakeholder engagement, infrastructure development, and training to achieve effective and compliant waste segregation. Waste protocols are governed by a national waste management policy mandate and institutional environmental sustainable development policies. Commitment from management to integrate environmental sustainability in healthcare provision anchors ongoing initiatives. A national policy document defines waste segregation protocols for imaging and pharmacy departments. Stakeholder consultation by a multidisciplinary committee was conducted to tailor the policy to institution-specific requirements and mitigate potential transitional barriers (L. Ammakiw et al., 2014).

Dedicated containers, equipment, temporary storage areas, and tracking systems are required to facilitate waste segregation in different departments. A multidisciplinary assessment determined these prerequisites in the laboratory department. Packaging and container

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requirements are specified in the instruction documentation accompanying national waste codes. Training curricula on waste segregation protocols were developed and integrated into the continuing professional development framework. They are organized asynchronously via an e-learning platform at the training phase and are subsequently revisited during other precisional subject events to comply with the institutional competency-based training policy.

Ongoing monitoring is incorporated in the professional development program through audits to verify the correct execution of waste segregation protocols. Periodical supervisory evaluations assess individual adherence to the defined work procedures.

### 7.1. Policy Development and Stakeholder Engagement

Healthcare facilities generate many types of waste, some of which can create significant health and environmental risks if improperly managed. Nevertheless, hazardous waste often remains poorly segregated and mischaracterized, preventing full regulatory compliance, wasting disposal resources, and creating secondary hazards. Stakeholder engagement is essential for developing compliant waste segregation policies with financial, legal, and liability consequences.

Applicable international and national regulations, as well as hospital requirements, must be considered during policy drafting. Laboratory, imaging, and pharmacy departments generate large volumes of hazardous waste and produce long serviceable waste streams and multidisciplinary buy-in is critical to influence attitudes and practices (Derrick. Gabela, 2007).

### 7.2. Infrastructure and Equipment Requirements

Providing dedicated containers for the segregation of waste supports effective implementation of waste segregation protocols. Waste-stream-specific containers are required to encourage correct segregation, highlighting the importance of dedicated receptacles. A whiteboard tracking system is used to assess compliance with protocols (Otieno Odhiambo et al., 2021).

### 7.3. Training, Competency, and Monitoring

The attainment of desired competencies in waste-burning processes must be verified continuously, and the commitment of the personnel to proper waste management must be regularly monitored. The training interventions remaining useful and appropriate during monitoring observations have been included in Appendix 2. Systematic observations on a bi-monthly basis on two contrasting process combinations: laboratory and imaging, and pharmacy enable to capture both areas with the minimum resource input. The process of waste-burning within University Hospital is assessed as consistently adequate across sites through the actual observations performed. Only the awareness of waste-burning procedures

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improved in pharmacy after the intervention, nevertheless it is noted that importance of waste management remained exceeds compared to laboratory or imaging departments (Hosny et al., 2018). The understanding of waste segregation increased on another hand, though none of the training topics have influenced this.

Departmental personnel retained interest in proper waste management and segregation (L. Ammakiw et al., 2014). It remains essential to keep waste-burning processes on the agenda and to investigate purposeful institutional training topics to amplify influence on waste-sharing behaviour subsequently. Additional training intervention on waste management for pharmacy, laboratory and imaging still is being absorbed to tailored content rather than a standard input, as the direct knowledge on waste process itself is approximately at the sufficient level following the previous exercise.

## 8. Compliance, Auditing, and Risk Management

Effective waste segregation practices are required to comply with local, regional, and national regulations affecting the segregation and disposal of hazardous materials from various healthcare processes (L. Ammakiw et al., 2014). An effective auditing programme is essential to ensure that waste streams are correctly identified and tracked in compliance with regional and national regulations. Internal audits should be initiated on a regular basis, covering all departments involved, and performance against department-specific key performance indicators reported to key stakeholders to ensure that expected operational and regulatory targets are met. A robust incident reporting system is a key requirement to ensure that all waste management incidents are identified, reported, and addressed in a timely manner. Incidents are to be investigated to determine the root cause, and corrective and preventive action plans developed and implemented to mitigate future occurrences.

Establishing a system for awarding a certification of compliance across departments on a periodic basis creates a strong incentive for departments and personnel to remain aware of compliance-related issues and maintenance of hazardous material tracking and reporting.

