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"Assessment of Infectious Healthcare Waste Disposal Practices Across Different Wards of Public and Private Hospitals: A Questionnaire-Based Cross-Sectional Study"

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Abstract

Background: Infectious waste was recognized as a significant hazard in healthcare settings due to its potential to spread diseases among staff, patients, and the public. Managing this waste properly was essential to prevent infections and maintain hospital safety standards. The study focused on understanding existing waste management practices and identifying gaps to improve health outcomes.
Objectives: This research aimed to assess infectious waste disposal practices in public and private hospitals, evaluate staff awareness and training, and recommend strategies for safer waste management.
Methods: A cross-sectional study design was employed, surveying healthcare staff across multiple wards in both public and private hospitals. Collected data was comprised of staff roles, waste segregation practices, storage and transport methods, treatment techniques, awareness of guidelines, and training frequency. Statistical analysis was performed using SPSS 20 to evaluate practices and associated challenges across different healthcare settings

among respective wards.
Results: Among 206 respondents, (66.5%) were nurses, (23.3%) doctors, (5.3%) department heads, and (4.9%) pharmacists. Color-coded segregation was reported by (90.8%), with only (72.8%) confirming proper labeling of bins. Nurses led initial segregation (43.7%), while cleaning staff accounted for (37.4%). Reported daily waste generation was (51.9%) in the 50–100 kg range, (34.5%) below 50 kg, (7.3%) between 100–200 kg, and (6.3%) above 200 kg. Storage in special rooms was noted by (80.1%). Treatment methods included chemical disinfection (83.0%), off-site incineration (80.1%), autoclaving (77.7%), and on-site incineration (58.7%). Training frequency varied, with (43.7%) receiving quarterly and (43.2%) monthly sessions. Awareness of WHO color-coded segregation guidelines was high at (93.2%), but (58.7%) reported encountering mixed waste categories as a major challenge.
Conclusion: The study concluded that while awareness of guidelines regarding hospital waste management was generally high, practical execution varied between hospital types. Nurses played a central role in segregation, storage, and disposal, but challenges such as improper labeling, inconsistent training, and mixed waste remained. These findings highlighted the need for better staff training, stricter labeling practices, improved infrastructure, and enforcement of standardized protocols to ensure safe and effective infectious waste management.

Introduction

Hospital waste is a unique kind of waste that is produced in small amounts and has a high risk of infection and harm. Hospital waste management means using methods to prevent the transmission of infections through hospital waste. During patient diagnosis, vaccination, surgery, and treatment, hospitals generate infectious waste that can spread illnesses to hospital employees, attendants, and the general public [1].

Biological laboratory waste (such as cultures, stocks, and growth media), pathological waste (such as human tissue, organs, or bodily fluids), contaminated sharp objects (such as contaminated needles, syringes, and surgical blades), bodily fluids or secretions (such as blood, pleural fluid, semen, vaginal secretions, vomit, feces, or urine), and single-use disposable equipment, utensils, and instruments soiled with potentially infectious agents are all considered infectious waste. The size of the hospital, the number of patients, the number of beds available, the segregation procedures, and the type of care given to the patients all influence the rates at which infectious waste is generated [2, 3]. The increasing prevalence of diseases like AIDS, hepatitis B, and C raises the danger of infection for those handling infectious waste and poses a concern to public health during transportation. Hospitals are the primary source of infectious waste.

The burden of infectious diseases, particularly AIDS, Hep B, and C, which spread along the I/V pathway, can be significantly reduced by effective waste management. The three R's Reduce, Reuse, and Recycle are typically applied to create a sustainable waste disposal system. According to national and international guidelines, each hospital should create a customized health management strategy tailored to its own needs. It should be make sure that hazards that hospital waste poses to people and the environment are reduced as much as possible. A number of elements, including adequate planning, financing, administration, and policy-level commitment, are necessary for the effective management of health care waste. They can have positive effects on people and the environment if correctly applied [4, 5].

The type of hospital, its patient capacity, and the rates of inpatient and outpatient turnover are important factors that contribute to waste generation. Planning for waste management, transportation, satellite and central storage, medical waste treatment, and hospital waste disposal is made easier with the use of this waste generation rate data. Waste handler assembly, training, teaching, and instruction are key components of waste segregation at the source site. Hospital waste is generated during patient

treatment and diagnosis and comes from a variety of sources within the hospital's premises. Various hospitalized patient wards, clinics, blood banks, labs, childcare centers, and nursing stations are examples of actual main sources. Counseling centers, pharmacies, cafeterias, offices, businesses, and dispensaries are examples of minor sources. Knowing how much waste is produced is essential for proper disposal. The amount of medical waste produced is not solely determined by the hospital's size and office space. Numerous factors influence the rate of waste generation, such as:

Waste segregation should begin at the location where waste is generated, such as at a patient's bedside, an operating room, a research facility, a laboratory, etc. Understanding the kinds and volume of waste produced in healthcare facilities is essential since it is the first step towards safe disposal. Making sure that clinical waste is not combined with domestic or other municipal (civil) waste is crucial. In addition to raising the hazards for the waste handlers, this eventually raises healthcare expenses. The initial data collected on the supplied waste is helpful in determining the necessary capacity for disposal, transportation, bags, satellite and central storage places, and so on. Data from waste collection can be used to provide information on waste production across the hospital [6, 7].

Infectious waste disposal practices vary significantly across different wards of a hospital due to the nature of medical procedures and patient care activities conducted in each area. In surgical wards, a high volume of potentially hazardous waste is generated, including blood-soaked dressings, used surgical gloves, sharp instruments, and discarded surgical tools. Studies from tertiary hospitals in South Asia, including Pakistan, reveal that while color-coded waste bins are present, adherence to segregation protocols is inconsistent. Often, surgical waste is disposed of along with general waste due to negligence or lack of supervision, leading to increased risks of exposure to blood borne pathogens such as hepatitis B and C among healthcare workers [8].

