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Medical waste management practices in Rural Liberia: Cross-sectional study of hospital personnel

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Abstract
Introduction: Medical waste management is a global and public concern with increased risk of injuries and transmission of diseases. The study described medical waste management practices among hospital personnel across the various hospital units and developed and present a plan of action. Method: A cross-sectional survey design was utilized to collect data from convenient sample of hospital personnel who worked at a government referral between December 2023 to January 2024. Results**:** A small portion (22.2%, n=10) of hospital personnel are trained in medical waste management. About 42% of hospital personnel segregated medical waste at the point of care into colored-coded containers based on waste categories. of hospital units (Antenatal Clinic and operating theater) segregate medical waste according to regulatory guidelines. Inactive and non-supportive training of hospital personnel in medical waste management, inadequate allocation, and availability of resources at all levels of care increases the risk of injuries and infectious disease transmission. Conclusion: Developing and implementing a medical waste management plan of action is an effective measure for preventing adverse effects at all levels of healthcare delivery.

Keywords: Medical waste, Waste management, Health risk, Hazardous waste

Introduction

Healthcare facilities are high-risk workplaces and medical waste generated, poses varying degrees of risk for patients, hospital personnel, visitors, and the environment. Improper medical waste management at the global level has resulted in 16,000 Hepatitis C Virus (HCV) infections, 66,000 Hepatitis B Virus (HBV) infections, and approximately 1,000 human immunodeficiency viruses (WHO 2018). As the population in many countries increases, health systems are compelled to expand healthcare facilities and health services subsequently increasing the generation of medical waste, thus adding to the roles and responsibilities of healthcare professionals in preventing adverse health and environmental problems (Ashtari *et al*. 2020) [8]. Additionally, medical waste pollutes the air, water, and land of the internal and external environment of the health facilities (Ghali *et al*. 2023) [17].

The waste generated from healthcare services globally is categorized as non-hazardous 85% and 15% of hazardous waste may lead to sharps-inflicted injuries, toxic exposure, chemical burns, air pollution, thermal injuries, or disease transmission (WHO, 2018). The World Health Organization indicated that hazardous waste produced per hospital bed per day is 0.5kg in developed countries and hazardous wastes produced per hospital bed per day is 0.2ky in developing countries. High-income countries generate an average of up to 0.5 kg of hazardous waste per hospital bed per day while low-income countries generate an average of 0.2 kg. Medical wastes are generated from patients' diagnostic procedures, treatment, immunization, and biomedical research. Medical waste could be contaminated by blood, bodily fluids, or other potentially infectious elements (WHO 2023, Janik-Karpinska *et al*. 2023) [21].

World Health Organization also projected that health risks of 30%, 1.8%, and 0.3% are eminent for people becoming infected with HBV, HCV, and HIV respectively for anyone who experiences one needle stick injury from the needle used on an infected patient. These types of waste have the potential to increase the risk for the transmission of the immunodeficiency virus (HIV), hepatitis B and C viruses (HBV/HCV), tuberculosis (TB), diphtheria, malaria, syphilis, brucellosis, and other transmissions if proper safety measures are not followed (Janik-Karpinska *et al*. 2023 [21], Bansod & Deshmukh 2023) [9]. The study found proper segregation of non-hazardous from hazardous waste in developed countries (Slutzman *et al*. 2023) [40]. Developing countries are resource-constrained and sanitation staff work with limited protective gear or vaccinations, increasing risk to healthcare workers and the environment. (Ali *et al*. 2017 [5], Mol *et al*. 2022) [29]. Many hospitals inappropriately handled healthcare waste with limited segregation methods, labeling of waste management containers and bags, and unsafe transportation, packaging, and storage (Thakur & Sharma 2021) [41]. Study found 3.6 kg of waste generated per bed per day with significant correlation between total waste and infectious waste in the hospital (Alighardashi *et al*. 2024) [7].

Injuries and the transmission of diseases during healthcare waste handling are caused by poor infrastructure, a lack of knowledge and training, a lack of regulatory enforcement, a lack of financial resources, limited involvement of the informal sector, a lack of treatment technologies, and improper waste segregation and packaging (Ferronato & Torretta 2019 [6], Olaniyi *et al*. 2021) [33]. The process of medical waste management includes segregation of waste in colored coded containers at the site of generation, pre-treat of highly infectious waste, transportation of segregated waste to the authorized central storage area, and treatment and disposal of medical waste within 48 hours (Bansod & Deshmukh 2023) [9].

Studies found that managing healthcare waste using incinerators, poses health problems from exposure to pollutants produced by incinerators, especially in developing countries (Cooka *et al*. 2023 [12], Ghali *et al*. 2023) [17]. Medical waste treatment with chemicals may result in chemical pollution of the environment if

appropriate environmental precautions are not considered (WHO 2018). Medical waste disposal in a landfill leads to the transmission of infectious agents and chemical contamination of the soil and groundwater (Janik-Karpinska *et al*. 2023) [21]. However, in studies conducted among healthcare workers in medical waste management practice, Akkajit *et al*. 2020) [4] found that 85% of health workers had a positive attitude toward medical waste management. About 61.3% of the observed units/wards/departments correctly segregated the waste by the national guidelines and 64.6%) of respondents segregated waste in the available color-coded bin using the standard operating procedure, (Tope *et al*. 2018 [43], Ibrahim *et al*. 2023) [19]. Studies found that established waste management committees and collaboration with international partners fostered the development of effective medical waste guidelines (Tilahun *et al*. 2023 [42], Ezeudu *et al*. 2022) [15].