### 8.1. Regulatory Compliance and Standards

Regulatory requirements, standards, and accreditation criteria are an important consideration to be addressed in the context of effective waste segregation in any health-care facility. National regulations at the level of Labour and Environmental Protection, together with European Commission Directives on the handling of healthcare waste, lay down the groundwork for appropriate pharmaceutical waste management, while the National Ministry for Health guidelines regulating healthcare implications impose waste segregation across the Hospital system in compliance with the Health-care Waste Management Code. Additionally, the management of cytotoxic and hazardous drugs is enforced by a chapter from the Pharmacopoeia on their disposal.

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Hospital accreditation by national and international bodies often includes waste segregation in the effort to reduce the potential negative environmental impact of the services provided. Reduced attention to waste segregation in their internal regulation may even lead to the failure of National Commission audits. For example, during the 2021 Self-Assessment of the Philippines according to the Antimicrobial Resistance Benchmarks, the lack of appropriate disposal of medicine wastes was recognized as a notable gap and one of the few "next-step" areas. International agencies, such as the World Bank, support and encourage attention to waste management, in particular, to the failure to segregate properly, with potential service-recovery options.

### 8.2. Auditing Frameworks and Performance Metrics

Auditing allows the institution to assess waste segregation practices against articulated goals and to document progress toward those objectives. The audit framework defines a set of key performance indicators (KPIs) that correlate with policy directives for waste segregation, together with a procedure for collecting quantitative and qualitative data against those performance measures. Auditing findings are regularly compiled into reports that communicate waste segregation performance to clinical and management stakeholders.

Waste segregation is analyzed through quantitative KPIs that characterize the type and quantity of waste generated. These KPIs include the mass of hazardous waste per laboratory and per laboratory FTE, as well as the proportion of attrition waste versus experimental waste. While the relative proportion of attrition waste versus experimental waste is an informative KPI for disciplines where both streams exist, it will not be universally applicable. Consequently, it is necessary to define lightweight alternatives for those disciplines unable to report on qualitative waste generation.

Inspection checklists serve as a qualitative audit tool to evaluate whether individual laboratory areas have implemented key work practices associated with waste diversion. The selection of relevant questions for the checklist draws on an understanding of national regulation regarding hazardous and biological waste types and disposal procedures. A systematic review of laboratory-specific procedures identifies anticipated gaps in compliance that the questionnaire can target effectively. Scoring frameworks classify responses according to degrees of conformance with accepted best practices rather than simple binary compliance. This permits performance benchmarking against current safety standards and encourages continuous improvement beyond bare regulatory adherence.

Even minimal waste segregation programs still require substantial resources for infrastructure, training, and monitoring. Auditing therefore assists in justifying requests for continued or additional support by documenting the impact of such programs along several dimensions. Quantitative waste metrics address institutional interest in waste generation rates,

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compatibility with sustainability initiatives, and internal cost-reduction goals. The advantage of selecting waste segregation as the initial focus for a laboratory safety program is that existing scientific expertise enables a priori estimation of these parameters without a formal data-gathering phase. Nevertheless, subsequent engagement with additional waste streams should be planned, and accompanying quantitative and qualitative metrics should be developed in parallel.

### 8.3. Incident Reporting and Corrective Actions

An incident reporting mechanism allows for the internal capture and documentation of guideline breaches and aberrations. Registered incidents then undergo a structured investigation that identifies the underlying root cause(s) and determines appropriate corrective actions. An incident log forms part of the departmental legislative compliance records.

An incident can be generated from various sources, including information from corresponding assurance frameworks, audit reports, and self-assessment. The reporting tool records the date, time, site, department, incident type, assurance framework, assessment methodology, outcome, and responsible party. A designated officer is tasked with monitoring incident levels and consequently tailoring communication and training interventions to relevant areas. Occurrences reported via the database are followed up directly by the responsible official, allowing for consistent tracking of issues and actions.

Periodic reviews combine captured incidents to assess repeat occurrences or high-impact issues; examination of reported incidents seeks to identify any trends by department, analysis method, or assurance mechanism (G. Garcia Alcántara et al., 2018).

## 9. Challenges and Best Practices

Waste segregation protocols across laboratory, imaging, and pharmacy departments encounter various challenges. These range from behavioral and cultural factors, such as clinician engagement, habit formation, and change management, to resource allocation and sustainability issues relating to budgeting, prioritization, and lifecycle planning. A third challenge involves the development of integrated waste management systems that promote cross-department collaboration, shared services, and continuous improvement.

Behavioral and cultural factors pose significant challenges to effective waste segregation protocols across departments. Clinicians are frequently engaged about policies that may conflict with established habits, and health warnings must be elevated within a structured change management context (Nassour et al., 2024). Clinicians tend to be less attentive than nonclinical staff because they do not participate directly in waste-generating scenarios. In laboratory departments, only 16% report being active users of the waste segregation policy,

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reinforcing the need for systems to promote compliance by influencing the attitudes of those who care about waste protocols.

