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Biomedical waste management disparities among laboratory professionals in Casablanca and their environmental and occupational health implications

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Abstract

Background

Biomedical waste management is a critical public health and environmental challenge, particularly in resource-limited settings. In Morocco, few studies have comprehensively assessed waste management practices in laboratory settings, leaving a substantial gap in understanding of the problem. This study aimed to evaluate the knowledge, practices, and challenges related to biomedical waste management among healthcare professionals working in medical laboratories in Casablanca, Morocco.

Methods

A cross-sectional study was conducted between October and December 2025 among healthcare professionals from public and private laboratories. Data were collected using a structured, self-administered questionnaire based on WHO guidelines. Chi-square tests were used to compare outcomes across professional groups, with $p < 0.05$ considered statistically significant.

Results

Among 464 participants (12.2% biologists, 67.0% technicians, 20.9% waste handlers), 62.5% reported receiving training. Striking disparities emerged: waste handlers demonstrated significantly lower knowledge of storage time ($p = 0.016$), color-coding use ($p = 0.027$), and chemical waste treatment ($p = 0.007$) compared to other groups. Occupational risks were alarming : 50.0% of waste handlers sustained sharps injuries ($p = 0.018$), yet only 15.7% reported them ($p < 0.001$). Paradoxically, waste handlers reported the highest satisfaction (70.8%) while biologists were the least satisfied (28.6%, $p = 0.040$).

Conclusion

This study reveals substantial and statistically significant gaps in biomedical waste management among laboratory professionals in Casablanca, with serious implications for environmental safety and occupational health. Urgent targeted interventions are needed, including reinforced training, improved PPE access, and strengthened monitoring systems.

Introduction

Biomedical waste (BMW) refers to any refuse generated during the diagnosis, treatment, or immunization of humans or animals. It encompasses materials that pose infectious, traumatic, chemical, or radiation risks [1]. Effective management of this waste is a critical environmental and public health imperative, as improper handling directly threatens ecosystems and biodiversity [2, 3].

Approximately 85% of medical waste is considered non-hazardous.The remaining 15% is highly perilous due to the presence of infectious agents, sharps, heavy metals, and pharmaceutical residues [4]. This hazardous stream, including contaminated sharps, anatomical waste, and discarded microbiological cultures, requires stringent protocols to prevent soil degradation, water pollution, and toxic exposure to wildlife [5].

The environmental burden of this waste has been intensified globally due to the exponential growth in healthcare activities. This surge was particularly pronounced during the COVID-19 pandemic, which generated a massive wave of waste and exposed the fragility of disposal systems [5, 6]. This situation calls for a critical reassessment of disposal methodologies based on their ecological footprint.

Incineration, although effective for sterilization, poses a major environmental concern when poorly controlled. It can release persistent organic pollutants (POPs), such as dioxins and furans. These compounds are potent carcinogens that bioaccumulate in the food chain, disrupt ecosystems, and contribute to long-term atmospheric pollution [7, 8]. Furthermore, improper landfilling of BMW leads to the leaching of heavy metals, pathogens, and toxic chemicals into groundwater, threatening water quality and soil health for decades [9]. Therefore, transitioning to robust, sustainable, and environmentally sound waste management strategies is a necessity for planetary health.

The effectiveness of any waste management system ultimately depends on human action. Studies underscore that the healthcare workers' knowledge and practices are pivotal in preventing environmental contamination [10, 11]. Inadequate knowledge and incorrect practices, such as failure to segregate chemical or pharmaceutical waste, directly lead to the inappropriate disposal of highly toxic compounds into the general waste stream. This waste then ends up in landfills or municipal incinerators, ill-equipped to handle it, thereby amplifying its ecological impact manifold [1]. Consequently, knowledge, attitudes, and practices (KAP) studies are fundamental diagnostic tools. They help identify gaps which, if addressed, could significantly reduce healthcare facilities' environmental footprint by ensuring waste is correctly segregated, treated, and disposed of using the most advanced and appropriate technologies available [12].

In Morocco, the city of Casablanca, as the country's largest metropolitan area and economic hub, embodies this dual challenge of public health and environmental protection. Its high concentration of medical facilities, including a dense network of laboratories, generates significant volumes of hazardous waste. This creates a potential pollution hotspot if management is not rigorous. However, practices within these laboratories and environmental awareness among professionals remain insufficiently explored.