In the context of Liberia, the outbreak of Ebola Viral Disease in 2014 exposed Liberia's weak health system and drew stakeholders' attention to improper management of medical waste (Nyenswah *et al*. 2022) [31]. An increase in health services delivery increases the generation of medical waste that exceeds the health facility's capacity for medical waste management. Health services for patients affected with infectious diseases such as HIV/AIDS, tuberculosis, measles, malaria, viral hepatitis, and Lassa fever among others account for 68% of the country's disease burden. Diagnostic testing, treatment, and vaccine-preventable disease programs at healthcare facilities to manage these diseases generate hazardous medical waste (MOH 2023, WHO 2022, WHO 2023). Infectious diseases overwhelm the health system, pose serious challenges for medical waste management at every point of healthcare delivery, and the risk of exposure to hospital personnel, patients, and the environment (Fall 2019) [16]. Kaposi *et al*. (2024) [22] found strong correlation between hazardous waste and association of infection. Improper management of hazardous medical waste is a source of disease transmission and the spread of drug-resistant microorganisms among hospital personnel and the general public (WHO 2023). Several counties in Liberia reported problems with medical waste management with approximately 70% of incinerators not functional (MOH 2022). Increased improper waste management within hospitals and healthcare facilities, as well as improper transportation and storage of medical waste, are the results of underfunded healthcare systems, insufficient training, and a lack of awareness of policies and laws on handling medical waste (Chisholm *et al*. 2021 [11], WHO 2022).

In 2021, the Liberia Ministry of Health (MOH) revised the national healthcare waste management plan which identified key challenges in the storage and collection of medical waste, no limit on the amount of healthcare waste package in bags, and many healthcare facilities lack guidelines for healthcare waste management which increases the problems with healthcare waste segregation and transportation (IFISH 2021). Studies found insufficient guidelines for medical waste management in Liberia, and medical waste contaminated with HIV/AIDS and other communicable diseases like tuberculosis, and hepatitis have serious ramifications for those working in the healthcare facilities as well as potential spillover effects on their families and the environment (IFISH 2021, David *et al*. 2016) [14]. Inappropriate healthcare waste guidelines pose challenges to the waste generated at healthcare facilities (David *et al*. 2016) [14]. The Liberian Code of Laws and Revised Public Health Laws in 2017 have no provision for healthcare or medical management regulations, instead, the focus is on domestic and industrial waste. Despite Chapter 47 (Healthcare Wastes) being included, the chapter contains a few paragraphs with limited content descriptions, implementations, and no regulatory framework for monitoring, evaluating, and ensuring compliance with public health laws. According to IFISH (2021), the guidelines have yet to be formulated into laws and actions as implemented by other countries (IFISH 2021).

Despite the established evidence from several studies, little priority attention is given to medical waste management practices and the risk to healthcare workers in Liberia. Medical waste management remains a major public health concern. More importantly, mixing medical waste with domestic waste, a risk for transmission of drug-resistant organisms to healthcare workers, patients, and visitors to healthcare facilities. Therefore, describing medical waste management practices provides valuable insights to determine if healthcare personnel, especially in rural Liberia, are employing medical waste management best practices to prevent disease transmission. This study aims to describe medical waste management practices among hospital personnel across the various hospital units to develop and present a plan of action.

The study utilized the Theory of Planned Behavior (Ajzen 2005) [2], an extension of the Theory of Reasoned Action (Ajzen & Fishbein 1980) [3]. The theory assumes that people behave rationally by their attitudes, arbitrary standards, and apparent behavioral control. The theory has been utilized in many studies for decision-making behaviors such as contraceptive choice, condom use, and preventive health screening as well as in developing health-promoting interventions (Flanagan & Beck 2024) [34]. The theory TPB was applied under the assumption that adherence to proper medical waste management practices (behavior) can be enhanced by increasing awareness, education, and continuous training of hospital personnel to increase control over disease prevention and injury.

Material and Methods

Design

This study utilized a cross-sectional survey design. A survey design was selected due to difficulty accessing rural healthcare facilities and health workers in the region, especially during the rainy season in Liberia. The design was chosen to construct quantitative descriptors that reflect the population's attitudes, behaviors, opinions, and beliefs that may be difficult to observe directly in the larger population of health professionals (Leavy 2023) [32].

Study Setting

The study setting is one of the hospitals located on the north-central coast of Liberia. The hospital is a public facility with its budget supplemented by the United States Agency for International Development, an international non-governmental organization. The reason for the selection was its rehabilitation process after a fire destroyed some parts of its infrastructures and exclusion from a main urban, sub-urban, and partly rural assessment conducted by MOH in other healthcare facilities. Additionally, High medical waste generation and potential risk for contamination were the basics for selecting the healthcare facility. The study

setting operates under the leadership of a medical director with oversight leadership of the County Health Officer, both are medical doctors.