The Intensive Care Units (ICU) and emergency wards produce an even higher proportion of critical infectious waste due to their involvement in high-risk, life-saving procedures. This includes waste such as used syringes, IV lines, suction canisters, and contaminated personal protective equipment (PPE). Because of the high patient turnover and urgency of care, staff often neglect proper disposal procedures. One study published in the Eastern Mediterranean Health Journal noted that 60–70% of waste in emergency departments was improperly segregated, leading to cross-contamination and environmental hazards. Emergency and ICU waste requires immediate and careful handling, yet many facilities lack protocols for swift collection and secure temporary storage, causing delays that can compromise both occupational and public health [9].

In contrast, general medical wards tend to generate a mix of non-infectious and mildly infectious waste. However, the lack of training among ward staff often leads to mixing of waste categories. Even routine items such as used cotton, gauze, or empty IV bottles are discarded without proper classification. As a result, the quantity of infectious waste reported from these wards is often overestimated, which burdens the waste management system and leads to inefficient resource allocation. Studies suggest that up to 40% of the waste in general wards classified as "infectious" could have been safely categorized as general waste if proper segregation had occurred [10].

The maternity and pediatric wards pose unique waste disposal challenges. Maternity wards produce biological waste like placentas, umbilical cords, and blood-soaked linens, which must be managed with heightened sensitivity. Meanwhile, pediatric wards generate sharps, disposable diapers, and vaccine-related waste. Due to cultural taboos and emotional sensitivity around childbirth-related waste, especially in developing countries, there is often resistance or reluctance among cleaning staff to handle such materials. Additionally, pediatric waste often includes a variety of plastics and mixed materials that are not adequately separated before disposal,

complicating treatment processes like incineration or autoclaving [11].

One of the major challenges in the disposal of infectious medical waste is improper segregation at the point of generation. Despite national and international guidelines recommending clear distinctions between general, infectious, and sharp waste, frontline healthcare workers often fail to follow these protocols. Research conducted in hospitals in South Asia indicated that 50% of infectious waste was improperly mixed with non-infectious materials due to a lack of awareness or insufficient availability of color-coded bins. This not only increases the volume of hazardous waste unnecessarily but also poses a serious risk to waste handlers who are not prepared to deal with high-risk materials [12].

Lack of awareness and training among healthcare personnel is another critical barrier. While doctors and nurses are somewhat informed about biohazard risks, ward attendants, janitorial staff, and waste handlers usually have little to no formal training on biomedical waste management. In many hospitals, these workers are not provided with personal protective equipment, and there is minimal supervision to ensure compliance with safe disposal practices. As a result, needle-stick injuries and exposure to infectious fluids are commonly reported among low-tier staff [13].

Finally, infrastructure issues remain a persistent problem. Many hospitals, especially in low- and middle-income countries, do not have functioning incinerators, autoclaves, or well-managed storage facilities for temporary holding of infectious waste. A field assessment by the World Health Organization in Pakistan highlighted that only 30% of surveyed hospitals had dedicated waste treatment units. In others, waste was stored in open, unguarded areas, often for hours or days, before being collected. Furthermore, transportation of waste from wards to disposal sites is often done manually, without trolleys or designated routes, exposing both workers and patients to infection risks. These systemic shortcomings undermine any training or policy in place, making proper waste disposal a major healthcare challenge [14].

Everyone who comes into contact with dangerous medical waste, whether they work in healthcare institutions, handle medical waste, or are exposed due to negligence, could be in danger. Physicians, nurses, healthcare support personnel, patients, and support service personnel, including laundry staff, waste management and transportation staff, and employees of waste-disposal facilities, are the primary risk groups. Globally, more than two million medical personnel are exposed to pathogens as a result of their daily work routines [15]. The health of hospital personnel, patient safety, and environmental preservation were directly influenced by the appropriate disposal of infectious waste. In many healthcare institutions, particularly in high-volume hospitals, the management of infectious waste was frequently overlooked due to excessive workload, inadequate training, and insufficient financial resources. Such neglect often resulted in serious consequences, including hospital-acquired infections, occupational hazards for medical staff, and the dissemination of pathogenic microorganisms into the community. To identify existing gaps and propose corrective measures, it was therefore essential to evaluate the prevailing disposal practices across various hospital wards.

The selection of this topic came from growing concerns regarding hospital waste management policies, particularly in the context of increasing patient loads and the rising complexity of medical procedures. Distinct wards such as emergency departments, maternity units, and surgical theaters produced varying types and quantities of infectious waste, each necessitating specific handling and management protocols. By examining these ward-level variations, we can better determine whether existing waste management policies were implemented uniformly or whether certain units were disproportionately vulnerable due to inadequate practices.

Such an assessment provided a basis for prioritizing interventions and optimizing resource allocation in the areas of greatest need.

Furthermore, this topic was chosen in recognition of the need for more context-

specific research that accurately reflected the realities of hospitals in regions such as Mirpur and comparable settings. While most international guidelines were formulated under ideal conditions, local challenges such as workforce shortages, inadequate infrastructure, and limited awareness required equal consideration. This research therefore sought to generate practical and contextually appropriate recommendations aimed at improving hospital hygiene, enhancing staff training, and raising patient care standards. Ultimately, the study contributed to strengthening infection control measures and promoting a safer healthcare environment.