Understanding the knowledge and practices of laboratory professionals in Casablanca is therefore not only a public health concern but also an urgent environmental one. Assessing their training, perceptions of ecotoxicological risks, and daily disposal practices is essential to identifying systemic leaks in the waste management chain that contribute to environmental degradation. Thus, this study aims to assess the knowledge and practices regarding solid and liquid waste management among medical laboratory

professionals in Casablanca. The findings will help identify key intervention points to bolster regulatory compliance, promote eco-responsible practices, and ultimately minimize BMW's environmental impact in the region.

Methods

1.1 Study Design and Setting

A cross-sectional study was conducted between October and December 2025. It aims to assess knowledge and practices regarding solid and liquid waste management among healthcare professionals working in medical laboratories in Casablanca, Morocco.

1.2 Study population and sampling

The target population comprised healthcare professionals directly involved in biomedical laboratory activities. These included medical biologists, laboratory technicians, and waste handlers, working in both public and private healthcare facilities in Casablanca.

Eligible participants were medical biologists, laboratory technicians, or waste handlers employed in a public or private medical laboratory in the Casablanca región, with at least one year of professional experience in their current position, and who provided voluntary informed consent to participate.

1.3 Data collection process

A structured, self-administered questionnaire was developed based on World Health Organization (WHO) guidelines and a comprehensive review of relevant literature. Its purpose was to evaluate knowledge and practices related to BMW management [13, 14]. The questionnaire was organized into five thematic sections.

- **Socio-demographic Characteristics**

This section collected information on age, gender, education level, professional experience, and facility type.

- **Knowledge Assessment**

This part evaluated participants' understanding of essential concepts and protocols in BMW management. It assessed awareness of national waste management policies, ability to recognize biohazard symbols, and knowledge of safety box disposal criteria. Additional questions examined the understanding of maximum allowable storage duration for BMW, proper treatment methods, and waste segregation protocols, including the use of color-coded containers. Further items explored appropriate methods for disposing of liquid chemical waste.

- **Practices Assessment**

This section evaluated the operational waste management practices implemented by healthcare professionals. It specifically investigated the application of key protocols, such as the use of separate waste containers, adherence to a color-coding system, and the availability of safety boxes for sharps. It also assessed critical operational procedures, including waste collection frequency, pre-treatment of liquid chemical waste before disposal, segregation of recyclable waste within the laboratory, and the use of a formal method to report full waste containers.

- **Incidents and challenges**

This section evaluated specific problems encountered in waste management. Participants were asked about previous needlestick injuries and whether these incidents were reported. Additional items assessed institutional mechanisms for recording accidents and supporting victims.

- **Perceived satisfaction and suggestions**

This final part first measured staff satisfaction with the waste management system in their laboratory. It then included an open-ended question to gather their suggestions and proposals for improving waste management.

1.4 Data analysis

Data analysis was performed using Jamovi Version 2.3.28.0. Descriptive statistics were expressed as frequencies and percentages for categorical variables, and as means ± standard deviations for continuous variables.

For analytical statistics, comparisons of knowledge and practice outcomes across different professional categories were conducted using Chi-square tests (χ^2) or Fisher's exact test for categorical variables. A p-value < 0.05 was considered statistically significant. Key results were visualized through tables to ensure a concise presentation of the findings.

1.5 Ethical considerations

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. The study protocol was approved by the Ethics Committee of Mohammed VI University of Sciences and Health (UM6SS) in Casablanca. Informed consent was obtained from all participants.

Results

2.1 Sociodemographic and professional characteristics

A total of 581 responses were collected. Of these, 464 were deemed valid and included in the final analysis. Among the respondents, 73% were employed in public sector laboratories. The mean age was 22.8 ± 9.6 years, and the majority were female (80.4%). Laboratory technicians represented the largest

professional group, accounting for 67% of participants. A detailed overview of sociodemographic and professional characteristics is presented in Table 1.

Table 1
Sociodemographic and professional characteristics of participants **n = 464**

Characteristics	Frequency (n)	Percent (%)
Sex		
Women	373	80.4%
Men	91	19.6%
Age		
[20–30[	290	62.6%
[30–40[	121	26.1%
>40	53	11.3%
Level of education		
Bachelor's degree	319	68.7%
Master's degree	48	10.4%
PhD	97	20.9%
Profession		
Medical biologist	56	12.1%
Laboratory Technician	311	67.0%
Waste handler	97	20.9%
Years of experience		
< 5 years	282	60.8
≥ 5 years	182	39.2
Sector		
Public	331	71.3%
Private	133	28.7%

2.2 Knowledge assessment

The survey results revealed notable variations in BMW management knowledge across occupational groups. Overall, most participants (62.5%) reported having received training in BMW management.