Sampling

The population includes hospital personnel who work at the public referral and teaching hospital. Convenient sampling also provides an easy way of gathering data (Flanagan & Beck 2024) [34]. The sample included clinical (medical doctors, midwives, nurses, public health technicians, laboratory technicians, and infection, prevention, and control workers) staff who generate and manage medical waste at the point of patient care and non-clinical staff who collect, transport, and dispose waste at the health facility. Utilizing convenient sampling, 49 hospital personnel who work at the hospital were recruited from the Medical and Surgical, Pediatric, Obstetrics and Gynecology, Operating room, Emergency-unit, Outpatient department, Laboratory, and infection, prevention, and control units but 45 completed the survey. Although probability sampling provides generalizable findings, nonprobability sampling provides useful information (Creswell & Creswell 2023) [13] on hospital personnel's perspectives on medical waste management practices. Participants were selected conveniently based on their availability and accessibility compared to using a predetermined, objective, or consistent process (Creswell & Creswell 2023) [13]. Convenient sampling is appropriate for hospital personnel study because they are often busy, and problematic to recruit based on the study context. However, with the help of research assistants, hospital personnel were recruited from all the hospital units to ensure representation and professional diversities. Participants willing and able to participate were asked to provide their emails to the researcher and complete the survey. Potential participants utilized WhatsApp, a social media end-to-end encryption platform to provide their emails for participation.

Instrument and Data Collection

The study utilized a structured survey tool adapted from Sahiledengle (2019) [38]. The questionnaire contained 40 closed-ended questions with Cronbach's alpha reported scores between 0.791 and 0.835 (Sahiledengle 2019) [38]. The questionnaire was divided into five parts: sample demographics (part 1), hospital training and utilization of waste management practices (part 2), standard precautions (part 3), segregation of medical waste generated at the point of care (part 4), and segregation of waste by the person generating the waste (part 5). The questionnaire contained quantitative questions such as structured responses where participants chose from the options, a rating scale where they rated their responses, and a Yes/No structured response option. The online survey collects data quickly, minimizes the risk of human errors in data entry, and increases the response rate likelihood (Flanagan & Beck 2024) [34]. Medical waste management practices questions included segregation, and decontamination before disposal with the options of Yes/No for participants' responses. The questions asked on training ware, do you have any training in managing medical waste? Response options for this question included Yes/No. The questions on participants' attitudes towards medical waste practices included response options of agree, disagree, and neutral.

The demographic questions included What is your age? What is your gender? What is your unit of work? What is your Profession? What is your educational status? The question on age has a multiple-choice format that uses age ranges for each response. Gender questions were asked using two gender categories (Male/Female) for each response. Questions on participants' educational status include options for diplomas to various levels of degrees for each response. Questions on participant units of work included hospital units with the option to specify others for each response. Questions on profession included professional diversity categories with the option to specify others for each response.

The standards and guidelines of statistical surveys (2006) from the Federal Committee on Statistical Methodology emphasize that by pretesting rather than pilot testing the survey components, researchers can ensure that all survey components work as intended and that measurement error is managed. The questionnaire was reviewed by experts using the Response to Intervention (RTI) questionnaire appraisal System (QAS) before data collection. The QAS is useful for the researcher to identify question elements that are likely to lead to response errors, problematic questionnaire items, and the effectiveness and structure of the questionnaire (CDC, 2018; Ratnam *et al*. 2011) [36]. To this end, experts examined the questionnaire by considering specific categories of question characteristics in a stepped-wise manner and, at each step, decided whether the question(s) exhibited characteristics likely to cause problems. Experts review the questionnaire as self-sufficient and self-explanatory.

The measure was employed to reduce bias before data collection. The strategies to reduce the risk of bias include an expert review of the questionnaire, justifying clear inclusion and exclusion criteria with justification, using a valid and reliable measurement (Wang & Cheng 2020) [46]. After distributing the questionnaire to participants, reminder emails or phone calls to participants were utilized to address concerns or questions on the survey to reduce non-response bias. Nonresponse bias is a type of selection bias that is common in mailed or online questionnaires and cross-sectional surveys. Along with the primary data collected from the survey, secondary data were collected in the form of an IPC manual, published articles, and literature to support the survey results.

Data Analysis

A spreadsheet was created using Google Sheets. The data on Google Sheets were downloaded into Excel and exported to SPSS version 25 for analysis. Three processes were utilized to analyze the survey data. First, the research questions were reviewed to ensure proper alignment with the research purpose. The survey questions that best address the research questions were targeted. Second, cross-tabulation was used to quantitatively analyze the relationship between multiple variables in tables and figures, to draw meaningful conclusions from the research (Creswell & Creswell 2023) [13]. The cross-tabulation helped to visualize whether some hospital units were more likely than others to perform proper medical waste segregation. It also helped decide where to concentrate efforts when developing an action plan to enhance the procedures for managing medical waste. Third, medical waste management practices, training, and hospital units were measured using Fisher's exact test.

Fisher's exact test was used to compute the (two-tailed) probability of obtaining a distribution of values in a contingency table, given the number of observations in each cell. Fisher's exact test is one of the precise tests, whereas the chi-squared test depends on an approximation. Fisher's exact test is used for smaller sample sizes <50, especially when more than 20% of cells in a contingency table have expected frequencies less than 5, as the approximation approach is not sufficient in these cases (Creswell & Creswell 2023 [13], Fernández-Cásseres & Russi-Pulgar 2023) [18]. Fisher's exact test was used to examine the association between hospital personnel training and medical waste practices and medical waste practices across hospital units.