The appropriate disposal of infectious waste constituted a critical component in maintaining a safe and healthy hospital environment. This study held significance as it aimed to enhance awareness among hospital administrators and healthcare staff regarding the prevailing waste disposal practices across different wards. Improper handling of infectious waste had been associated with numerous environmental hazards and hospital-acquired infections. Conversely, systematic and proper disposal greatly minimized the risk of nosocomial infections. By examining the processes of collection, segregation, transportation, and final disposal, the study was able to identify hazardous practices that might otherwise have gone unnoticed in routine hospital operations [16-18].

This study further enabled the identification of specific wards or units where waste management procedures were inadequate, thereby providing a basis for targeted interventions. The practical contribution of this research lay in its ability to generate evidence-based recommendations for strengthening waste management systems. These recommendations included improved staff training, the provision and appropriate use of color-coded waste bins, and the establishment of stricter monitoring techniques. The implementation of such measures not only safeguarded healthcare workers but also significantly reduced the risk of infection among patients and visitors. Moreover, the findings encouraged compliance with national environmental and healthcare regulations, which was vital for protecting institutional credibility and preventing regulatory penalties.

On a broader scale, the study fostered a culture of accountability and hygiene within the hospital environment. By increasing awareness and reinforcing effective waste management practices, hospitals were better positioned to maintain a safer, cleaner, and more efficient healthcare setting.

METHODOLOGY

Study Design

A descriptive cross-sectional study design was used.

Study Setting

The study was conducted in Emergency, ICU, Surgery, Maternity, and OPD in following public and private hospitals including Divisional Headquarters Teaching Hospitals, Mirpur, AJK, Ahsan Medical Complex, Mirpur, AJK, Riasat Hospital, Mirpur, AJK., Ladies & Children's Hospital, Mirpur, AJK, Javed Medical Complex, Mirpur, AJK, City Hospital, Mirpur, AJK, Al Seha Hospital, Mirpur, AJK.

Study Duration

The study was conducted from October 2024 to July 2025 covering both routine and emergency operational periods to ensure comprehensive assessment of waste disposal practices.

Study Population

The study population was comprised of healthcare workers such as doctors, nurses, department heads, chemists, janitorial staff, and waste management personnel directly or indirectly involved in waste management in the selected hospital wards.

Sampling Technique
A convenient sampling technique was used to recruit participants from different wards of selected public and private hospitals in District Mirpur, AJK. The hospitals and wards were selected based on accessibility and relevance to the study topic. This non-probability method was chosen due to time constraints and ease of access to healthcare staff during routine working hours.

Sample Size
Rao-soft sample size calculator was used to calculate sample size at 95% confidence interval and 5% margin of error for sample size 385, where N=206 participants, based on the actual number of healthcare workers who consented and participated in the study across the selected hospitals.

Data Collection Tool
A self-structured questionnaire was designed using variables from different pre-validated literature studies to gather information from healthcare staff [19].

Statistical Tools
Data were analyzed using SPSS version 20. Descriptive statistics was used to calculate frequency, percentage and cross tabulation of waste disposal practices. While Inferential statistics, such as Chi-square test was used to identify associations between hospital type, ward type, and adherence to waste management guidelines. A p-value < 0.05 was considered statistically significant.

Ethical Considerations
This study was conducted with the permission of the respective institute Akson College of Pharmacy Joint venture with Mirpur University of Science and Technology, Mirpur, AJK bearing reference number 598/04/EX/ACP/25. The permission from Executive Directors of aforementioned study settings was also taken prior to the conduction of the study.

RESULTS
The study was comprised of total 206 respondents, 137 (66.5%) were nurses, 48 (23.3%) were physicians, 11 (5.3%) were department heads, and 10 (4.9%) were chemists. Both private hospitals (123, 59.7%) and public hospitals (83, 40.3%) provided data. 87 (42.2%) hospitals had fewer than 100 beds, 62 (30.1%) had between 100 and 300 beds, and 57 (20.7%) had more than 300 beds. A detailed description is given in Table 1 below;

Table 4.1: General Information

General Information Variables		**Frequency (n)**	**Percentage (%)**
Hospital Name	DHQ	83	40.3
	Riasat Hospital	21	10.2
	Javed Medical Complex	11	5.3
	Al-Seha Hospital	44	21.4
	City Hospital	12	5.8
	Ahsan Medical Complex	18	8.7

	Ladies & Children Hospital	17	8.3
Type of Hospital	Public	83	40.3
	Private	123	59.7
Number of Beds	<100	87	42.2
	100-300	62	30.1
	>300	57	27.7
Respondent's Position	Head Of Department	11	5.3
	Pharmacist	10	4.9