Waste handlers showed the highest proportion of trained individuals (71.1%), followed by laboratory technicians (62.3%).

Awareness of national or local policies was lower, with only 51.3% of respondents affirming awareness. Waste handlers reported a particularly low rate (45.4%). Knowledge of correct treatment methods and safety box disposal times was limited, with less than half of respondents answering correctly (43.5% and 42.7%, respectively).

While most professionals (85.1%) recognized the need for biohazard symbols on containers, knowledge of the maximum storage time for BMW within healthcare facilities was poor overall (56.9% correct). This differed significantly by profession ($p = 0.016$). Waste handlers demonstrated the lowest level of knowledge on this topic (33.0% correct), contrasting sharply with medical biologists (78.6%). Finally, a low percentage of professionals (26.1%) reported compliance with laboratory waste management standards. Medical biologists again reported the highest rate (50%) (Table 2).

Table 2
Comparison of BMW Management Knowledge among Medical Biologists, Laboratory Technicians, and Waste Handlers

Variable	Response category	Overall N (%)	Medical biologist n (%)	Laboratory technician n (%)	Waste handler n (%)	p-value
Training in BMW management	**No**	174 (37.5)	28 (50.0)	117 (37.6)	28 (28.9)	0.439
	Yes	290 (62.5)	28 (50.0)	194 (62.4)	69 (71.1)	
Awareness of national or local policies	**No**	226 (48.7)	16 (28.6)	133 (42.8)	53 (54.6)	0.121
	Yes	238 (51.3)	40 (71.4)	178 (57.2)	44 (45.4)	
BMW treatment method	**Incorrect**	262 (56.5)	36 (64.3)	182 (58.5)	44 (45.4)	0.455
	Correct	202 (43.5)	20 (35.7)	129 (41.5)	53 (54.6)	
Knowledge of safety box disposal time	**Incorrect**	266 (57.3)	40 (71.4)	169 (54.3)	57 (58.8)	0.532
	Correct	198 (42.7)	16 (28.6)	142 (45.7)	40 (41.2)	
Biohazard symbols on containers	**No**	69 (14.9)	12 (21.4)	36 (11.6)	24 (25.0)	0.094
	Yes	395 (85.1)	44 (78.6)	275 (88.4)	73 (75.0)	
Maximum storage time of BMW	**Incorrect**	200 (43.1)	12 (21.4)	125 (40.2)	65 (67.0)	**0.016**
	Correct	264 (56.9)	44 (78.6)	186 (59.8)	32 (33.0)	
Compliance with laboratory waste	**No**	343 (73.9)	28 (50.0)	234 (75.2)	81 (83.5)	0.086

Variable	Response category	Overall N (%)	Medical biologist n (%)	Laboratory technician n (%)	Waste handler n (%)	p-value
management standards	**Yes**	121 (26.1)	28 (50.0)	77 (24.8)	16 (16.5)	

2.3 Practices and satisfaction assessment

The analysis of self-reported practices reveals generally good adherence to certain fundamental BMW management protocols, though with significant disparities between professional groups. The use of separate waste containers was widespread (88.6%), and safety boxes for sharps were available for the majority of professionals (86.2%). However, implementation of the color-coding system, a critical component for effective waste segregation, showed statistically significant variation ($p = 0.027$). Waste handlers lagged considerably behind other groups (41.2% vs. >70% for other groups). Regarding operational practices, knowledge of correct waste collection frequency was generally low (35.8% correct). The medical biologist performed significantly better ($p = 0.047$).

A notable gap was observed in the treatment of liquid chemical waste before disposal. A large majority of laboratory technicians (74.0%) and medical biologists (64.3%) reported compliant practices. In stark contrast, only 33.0% of waste handlers affirmed doing so, a difference that was highly significant ($p = 0.007$). Practices regarding the segregation of recyclable waste and the use of formal reporting methods for full containers were moderate and showed no significant differences between groups (Table 3).