Data were analyzed using Fisher's exact test at a significance level, of 0.05(95%) confidence interval) with the help of SPSS version 25. Fisher's Exact test was used to establish whether there was a significant association between hospital personnel training and medical waste practices and differences in medical waste practices across hospital units. Demographics offered particular details on participants' attributes, such as their age, gender, professional diversities, educational background, and work units within the hospital. Researchers are at risk of adopting the belief that the phenomena of interest are the same regardless of the study conditions if sample demographics are not included (Borgstede & Scholz 2021) [23]. As a result, focus has been placed on presenting this study's findings while highlighting the demographic characteristics of the research participants. The hospital units include Medical/Surgical, Pediatrics, Emergency, Out-participants, Laboratory, Operating Theater, Obstetrics/Gynecology, Anti-natal, Infection, Prevention, and Control units. Nurses, midwives, laboratory technicians, Physician Assistants, waste handlers, and public health officers who worked at the hospital are among the diversity of health professionals. Training of participants in medical waste management which included segregation at the point of generation and decontamination before disposal was analyzed on a Yes/No basis. Questions on medical waste management practices were analyzed on a Likert Scale. The data were organized into percentage distributions and interpreted in tables, and other numerical summaries using SPSS.

Ethical Consideration

Following the approval of the study by the Institution Review Board, a formal letter was emailed to the hospital for permission to conduct the study. A recruitment message was emailed to potential participants before data collection. The email included the expression of intention to participate providing information on the study objective, and opting out of the survey if they choose to do so. Ethical considerations to these issues avoided the possibility of confidentiality and privacy breaches (Lee *et al*. 2016) [24, 25].

The survey link was contained in the recruitment e-mail message. The questionnaire was linked using Google Forms, a survey administration software. The emails were based on participants' availability, accessibility, and voluntarism. The first page of the survey contained informed consent which required potential participants' acceptance or declined participation. Participants who agreed gained access to complete the survey. If declined, access to the questionnaire was denied. Only one response per participant was allowed without the possibility of taking the survey multiple times. Questions were listed as required to ensure data completeness.

Results

Medical waste management practices of hospital personnel were examined using an online survey. Data gathered through a structured questionnaire was examined using statistical tests, then interpreted, and presented in tables to yield relevant conclusions. Forty-five hospital personnel were conveniently sampled to participate in the study with a response rate of 90%.

Sample Characteristics

Participants' characteristics are shown in (Table 1). The majority of the respondents 44.4% (n=20) (SD=11.7) were between the ages of 37-47 years. The mean age was 42.3 with a minimum of 26 and a maximal of 59. Most of the respondents 62.2% (n=23) were males compared with females. Five of the participants did not respond to the gender question. Most of the participants worked in the antennal clinic at the hospital and waste department accounting for 26.7% (n=12) and 20% (n=9) respectively. Nurses accounted for 44.4% (n=20) while 20% (n=9) were public health officers. The least respondents were waste handlers 4.4% (n=2). The educational status of respondents shows 51% (n=22) had diplomas followed by 44.4% (n=20) 1st degrees.

Table 1: Participants Characteristics

Characteristic		**N**	**%**
Age in yrs.			
	26 - 36	17	37.8
	37 – 47	20	44.4
	49 – 59 (m=42.3; SD=11.7; Min=26; Max=59)	8	15.5
Gender	Male	23	62.2
	Female	17	37.8
Work Dept.			
	Med/Surg	1	2.2
	Peds	1	2.2
	OB/GYN	7	15.6
	OT	1	2.2
	ER	5	11.1
	OPD	6	13.3
	Lab	3	6.7
	ANC	12	26.7
	Waste	9	20.0
Hosp PERS			
	Nurse	20	44.4
	Midwives	8	17.8
	Waste handler	2	4.4
	Lab Techs	3	6.7
	Pas	3	6.7
	PHOs	9	20.0
Education			
	Diploma	22	48.9
	1st Degree	20	44.4
	2nd Degree	3	6.7

The results of Fisher's exact test (p = [0.05] (0.540) do not suggest (0.540) a significant association between [training] and [medical waste practices. Approximately 22% (n=10) of hospital personnel were trained in medical waste segregation and decontamination before disposal. Only 5 (33.3%) were trained in medical waste segregation into color-coded bins.

Table 2: Training* Medical Waste Management Practices

Category	Segregation		Decontam.		Disposal		*Total*	*p*
	Ct/Exp	%	Ct/Exp	%	Ct/Exp	%		
Trained	5(3.3)	33.3	2(2.4)	18.2	3(4.2)	15.8	10	
Untrained	10(11.7) 15	66.7	9(8.6) 11	81.8	16(14.8) 19	84.2	35 45	0.540

Approximately 6(33.3%) of hospital units, operating theaters, and anti-natal clinics segregated medical waste accordingly decontamination appropriately before disposal. Furthermore, the pediatrics, medical, and surgical units failed to segregate medical waste into categories according to the level of risk (0%). Only 22.2% of the ER properly segregated medical waste while 100% of hospital units used appropriate PPEs. Fisher's exact test (p = 0.758) shows no statistically significant difference between hospital units and medical waste practices. The table shows that the ANC unit and OT practice proper medical waste management compared to other hospital units.