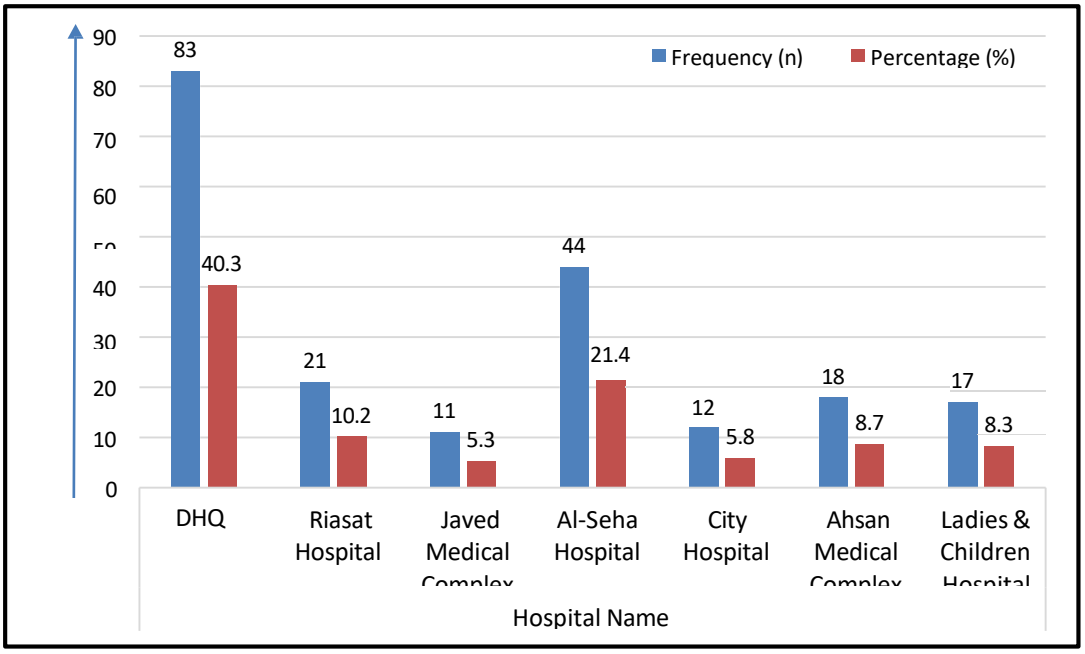

Fig 4.1.1 Frequency and Percentage of Hospital Name

Out of 206 responders, 197 (95.6%) reported contaminated materials such as gloves and bandages, 194 (94.2%) reported pharmaceutical waste, 170 (82.5%) reported sharps and 117 (95.6%) reported pathological waste. Regarding the approximate amount of infectious waste generated each day, 107 (51.9%) reported 50–100 kg, 71 (34.5%) less than 50 kg, 15 (7.3%) 100–200 kg, and 13 (6.3%) more than 200 kg. A detailed description is given in Table 2below.

Table 2: Infectious Waste Generation

Infectious waste generation Variables			**Frequency (n)**	**Percentage(%)**
Types of infectious waste	Sharps (needles, scalpels)	Yes	170	82.5
		No	36	17.5

generated in hospital	Pathological waste (tissues, organs)	Yes	117	56.8
		No	89	43.2
	Contaminated materials (bandages, gloves)	Yes	197	95.6
		No	9	4.4
	Pharmaceutical waste (Expired items, Opened Vials, IV bags)	Yes	194	94.2
		No	12	5.8
Approximate daily infectious waste generation	<50 kg		71	34.5
	50-100 kg		107	51.9
	100-200 kg		15	7.3
	>200 kg		13	6.3

Among 206 respondents, 187 (90.8%) confirmed the use of a color-coded waste segregation system, whereas 19 (9.2%) did not. Although 150 (72.8%) said that bins were provided and appropriately labelled at all garbage generating places whereas 56 (27.2%) disagreed. For the disposal of infectious trash, 147 (71.4%), 45 (21.8%), 11 (5.3%), and 3 (1.5%) people used red bins, yellow bins, and green bins respectively. 90 (43.7%) nurses, 77 (37.4%) cleaning workers, 32 (15.5%) members of the waste management team, and 7 (3.4%) doctors carried out the initial trash segregation. A detailed description is given in Table 3 below;

Table 3. Waste Segregation and Collection

Waste segregation and collection Variables		**Frequency (n)**	**Percentage (%)**
Does your hospital use a color-coded system for waste segregation?	Yes	187	90.8
	No	19	9.2
Are waste bins properly labeled and available at all points of waste generation?	Yes	150	72.8
	No	56	27.2
What color-coded bin is used for infectious waste disposal?	Red	147	71.4
	Yellow	45	21.8
	Green	3	1.5
	Blue	11	5.3

Who is responsible for initial waste segregation?	Doctors	7	3.4
	Nurses	90	43.7
	Cleaning Staff	77	37.4
	Waste Management Team	32	15.5

Out of the 206 respondents, 185 (89.8%) said they complied with government regulations, while 21 (10.2%) said they didn't. 90 (43.7%) received training quarterly, 89 (43.2%) monthly, 15 (7.3%) never received training, and 12 (5.8%) were trained annually. A detailed description is given in Table 4 below.

Table 4: Compliance & Training

Compliance and Training Variables		**Frequency (n)**	**Percentage (%)**
Is your hospital compliant with government regulations on medical waste management?	Yes	185	89.8
	No	21	10.2
How often hospital staff are trained on waste management protocols?	Monthly	89	43.2
	Quarterly	90	43.7
	Annually	12	5.8
	Never	15	7.3

(Chi-Square Test)

While comparing hospital types with variables regarding waste segregation and collection practices, the use of a color-coded system showed no significant association ($p=0.866 > 0.05$), with similar adoption in private (112) and public (75) hospitals. Proper labeling and availability of waste bins, however, showed a significant association ($p=0.001 < 0.05$), with compliance nearly equal in public (74) and private (76) hospitals, but a higher number of "No" responses in private (47) compared to public (9), indicating differences in practices between the two hospital types. For the color-coded bin used for infectious waste disposal, red bins were most common (private 95, public 52), followed by yellow (public 24, private 21), green (public 2, private 1), and blue (private 6, public 5), with a p-value of 0.130 (>0.05), indicating no significant association and similar choices in bin color. Regarding responsibility for initial waste segregation, nurses were the highest (private 56, public 34), followed by cleaning staff (private 51, public 26), waste management teams (public 22, private 10), and doctors (private 6, public 1); the p-value was 0.002 (<0.05), showing a significant association and differences in responsibility distribution between public and private hospitals. A detailed description is given in table 5 below.