Resource allocation and sustainability issues also affect the implementation of waste segregation protocols. Budgets for waste segregation are often limited, and existing equipment and services frequently require substantial replacement, making prioritization difficult. A deployment lifecycle approach that weighs the operational obligations of systems with noncritical budgets can support proactive planning (Louis Williams, 2013).

Integrated waste management systems that allow analysis of common interventions across multiple departments have shown benefits across numerous hospitals. Broader cross-department brainstorming, capture of successful methods for widespread adoption, and shared implementation resources for low- and non-priority early adoption can similarly be effective (L. Ammakiw et al., 2014).

### 9.1. Behavioral and cultural Factors

Communication of change is often overlooked in organizations and is addressed only as a consequence to the initial communication of the change itself. Awareness, education and knowledge help move the individuals to understand and comply with the actions being requested (L. Ammakiw et al., 2014). Communication is more effective when the principles of customizing the feedback, two-way dialogue and putting the program into the perspective of the individual and organization address awareness and understanding (Chezian Sengodan, 2014).

### 9.2. Resource Allocation and Sustainability

Effective waste segregation systems require extensive planning, resource allocation, and personnel training. Implementing them in laboratory, imaging, and pharmacy departments introduces unique challenges that must be addressed for successful uptake and long-term sustainability.

The program requires a dedicated budget for policy drafting and consultation with a multidisciplinary team. The effort necessitates planning, stakeholder engagement, and implementation across the participating departments; budgets must therefore be allocated, invoicing procedures established, and expense tracking undertaken. Nevertheless, specific funding for waste segregation has not yet been prioritized.

Supporting infrastructure and supplies include waste containers, collection bins, tracking databases, discipline-specific training programs, and supporting materials. Developing a comprehensive strategy that describes existing practices, future objectives, required actions, and associated resources can assist managers in presenting the business case to senior leaders and regulators and obtaining support during the long implementation process.

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Lab systems generating hazardous or biohazardous waste and imaging systems producing hazardous materials or consumables require greater attention than pharmacy systems to ensure department-wide policy adherence. A strategy for the complete lifecycle of the program—from initial inception to comprehensive implementation—encourages prospective stakeholders to consider the life-cycle and phase-out planning measures that may be necessary to sustain momentum and support. (Chezian Sengodan, 2014)

### 9.3. Integrated Waste Management Systems

Integrated Waste Management Systems comprise well-structured processes that involve appropriate planning, co-ordination, and monitoring. As an integral part of the waste management process, segregation of waste in health care facilities is a critical step in any waste management protocol. All the wastes produced in health care institutions come under three categories: hazardous waste, infectious waste and non-infectious waste. Implementing a waste segregation protocol will assist in the safe disposal of all types of waste that are generated daily. Effective waste management consumes time and effort during planning and it becomes feasible only when waste is segregated at the source. The following procedures help in the implementation of waste segregation. Even after segregation at the point of generation, it is essential to use waste management systems that prevent chances of contamination of the collected waste material since both hazardous and non-hazardous waste are handled. The implementation of the waste segregation system ensures minimum input, maximum output and if efficiently carried out, reduces the chances for human and environmental hazards (Derrick. Gabela, 2007). Addressing hazardous waste through a Health Care Waste Management System brings down the risk to employees, patients and the urban public. Influence by supervisory staff and coworkers are significant improvement motivators amongst waste collectors and personal protective measures is to be adopted at sink areas. The waste segregation system ensures maximum safety for laboratory personnel dealing with cell lines and hazardous chemicals.

## 10. Conclusion

Healthcare waste management and segregation of hazardous waste are among the most pressing health and environmental issues facing Kenya and the world today. This paper outlines the processes and procedures involved in the implementation of waste segregation protocols across the laboratory, imaging, and pharmacy departments of Kenyatta University Teaching, Referral & Research Hospital (KUTRRH). Health hazards associated with inappropriate waste disposal can cause infections, vector-borne illnesses, and poisoning. Waste segregation is intended to reduce such hazards by limiting the volume of hazardous waste destined for disposal and by minimizing worker exposure to hazardous waste through training and restricted access (Louis Williams, 2013). The top-level objective of KUTRRH is to establish conditions for accreditation by the African Pool of Assessors for the ISO

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15189:2012 international standard for medical laboratories, which takes into consideration the proper management of healthcare waste (L. Ammakiw et al., 2014).

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