Table 3: Hospital Units* Medical Waste Management

Hospital Units		Segre.		Decontam.		Decontam.	
		Ct/Exp	%	Ct/Exp	%	Ct/Exp	%
	Med/Surg	0(.4)	0	0(.2)	0	1(.4)	5.3
	Peds	0(.4)	0	1(.1)	12.5	0(.4)	0
	OB/GYN	3(2.8)	16.7	0(1.2)	12.5	3(3.0)	15.8
	OT	1(3.0)	5.5	1(1.2)	0	1(.4)	5.3
	ER	4(.2)	22.2	1(.4)	0	1(2.1)	5.3
	OPD	2(2.4)	11.1	2(1.1)	25	2(2.5)	10.5
	Lab	0(1.2)	0	1(.5)	12.5	2(1.3)	10.5
	ANC	5(4.8)	27.8	2(2.1)	25	5(5.1)	26.3
	Waste	3(2.8)	16.7	1(1.2)	12.5	4(3.8)	21
Total		18		8		19	0.758

Regarding attitudes toward medical waste segregation practices, 24(53.3%) disagreed that the person generating the waste should do waste segregation. Nearly 20(44.4%) of hospital personnel remained neutral on the color-coding system for waste segregation of the hazards associated with medical waste.

Discussion

Limited studies are carried out on medical waste management practices on waste segregation, decontamination before disposal, and hospital personnel training in Liberia (Ghali *et al*. 2023 [17], MOH 2022, WHO 2022). The increasing incidence of infectious diseases (MOH 2022, WHO 2022) and the growing need for medical waste treatment reported by this study require a more rapid response from the healthcare delivery system on medical waste management. The lack of medical waste segregation at the point of care increases the quantity of hazardous waste, thus requiring treating waste to reduce the risk of spreading diseases among hospital personnel and patients. As the healthcare system delivers care to the population in need, medical wastes are created with a growing need to treat and dispose of the waste safely. This study confirmed WHO (2018) exertion that medical waste generated at the point of care must be properly segregated and decontaminated before disposal using an autoclave, incinerator, or other safe and approved methods authorized by a health system.

Demographic Characteristics

This study used a convenient sample of 45 hospital personnel who participated. Participant demographic factors for medical waste management show that RNs made up the majority of responders. Nurses are employed in the hospital's surgical ward, pediatric ward, operating room, emergency room, and outpatient department, and occasionally work in the ANC or OB/GYN units. However, waste handlers, laboratory technicians, physician assistants, and public health officers accounted for a fraction of hospital personnel.

Most respondents showed a positive attitude towards never sorting through waste in the waste bin consistent with a study (Akkajit *et al*. 2020) [4] which shows the majority of hospital staff had a positive attitude towards avoiding sorting through medical waste bins. More than half of the respondents have a negative attitude towards medical waste segregation by the person generating the waste while more than three-quarters of respondents agreed that medical waste should be segregated at the point of care. The findings are at odds with studies (Akkajit *et al*. 2020 [4], Ezeudu *et al*. 2022) [15], where most participants had positive attitudes about medical waste management procedures in contrast to the findings of this study. However, this study found positive attitude was not generalized to all the questions on medical waste management but to participants' responses to each question item.

Hospital Personnel Training

The results of this study support those of other studies (Olaniy *et al*. 2021, Miamilioti & Michael 2023) which revealed inadequate training of hospital staff, improper waste segregation, and challenges with monitoring and evaluation. However, this study shows significant outcomes compared to findings from previous studies that training was associated with medical waste management practices. This study found no statistically significant association between hospital personnel training and medical waste management and no difference in medical waste management practices across hospital units. This study results affirmed (Singh *et al*. 2021, Wafula *et al*. 2019) [45], that training of the hospital staff impacted waste management as well as emphasizing continuous training, supervision, and resource appropriation. Singh *et al*. (2021) and Wafula *et al*. (2019) [45] found that training of hospital

staff was associated with medical waste management using pre-tests and post-tests. However, the current study found that the availability of medical waste management resources and continuous training are catalysts for applying knowledge acquired from training. Thus, adequate and continuous training is complemented by adequate resource appropriation and effective policy. It can be argued that infrequent training makes hospital personnel less effective in sustained medical waste management approaches. The approbation of the finding is contingent on the lack of continuous medical waste management education, training, and inappropriate resource allocation.

Although adequate and continuous education and training bridge gaps in medical waste management, applying knowledge acquired from education and training depends on variables such as effective policy implementation, policy implementation checks, appropriation of medical waste management resources, adequate funding, stakeholders' interest, and involvement. In applying the theory of planned behavior, adequate and continuous training is one of the drivers of proper medical waste management practices (behavior control). Limited trained hospital personnel in medical waste management revealed the failure of hospital personnel to identify and segregate waste into categories, and decontamination before disposal.

Medical Waste Management Practices Across Hospital Units

Compared to findings in some studies (Tope *et al*. 2018 [43], Ibrahim *et al*. 2023) [19] that showed the majority of the observed units/wards/departments correctly segregated the waste by the national guidelines, this study shows majority of respondents did not segregated waste in the available color-coded bin using the standard operating procedure. There were no statistically significant differences in medical waste management practices across hospital units. Nearly two-quarters of hospital units (ANC and OT) practice standard practice of medical waste management according to MOH guidelines. Even though medical waste management practices vary across hospital units, management implementation is difficult to enhance behavior control. To guarantee the safe handling of waste (behavior control) at the point of care, hospital personnel must utilize national medical waste management guidelines. Yet, the findings in this study show that most hospital personnel are unaware of national policies.