Table 5: Type of Hospital versus Waste Segregation & Collection

Variables of Waste Segregation & Collection		Type of Hospital		P- Value
		Public	Private	
Does your hospital use a color coded system for waste segregation?	Yes	75	112	0.866
	No	8	11	
Are waste bins properly labeled and available at all points of waste generation?	Yes	74	76	0.001
	No	9	47	
What color-coded bin is used for infectious waste disposal?	Red	52	95	0.130
	Yellow	24	21	
	Green	2	1	
	Blue	5	6	
Who is responsible for initial waste segregation?	Doctors	1	6	0.002
	Nurses	34	56	
	Cleaning staff	26	51	
	Waste Management Team	22	10	

While comparing hospital types with variables regarding infectious waste treatment and disposal methods, on-site incineration showed a significant association ($p=0.001 < 0.05$), with "Yes" responses higher in public hospitals (63) compared to private hospitals (58), while "No" responses were more frequent in private hospitals (65) than in public hospitals (20). Off-site incineration was used more by private hospitals (106 yes, public 59 yes) with a p-value of 0.008 (<0.05), again indicating a significant association between hospital type and use of off-site facilities. Autoclaving showed higher 'Yes' counts in private hospitals (99 vs. 61) but had a p-value of 0.237 (>0.05), indicating no significant association between hospital type and this method. Similarly, chemical disinfection was more reported in private hospitals (104 yes, public 67 yes), but with a p-value of 0.473 (>0.05), showing no significant association. Finally, waste handed over to development authorities was higher in private hospitals (101 yes, public 65 yes) but the p-value of 0.499 (>0.05) indicated no significant association between hospital type and this disposal practice. A detailed description is given in table 6 below;

Table 6: Type of Hospital versus Waste Treatment & Disposal

Variables Waste Treatment & Disposal			Type of hospital		P-Value
			Public	Private	
What methods are used for infectious waste treatment?	On-site incineration	Yes	63	58	0.001
		No	20	65	
	Off-site incineration	Yes	59	106	0.008
		No	24	17	
	Autoclaving	Yes	61	99	0.237
		No	22	24	
	Chemical Disinfection	Yes	67	104	0.473
		No	16	19	
	Handed over to development authorities	Yes	65	101	0.499

While comparing hospital types with variables regarding suggestions for improving infectious waste management, staff training was suggested more frequently in private hospitals (101) compared to public hospitals (58), whereas the recommendation for placing more bins in all wards was higher in public hospitals (23) than in private hospitals (17). These findings indicated differing priorities between hospital types in improving waste management practices. Mix all wastes was suggested slightly more in private (3) than public (1) hospitals, and delay disposal was also higher in private (2) than public (1). The overall p-value was 0.096 (>0.05), indicating no significant association between hospital type and the types of improvement recommendations, suggesting that both public and private hospitals showed comparatively consistent ideas for improving infectious waste management. A detailed description is given in table 7 below.

Table 7: Type of Hospital versus Suggestions for Improvement

Variables of Suggestions for Improvement		Type of Hospital		P- Value
		Public	Private	
What recommendations do you have for improving infectious	More bins in all wards	23	17	0.096
	Staff training	58	101	

waste management in your hospital?	Mix all wastes	1	3	
	Delay disposal	1	2	

The Purpose of this study was also to understand the difference between a private and a public sector hospital through various expert areas as elaborated in table 8. DIFFERENCE BETWEEN PUBLIC AND PRIVATE HOSPITALS

Table 4.12: Public versus Private Hospitals

Category	**Public Hospitals**	**Private Hospitals**
Infectious Waste Generation	Produce larger volumes of waste due to high patient inflow and complex procedures.	Generate smaller quantities, indicating smaller scale operations and less intensive care.
Sharps Waste	Waste generation is more consistent, reflecting organized medical processes.	Pattern varies more, possibly due to less uniform waste management protocols.
Pathological Waste	Common due to frequent surgical and emergency procedures.	Less common as fewer complex surgeries are conducted.
Contaminated Materials	Extensively used; reflects high medical activity and routine care needs.	Also commonly generated, showing similar procedural requirements.
Pharmaceutical Waste	Generated through centralized medical supplies and standard drug use.	Slightly higher due to broader prescription practices and stock usage.
Color-coded Waste Segregation	Systematically implemented, showing good policy adherence.	Also well adopted, indicating comparable awareness.
Bin Labeling & Availability	More reliable bin placement and proper labeling observed.	Inconsistent labeling and availability, showing room for improvement.
Waste Segregation Responsibility	Assigned to specialized teams and trained nursing staff.	Handled primarily by nurses and cleaning staff with less formal allocation.
Waste Storage	Stored in designated, secured rooms according to protocol.	Similar storage arrangements followed, maintaining safety.
Waste Collection Frequency	Collected multiple times daily due to volume and regulation.	Typically collected once daily, aligned with lower waste levels.
Internal Waste Transportation	Use of sealed, covered carts minimizes contamination risks.	Often transported in open bins, increasing hygiene concerns.
Treatment Methods	Prefer on-site treatment like incineration for immediate handling.	Rely more on outsourcing to off-site treatment facilities.
Training Frequency	Conducted quarterly to maintain awareness.	More frequent (monthly) trainings are provided to staff.
Regulatory Compliance	Generally compliant with waste rules and health policies.	Slightly higher regulatory alignment and documentation practices.
Waste Disposal Practices	Disposal done via on-site methods like landfill and incineration.	Use commercial services for off-site disposal and item returns.
Challenges	Fewer challenges reported, mostly linked to resources.	More barriers reported in compliance and waste treatment capacity.