Developing a training program must consider all aspects of proper medical waste management, including segregation and management, infection prevention and control, and roles and responsibilities. Training in occupational health and safety should ensure hospital personnel are aware of and understand the potential risks associated with hospital waste, the importance of immunization against infectious diseases, and the significance of consistent use of personal protective equipment.

Segregation

Separating infectious waste from noninfectious waste is a crucial aspect of medical waste management, particularly at the point of care. Proper segregation is achieved by making use of standardized colored-coded containers to effectively separate infectious waste from general waste. To maintain such a system requires continuous training, appropriation of resources, monitoring, and evaluation. The significance of hospital waste segregation stems from the potential risk of disease agent transmission from the waste to patients and hospital staff. Yet, segregation of medical waste from the point of care remains a challenge among hospital personnel and in various hospital units. This study shows bridge in medical waste segregation in the hospital units is due to a lack of or limited colored-coded waste bins. Compared to Udayanga *et al*. (2023) [44], less than three-quarters of health workers utilized a colored-coding system for the segregation of waste at the point of care. Waste segregation facilitates the reduction of hazardous waste and the risk of hospital-acquired infection. The lack of or limited colored-coded bins in each unit revealed that nonhazardous and hazardous waste were mixed, thus increasing the likelihood of generating more hazardous waste. The finding demonstrated improper medical waste segregation into safety and colored-coded containers based on their associated risk, which remains a challenge across the hospital units. However, this study supports the usage of colored-coded bins in each hospital unit to separate waste based on associated risk. Mixing medical waste in a single container does not only increase the amount of hazardous waste generated but also increases the risk of infectious disease transmission among waste handlers. The mixing of most medical waste at the point of generation is due to limited resources. The study findings suggest argent action toward intensive, quarterly training of hospital personnel who work in the various hospital units in medical waste management, especially waste handlers. Similarly, separating waste generated in each hospital unit allows for the decontamination stage to begin.

Decontamination Before Disposal

Segregation of medical waste into categories at the point of care is the first step for proper medical waste management. Decontamination of segregated infectious waste plays a cardinal role in preventing hospital-acquired infections due to improper medical waste management. This study demonstrated that medical waste was not being decontaminated after segregation, and there were no further attempts to decontaminate the waste before disposal. Compared with another study (Udayanga *et al*. 2023) [44], medical waste decontamination wastes after segregation prevent disease transmission when removing waste from the hospital units. Segregation is not effective at the point of generation if segregated waste is not decontaminated before removal from the hospital units. Sharps used for parenteral injections and other invasive procedures were sometimes not segregated nor decontaminated across the hospital units, thus increasing the risk for injuries and infectious disease transmission among waste handlers.

Therefore, most hospital personnel and units are in bridges of proper medical waste management according to national guidelines. Creating awareness and information sharing about the risks of medical waste and best practices among all stakeholders including the hospitals, other healthcare facilities, and the general public is very important. Awareness and information sharing can also be enhanced by posting medical waste segregation and classification posters on each unit and directly over each colored-coded waste bin to help reduce the odds of improper waste management. The disposal of blood and body fluids is also a major public health concern. This study found that most respondents segregate infectious wastes such as blood, blood products

and other body fluids. Conversely, improper segregation of diagnostic laboratory waste also increases the risk of injury, such as chemical burns.

This study also found all hospital personnel used appropriate PPEs especially gloves and face masks during medical waste handling, an important precautionary measure to prevent hospital personnel from hospital-acquired infectious. Based on these findings, it is important to move beyond guidelines and develop a medical waste management plan of action. Compared to the guidelines, the plan of action is more useful because it helps give stakeholders the framework for thinking through effective medical waste management (Lee & Lee 2022).

Medical Waste Management Plan of Action

The medical waste management plan of action is a strategy designed for the hospital but can also be utilized by other healthcare facilities to address challenges and issues surrounding proper medical waste management. A well-prepared plan of action (Lee & Lee 2022) involving all stakeholders is effective in managing medical waste without decreasing the quality of medical services provided by healthcare workers. By implementing the strategies and recommendations outlined in the plan of action, healthcare facilities personnel can contribute to the reduction of medical waste exposure and promote sustainable proper medical waste management practices.

The goal of the medical waste management plan of action is to prevent adverse health outcomes associated with improper medical waste management practices. Similarly, the plan of action establishes a clear framework and pathways to improving medical waste management practices. Additionally, the plan of action seeks to enhance awareness, knowledge, and compliance of healthcare facilities personnel regarding proper medical waste management practices. Furthermore, the plan takes into account key stakeholders' involvement and responsibilities including hospital personnel, regulatory authorities, and policymakers.

Therefore, the key benefits of the medical waste plan of action are to 1) identify weaknesses in medical waste management processes for redress, 2) ensure medical waste management weaknesses are addressed properly, 3) identify stakeholders, and 4) allow for prioritization of waste management resources, policies, and compliance. Targeted stakeholders, including the MOH, hospital administration, Infection, Prevention, and Control (IPC) team, Best Practice Committee (BPC), medical waste workers, and healthcare professionals, must work together to make the plan of action a reality. These stakeholders can guarantee the allocation of resources and adopt more cooperative, successful medical waste management best practices.