DISCUSSION

Based on the data from 206 respondents comprising 137 nurses (66.5%), 48 physicians (23.3%), 11 department heads (5.3%), and 10 chemists (4.9%), the findings clearly indicated that nurses formed the largest professional group, reflecting international patterns. This result was consistent with a national study conducted in Saudi Arabia by Kattan and Al-Hanawi in 2025, which reported that nurses constituted the majority of the healthcare workforce across both public and private hospitals, although with notable disparities in their distribution. The study further showed that 59.7% of respondents were from private hospitals and 40.3% from public institutions, a trend that resonated with the Saudi findings where private healthcare facilities exhibited greater staffing inequalities compared to public hospitals [20].

The study revealed that out of 206 respondents, 95.6% reported the presence of contaminated materials such as gloves and bandages, 94.2% reported pharmaceutical waste, 82.5% reported sharps, and 95.6% reported pathological waste. In terms of quantity, 51.9% of hospitals generated 50–100 kg of infectious waste daily, 34.5% generated less than 50 kg, 7.3% produced 100–200 kg, and 6.3% exceeded 200 kg per day. Comparable findings had been reported internationally; for instance, a study in West Guji, Ethiopia, documented an infectious waste generation rate of 2.1 kg per bed per day, with sharps accounting for only 1.6% and pathological waste 2.8%, substantially lower than the higher proportions observed in the present study. Similarly, hospitals in Lebanon reported an average generation rate of 1.14 kg per bed per day, with larger private hospitals producing up to 2.45 kg per bed per day. A broader global review also indicated that infectious waste generation typically ranged between 0.16 and 2.5 kg per bed per day, with extremes reaching up to 3.95 kg under certain conditions. These comparisons suggested that while awareness of infectious waste categories was high in this context, the relatively elevated reporting of sharps and pathological waste might have pointed to misclassification or inadequate segregation practices, a challenge that was also highlighted in global evidence [21].

Among the 206 respondents, 90.8% confirmed the use of a color-coded waste segregation system, and 72.8% reported that bins were properly labeled and placed at all waste-generating points, while 71.4% used red bins for infectious waste, followed by 21.8% using yellow and 5.3% using green bins. Initial segregation was primarily done by nurses (43.7%), followed by cleaning workers (37.4%), the waste management team (15.5%), and doctors (3.4%). These findings indicated a well-established segregation system and active frontline involvement, particularly by nursing staff. A similar trend was observed in a study conducted in Dire Dawa, Ethiopia, where although 64.6% of healthcare workers used color-coded bins, only 56.4% practiced proper segregation overall. That study also highlighted that the availability of color-coded bins increased the likelihood of correct segregation by nearly tenfold, and the presence of visual instructions such as posters increased it by more than eight times, suggesting that while infrastructure was crucial, training and SOP visibility were equally important to ensure compliance [22].

Among the 206 respondents, 80.1% reported that infectious waste was stored in a designated room, while 12.6% used open spaces, 3.9% in labs, and 3.4% in patient rooms. For internal transport, 45.1% used sealed containers, another 45.1% relied on open bins, and only 9.7% used covered carts. Collection frequency varied by department: most Emergency (85%) and ICU (63.6%) areas received multiple daily waste pickups, whereas other wards followed a mixed schedule, once daily (47–60%), multiple times daily (27–42%), and occasional collection every two to three days (6–12%). These operational patterns closely mirrored those reported in a 2021 study conducted across 16 teaching hospitals in Peshawar, Pakistan, which found that while most hospitals had designated storage rooms and incineration facilities, there were critical lapses in internal transport, many still relied on open bins and dumping rather than sealed trolleys or carts and inconsistent collection throughout hospital units. That

study further emphasized that non-compliance with WHO and national Hospital Waste Management (2005) guidelines led to unsafe handling practices. Similarly, the present data highlighted strengths in central storage and frequent collection in critical areas, but also revealed that nearly half of facilities still used open bins for internal transfer and some wards experienced infrequent waste removal gaps that contravened recommended safety protocols [23].

Among the 206 respondents, the majority reported having used multiple infectious waste treatment methods, including chemical disinfection (83.0%), waste handover to designated officials (80.6%), off-site incineration (80.1%), autoclaving (77.7%), and on-site incineration (58.7%), reflecting a mixed reliance on both modern and traditional practices. A relevant comparison was provided by a Life Cycle Assessment study from Istanbul, Turkey, which showed that incineration had significantly higher environmental and health impacts, particularly human toxicity, whereas autoclave sterilization had negligible adverse effects. In light of this, the high uptake of autoclaving and chemical disinfection in the present study indicated a positive shift toward safer, lower-impact methods, aligning with international recommendations to prioritize sterilization over combustion. However, the continued dependence on both off-site and on-site incineration highlighted the persistence of higher-impact practices that, if not well controlled, could release toxic emissions such as dioxins and heavy metals. Overall, these findings suggested that healthcare facilities were in a transitional phase, increasingly adopting modern methods but still constrained by regulatory and capacity factors, emphasizing the need to strengthen reliance on autoclave and chemical disinfection while gradually phasing down incineration to achieve more sustainable and health-conscious waste management systems (Kılıç & Kuzu *et al.*, 2021).

In the present study, out of 206 respondents, most had demonstrated awareness and compliance with waste management protocols: 93.2% were aware of WHO color-coded segregation, 84.9% ensured PPE use, 85.4% reported using leak-proof containers, 84.0% had received training, and 70.4% confirmed approved treatment methods. These findings indicated strong institutional compliance and alignment between knowledge and practice. In contrast, a study in Dire Dawa, Ethiopia showed that only 56.4% of healthcare workers practiced proper segregation despite high awareness, with PPE use at just 65%. Compared with these results, the present study reflected stronger integration of training and knowledge into practice, though unsafe behaviors such as burning sharps or using plastic bags still persisted [24].