Table 4: A plan of action for medical waste management best practices.

Task	Target/Measure	Timeline	Responsibilities
Raise awareness of the importance of a waste management plan of action	Put waste management posters on every hospital unit to ensure best practice	Continuous	MOH, hospital administration, IPC team and BPC
Make available medical waste equipment and supplies	Sustained distribution of medical waste equipment and supplies in each unit	Continuous	Hospital administration
Color-coded waste bins are placed in each hospital unit	Put waste into bin based on waste classification	Continuous	IPC team, BPC, hospital personnel
Training required	Training in medical waste classification, waste volume reduction, segregation, labeling waste bin/bags, collection, transportation, use of PPE and decontamination, storage, and disposal	Quarterly	The IPC team and BPC
Briefing required	Provide updates on progress and challenges	Weekly	IPC team, BPC, and waste handlers
Coordinate monitoring and evaluation	Use the MOH/NPI tool in collaboration with international standards	Continuous	Hospital administration, BPC, and IPC team
Review process and outcome	Conduct processes and outcome evaluation	Quarterly	Administration, IPC, BPC, and unit supervisors
Reduce medical waste generated	Revisit standards for providing healthcare services to patients	Quarterly	MOH, Hospital administration, and BPC
Immunization against infectious diseases	At-risk hospital personnel	Regularly	Administration, IPC, and BPC
Review and revise MWM strategy, policy, and compliance	Keep medical waste management plan of action current	Annually	MOH, NPHIL, Hospital administration, and Partners, with government support and commitment

Embedding medical waste management policy in Liberia's health strategy, implementing intensive awareness programs, waste management reduction initiatives, and monitoring and evaluation are essential for implementation at all levels of healthcare. A study found the implementation of awareness programs, comprehensive policies, waste reduction initiatives, and effective monitoring and evaluation, the healthcare facility can reduce their waste, and prevent the spread of diseases (Ali *et al*. 2020). Compared to Liberia, studies (Wafula *et al*. 2019 [45], Udayanga *et al*. 2023) [44] in other low-income countries acknowledged neglect of the issue and few studies have been done in this field. Therefore, it is important to address medical waste management practices at all levels of healthcare.

The plan of action specified indications, task analysis, and timelines to achieve the overall objective. The responsibilities of key stakeholders are clarified. Compositions of the BPC include hospital unit supervisors headed by a public health expert. At the same time, the IPC team consists of those who generate and handle medical waste. The infection prevention and Control team is responsible for reviewing medical waste management inventory, and ensuring resource availability and appropriation. On the other hand, the BPC is responsible for keeping the IPC team in check. The infection, Control, and

Prevention team and BPC have shared responsibilities to ensure implementation, compliance, and sustainability. The MOH, National Public Health Institute, hospital administration, and Partners are responsible for developing or reviewing medical waste management policies based on medical waste data. The collaborative efforts of stakeholders are to prevent infectious disease exposure and injury to patients, hospital personnel, visitors to the hospital, and waste handlers. However, clinical staff need to be fully aware of their critical role in effective medical waste management because they are at the forefront of sorting waste at the point of generation. Through these activities, healthcare facilities can reduce medical waste generation and prevent the spread of diseases. Therefore, a well-prepared plan of action involving all stakeholders is effective without decreasing the quality of medical services provided by healthcare workers (Lee & Lee 2022).

This study found that little over two-quarters of hospital personnel acknowledged the absence of medical waste management guidelines in the hospital units or ever utilized any guidelines. The presence of guidelines in hospital units is necessary for quick referrals during medical waste management implementations. However, guidelines without regular training of hospital personnel and inequitable distribution and appropriation of resources pose challenges to best practices. It is important to emphasize the need for continuous awareness and training outlined in the plan of action. These exertions are supported by Udayanga *et al*. 2023 [44] and Adu *et al*. 2020 [1] emphasizing adequate levels of awareness, training in medical waste management, and related hazards have direct impact on hospital employees' attitudes, behaviors, and monitoring. These are also supported by the TPB which posits that behavior is guided by perceived consequences of changing behavior (attitude), behavior control, and perceived expectations of others (subjective norm). Despite the MOH's requirements and expectations, the hospital has yet to develop a medical waste management plan of action but heavily relies on IPC guidelines based on adequate physical infrastructure.

Both new employee orientations and training sessions should cover policies and procedures for the proper classification, segregation, labeling, handling, decontamination, transportation, storage, and disposal of medical wastes. Procedures for managing medical waste, reducing or eliminating risks, and assessing the results should form part of the medical waste management training. Similarly, updated information on risk and control processes is crucial in the training sessions. The training materials are developed with input from the hospital unit supervisors, IPC team, hospital administration, and Best Practice committee. The Ministry of Health provides technical and financial support, despite the hospital administration overseeing and managing the medical waste management Plan of Action.

Similarly, medical waste guidelines should include information on reporting and handling occurrences and exposures to medical waste. These guidelines should be posted on each hospital unit. Hospital management obtains a monthly report on the outcomes of routine monitoring. Medical waste management must always be incorporated into the hospital management general planning. The hospital's infection control team, the County Health Team, and the Best Practice Committee collaboratively integrate Infection Control standards and performance evaluation into the guidelines.

Numerous challenges slow down medical waste management programs according to the human development index, life expectance, healthcare expenditure, and environmental performance index (Singh *et al*. 2021). However, every year, the Medical Waste Management Plan of Action's objectives, outcomes, and efficacy will be monitored for program efficacy and assessed for resource adequacy by the county health team, the best practice committee, and the hospital infection control team to ensure progress is sustained and monitoring continues. Any modifications are addressed at the yearly Medical Waste Management Plan of Action update, and any adjustments to the applications or interactions will be included in the revised Plan of Action.

The medical waste management plan of action is aligned with the secretariat of the Basel Convention and the World Health Organization (2004) which emphasizes the preparation of national healthcare waste management plans in Sub-Saharan Countries. These organizations clarified that a healthcare facility's waste management plan should integrate all aspects of managing waste, from avoidance and minimization, proper segregation and containment, safe handling, storage, and transport, to treatment and disposal. However, the findings of this study draw urgent attention to a preferred medical waste plan of action rather than a waste management plan. The plan of action provides a framework for addressing the issues arising from medical waste and improving the regulatory framework on medical waste management at the healthcare facility. Developing and implementing a medical waste plan of action to achieve the desired objective is based on sustaining medical waste management best practices.

Medical waste management measures are always evolving due to the desire to prevent risks of exposure, increase sustainability, and boost efficiency. Apart from the plan of action for managing medical waste, this study highlights the importance of influencing the direction of waste management in the future. Future directions are required to maintain and broaden the knowledge about reducing exposure to medical waste. Health sector coordination, policy and implementation, adequate training, research, equity in funding, and regular distribution of medical waste management resources increase the drivers of sustainability and prevent the adverse consequences of medical waste. Due to limited medical waste management research in Liberia, research supported by MOH and other stakeholders has the potential to push data quality of medical waste management to identify, analyze the problem, and develop or modify policies. Studies found that policies on medical waste management and implementation ensure compliance with minimal exposure in the hospital environment (Akkajit *et al*. 2020 [4], Janik-Karpinska *et al*. 2023) [21]. Despite challenges to implementing policy, it is important to emphasize the importance of stakeholder coordination to ensure equity distribution of medical waste management resources and implementation checks. Sustainability of medical waste best practices eliminates the risk of hospital-acquired infections due to improper medical waste management practices.

Strengths and Limitations

The study facilitates understanding of the reason for improper medical waste management practice, contributes to the knowledge gap on medical waste practices, and

provides useful information to hospital personnel, policymakers, patients, and visitors to healthcare facilities. Similarly, the developed plan of action is useful in medical waste management program planning, implementation, and coordination among stakeholders to improve medical waste management practices geared toward sustainability. However, due to the inherent healthcare services provided at the hospital, the study was unable to define waste produced in other units of the hospital not directly involved at the point of care but could impact occupational health and safety. Additionally, the study focuses on waste generated at the point of care without considering, methods of waste transportation, disposal, and associated risks. It is difficult to generalize the findings to a larger population due to the small sample size and sampling method. Research on small samples has been associated with several challenges. However, the more stringent assumptions imposed on the population with a sample drawn from a normal probability distribution offer statistical validity (Indrayan & Mishra 2021 [20], Shafer 2024) [37]. There was little research on Liberia's medical waste management practices, thus limiting previous research to this study. Determining the sample size using non-probability sampling does not accurately represent the overall population or relevant group. As a result, non-probability sampling limited generalization. However, the findings can be utilized to conduct further research on medical waste management practices in the area of interest.

Implications for Practice

This study has several implications. Healthcare facilities can be well advised to invest resources in improving internal medical waste management practices at all levels of care and prioritizing budgetary allocations in managing medical waste based on data. Use of proper medical waste management best practices informed by data and policy that ensures control of the spread of nosocomial infections. Continuous and effective training in hospital medical waste management competence and monitoring is needed for compliance.

Future Research

The findings informed several recommendations for future research. There is a need to explore factors influencing hospital personnel's nonadherence to proper medical waste management practices. These factors can be addressed and utilized as determinants to develop a broader medical waste management program. Conducting further research to determine risks and effects of exposure that would set the stage for impartments in medical waste management such as converting medical waste to energy. Although this study focused on hospital-based medical waste management, there is also a need to conduct studies on household medical waste management, considering the direct impact on the communities. Additionally, researchers can utilize the data to expand their research in their area of interest in medical waste management.

Conclusion

The study produced valuable information regarding hospital medical waste management that can be applied to preventing diseases and injuries caused by exposure to hazardous hospital waste inside the environment. Hospital personnel can succeed in growing public health concerns for safe occupational and environmental health by taking a proactive approach to medical waste management. The medical waste management plan of action can be an effective and efficient compliance-related practice in healthcare settings if it is properly implemented, monitored, evaluated, and sustained. The findings informed policy, and compliance ensuring proper training and safety measures to protect hospital personnel, patients, visitors to the hospital, and the general public from the adverse effects of medical waste. In addition, hospital personnel and hospital units must utilize resources appropriately to employ proper medical waste management to prevent nosocomial infection, especially at the point of generation and handling.

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