Out of the 206 respondents, 185 (89.8%) had confirmed compliance with government regulations regarding infectious waste management, while only 21 (10.2%) had admitted non-compliance. Additionally, 90 (43.7%) of the participants had reported receiving training quarterly, 89 (43.2%) monthly, 12 (5.8%) annually, and just 15 (7.3%) had never received any formal training. These findings highlighted that frequent training, monthly or quarterly, played a key role in maintaining regulatory compliance. This was consistent with the study conducted in Gondar City, Ethiopia, which revealed that healthcare workers who underwent training were over 10 times more likely to demonstrate good waste management practices compared to those untrained. The Ethiopian study emphasized that regular education significantly improved adherence, especially among staff from private facilities and cleaners, supporting the present study's implication that ongoing training ensured compliance. Hence, both local and international evidence underscored that structured, repeated training was vital to fostering a compliant and safe healthcare waste management system [25].

Among 206 respondents, the most common method for disposing of sharps, pathological waste, contaminated materials, pharmaceutical, chemical, and general waste was off-site incineration, while on-site incineration, return to supplier, and landfill served as secondary methods; chemical disinfection and autoclaving were

used far less frequently. This heavy reliance on incineration aligned with the findings of a 2021 study conducted in Istanbul by Kılıç and Kuzu, which compared the environmental impacts of incineration and autoclaving for medical waste treatment. Their study concluded that although incineration was widely used, it produced significantly higher environmental and human toxicity risks compared to autoclaving, which was a safer and more eco-friendly alternative. The low usage of autoclaving (e.g., 0.5% for sharps, 1.5% for pathological waste) in the present study highlighted a gap in sustainable practice, emphasizing the need for transitioning toward cleaner methods. The Istanbul study strongly supported broader adoption of autoclaving and chemical disinfection, especially for infectious waste, to reduce emissions and protect both healthcare workers and the surrounding environment [26]. Among 206 respondents, the most significant barriers to effective infectious waste management were lack of staff awareness (92.2%), regulatory compliance issues (75.7%), and insufficient treatment facilities (69.9%), while budget constraints were viewed variably (50% yes/no). Operational concerns included mixed waste categories in wards (58.7%), incorrect labeling (30.1%), and minor issues such as misuse of storage space (8.3%). When they encountered peer non-compliance, most respondents (61.2%) reported the issue to the infection control team and 32.0% intervened directly. PPE usage varied: 52.9% wore gloves and masks, 37.4% wore full PPE, 8.7% wore gloves only, and 1.0% believed PPE was not required. Confidence in waste disposal practices was high, with 67.0% being extremely confident. These results closely mirrored the findings of the study conducted at two apex hospitals in Faisalabad, Pakistan, which highlighted that although biomedical waste protocols existed, staff had limited knowledge of BMWM rules, training was weak, accountability was lacking, and non-compliance persisted despite formal policies. Both studies emphasized that merely having regulations was insufficient; without sustained training, enforcement mechanisms, and leadership oversight, awareness rarely translated into safe, consistent practice [27]. Among 206 respondents, the majority (77.2%) identified improving staff training as the most important measure to enhance hospital infectious waste management, while 19.4% suggested adding more bins in wards to support effective waste segregation. Alarmingly, a small percentage endorsed unsafe practices, 1.5% proposed delaying waste disposal, and 1.9% recommended mixing all types of waste, both of which contradicted international safety standards. These findings are aligned with a 2023 action-research study conducted at Farabi Hospital in Malekan, Iran, which showed that structured staff training significantly improved knowledge scores and reduced total and infectious waste volumes by over 23% and 32%, respectively. The Iranian study highlighted that participatory training, leadership engagement, and system-level support led to measurable improvements in both knowledge and practice. This comparison reinforced that while staff training was critical as recognized by over three-fourths of the respondents, it needed to be paired with institutional commitment and operational reinforcements to achieve lasting compliance and safer waste management [28]. The present study found no significant difference between public and private hospitals in the generation of contaminated materials and pharmaceutical waste, suggesting similar practices in waste handling and disposal across both sectors. However, significant differences were observed in the generation of sharps and pathological waste, where public hospitals showed higher volumes, likely due to greater patient load and more complex medical procedures. Additionally, public hospitals generated more infectious waste in higher weight categories (100–200 kg and >200 kg), while private hospitals reported more in the lower categories (<50 kg and 50–100 kg), indicating a significant association with hospital type. These findings are consistent with a study in Ethiopia, which reported that public hospitals produced more pathological and total waste due to larger service capacity, while private hospitals had a higher percentage of hazardous waste per bed. The international study supported the

idea that hospital size, patient volume, and facility type significantly influenced waste patterns similar to the present study's conclusion [29].

The present study found that both public and private hospitals showed similar adoption of color-coded systems for waste segregation, indicating a shared baseline understanding of standard waste management protocols. However, a significant difference was observed in the proper labeling and availability of waste bins, where private hospitals showed much lower compliance, and in the distribution of responsibility for initial segregation, where private hospitals relied more on nurses and cleaning staff, while public hospitals involved dedicated waste management teams. Despite no major difference in the color choices of infectious waste bins, the practical execution of segregation protocols varied. These results are aligned with the findings of Assemu, Tafere, Gelaw & Bantie in Ethiopia, who reported that while many hospitals had color-coded systems in place, the lack of proper labeling, inconsistent use of bins, and reliance on untrained staff in private facilities led to poor segregation practices, emphasizing that the presence of infrastructure alone was not sufficient. The study highlighted the global challenge of maintaining consistent waste handling quality across healthcare sectors and supported the need for stricter monitoring and routine staff training.

However, significant differences were found across various departments including ICU, surgical, gynecology, general, pediatric, and dialysis wards, where private hospitals mostly relied on once-daily waste pickups, while public hospitals maintained more frequent multiple daily collections, with all p-values below 0.05. Additionally, internal waste transportation methods differed notably, as private hospitals used more open bins and sealed containers, whereas public hospitals used more covered carts, aligning more closely with safe handling standards. These findings are aligned with those of Ibrahim, Kebede & Mengiste, who compared public and private hospitals in Dire Dawa, Ethiopia and reported that public hospitals had more structured and frequent waste collection routines and better waste transport practices, including the use of covered trolleys and trained staff, while private hospitals lacked consistency in execution despite having basic systems. This suggested that although infrastructure existed in both sectors, public hospitals tended to follow safer and more consistent waste management practices (Ibrahim *et al*., 2023).

The present study found significant differences in the treatment and disposal of infectious waste between public and private hospitals. Public hospitals were more likely to have used on-site incineration, while private hospitals relied more heavily on off-site incineration, with both showing statistically significant associations. In contrast, no significant differences were found between hospital types in the use of autoclaving, chemical disinfection, or handover of waste to development authorities, indicating similar adoption of these methods across sectors. These findings are consistent with a study by Khalid in Pakistan, which reported that many hospitals, especially private ones, often outsourced waste disposal due to non-functional on-site incinerators, highlighting a gap between infrastructure availability and its practical use. This underscored the need for better operational oversight, routine maintenance, and stronger regulatory enforcement to ensure safe and independent infectious waste management across both public and private healthcare facilities [30].

The study showed that public and private hospitals demonstrated similar levels of awareness and adherence to infectious waste disposal guidelines, including practices like color-coded segregation, PPE usage, biohazard labeling, and secure containment, with all p-values > 0.05, suggesting no significant difference. However, sharps disposal practices and waste collection frequency significantly differed; private hospitals were more likely to have disposed of needles improperly in regular trash and had less consistent collection schedules. These findings are supported by a 2025 study from Ghana, which also observed high awareness but weak practical adherence in private hospitals, especially in sharps management and collection frequency. The

comparison emphasized that awareness alone was insufficient without enforcement and monitoring, particularly in high-risk waste categories.

The study found no significant difference between public and private hospitals in compliance with government medical waste regulations, indicating both sectors generally adhered to required standards. However, staff training frequency differed significantly: private hospitals held monthly training sessions more often (63 vs. 26), while public hospitals favored quarterly training. This finding are aligned with a 2024 quasi-experimental study at Sahloul University Hospital in Tunisia, which demonstrated that regular training significantly improved waste management practices, notably increasing proper sorting of sharps and intra-service collection compliance [31].

The present study revealed that nurses reported the highest generation of infectious waste across categories, with differences reaching statistical significance for contaminated materials, pharmaceutical waste, and total daily waste, while sharps and pathological waste did not differ significantly by role ($p > 0.05$). This suggested that nurses, due to their central role in direct patient care and task handling, contributed most to waste generation. These findings are aligned with the results of a quasi-experimental study in Pakistan, which found that nurses and paramedical staff demonstrated significantly higher knowledge, compliance, and retention in healthcare waste management compared to physicians, and maintained better disposable practices in follow-up assessments. The study revealed a significant association between the professional role of healthcare staff and their involvement in various infectious waste treatment and disposal techniques. Nurses were the most actively engaged group, reporting the highest participation in methods such as on-site incineration, off-site incineration, autoclaving, chemical disinfection, and handing over waste to developmental authorities. The statistical significance of these associations highlighted the central role nurses played in hospital waste management systems. This suggested that due to their frequent and direct contact with infectious waste, nurses were more likely to be responsible for ensuring that proper disposal protocols were followed. These findings are consistent with a study by Hamed, conducted in Egypt, which emphasized the pivotal role of nurses in biomedical waste management. The study showed that after receiving targeted training, nurses exhibited improved compliance with advanced waste treatment techniques, particularly autoclaving and chemical disinfection. This further reinforced the idea that empowering nursing staff through education and resources was crucial for effective and safe hospital waste management. The study analyzed staff compliance with waste regulations and training frequency across different professional roles. It found a significant association between job position and compliance with government waste regulations, with nurses reporting the highest compliance, followed by doctors, pharmacists, and department heads. Training frequency also varied significantly by role: nurses mostly reported quarterly training (68 respondents), followed by monthly sessions (57), whereas doctors attended fewer sessions. This underscored that nurses not only adhered to regulations more consistently but also received training more frequently than other staff groups. Similar findings are reported in a quasi-experimental study in Rawalpindi, Pakistan, by Kumar, which showed that nurses and paramedical staff gained significantly higher knowledge and sustained better practices, compared to doctors, after healthcare waste management training [32].

CONCLUSION

Based on the results and findings, it is concluded that public hospitals primarily use on-site incineration and proper PPE guidelines, whereas private hospitals rely more on off-site disposal and use less sophisticated equipment. Color-coded waste segregation practices were implemented more consistently in private hospitals than in public facilities. Private hospitals demonstrated stronger segregation and transport systems,

while public hospitals struggled with improper labeling and unsafe sharps disposal. Private hospitals showed higher compliance with protocol-based segregation, labeling, transportation, and disposal than public institutions. Study results highlighted that improper waste disposal practices have significant implications for infection control and hospital safety.

Conflict of Interest

The authors have no conflict of Interest

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