Table 3
Comparison of BMW management practices among medical biologists, laboratory technicians, and waste handlers

Variable	Response category	Overall N (%)	Medical biologist n (%)	Laboratory technician n (%)	Waste handler n (%)	p-value
Separate waste containers	Yes	411 (88.6)	40 (71.4)	283 (91.0)	89 (91.7)	0.121
	No	53 (11.4)	16 (28.57)	28 (9.0)	9 (8.3)	
Color-coding system	Yes	354 (76.3)	40 (71.4)	270 (86.8)	40 (41.2)	**0.027**
	No	110 (23.7)	16 (28.6)	41 (13.2)	57 (58.8)	
Availability of safety boxes for sharps	No	64 (13.8)	0 (0.0)	44 (14.2)	20 (20.6)	0.193
	Yes	400 (86.2)	56 (100.0)	267 (85.8)	77 (79.4)	
Waste collection frequency	Incorrect	298 (64.2)	36 (64.3)	246 (79.1)	77 (79.4)	**0.047**
	Correct	166 (35.8)	20 (35.7)	65 (20.9)	20 (20.6)	
Treatment of liquid chemical waste before disposal	No	165 (35.6)	20 (35.7)	81 (26.0)	65 (67.0)	**0.007**
	Yes	299 (64.4)	36 (64.3)	230 (74.0)	32 (33.0)	
Segregation of recyclable waste in the laboratory	No	205 (44.2)	28 (50.0)	141 (45.3)	36 (37.1)	0.713
	Yes	259 (55.8)	28 (50.0)	170 (54.7)	61 (62.9)	
Use of formal method to report	No	129 (27.8)	24	81	24	0.406

Variable	Response category	Overall N (%)	Medical biologist n (%)	Laboratory technician n (%)	Waste handler n (%)	p-value
full waste container			(42.9)	(26.1)	(24.7)	
	Yes	335 (72.2)	32 (57.1)	230 (73.9)	73 (75.3)	

2.4 Occupational incidents, challenges, and perceived satisfaction

The assessment of occupational safety revealed significant concerns regarding sharps injuries and reporting mechanisms. A substantial proportion of respondents (28.7%) reported having sustained a sharps injury at work, with a significantly higher incidence among waste handlers (50.0%, p = 0.018). However, the overall rate of reporting these injuries was critically low (15.7%), with stark disparities between professional groups (p < 0.001). While 41.7% of waste handlers reported their injuries, none of the medical biologists and only 10.4% of laboratory technicians did so. Despite this under-reporting, a majority of professionals (76.5%) believed that care was available for victims of work-related accidents. The existence of a formal registry for BMW accidents was confirmed by just over half of the respondents (51.3%), with no significant difference between groups.

Concerning resources, the provision of personal protective equipment (PPE) for waste management was reported by 72.2% of participants overall. Satisfaction with current waste management practices was divided, with less than half of the respondents (47.0%) expressing satisfaction. This perception varied significantly by profession (p = 0.040). Waste handlers were the most satisfied group (70.8%), whereas medical biologists were the least satisfied (28.6%).

All participating professionals (100%) recommend the implementation of reinforced and continuous training. Furthermore, a majority (56%) emphasized the critical need to improve the consistent availability of PPE, while 35% recommend strengthening monitoring and control mechanisms to ensure adherence to safety protocols.

Discussion

This study provides a critical evaluation of BMW among healthcare professionals in Casablanca, Morocco. The findings reveal significant gaps in both knowledge and practice, with direct and serious implications for environmental safety and public health.

3.1 Context and contribution of the study

This study addresses a significant gap in the literature. While KAP studies on BMW management have been conducted in other low- and middle-income countries, including studies from Sub-Saharan Africa

and South Asia reporting knowledge adequacy rates ranging from 40% to 75% [10, 11], comprehensive data from Morocco and the broader North African region remain scarce. Our study adds provides the first large-scale assessment focused specifically on laboratory settings in Morocco, a context characterized by a dual public-private laboratory network and a regulatory framework that, while existent, remains insufficiently monitored and enforced.

3.2 Knowledge and practice gaps

The disconnect between high self-reported training rates and poor knowledge on key technical points, such as correct treatment methods and storage times, is a major concern. This is particularly alarming from an environmental perspective. Specifically, a lack of knowledge regarding maximum storage time for BMW (waste handlers showed the lowest rate at 32.99% correct) increases the risk of waste accumulation. This can lead to pathogens' proliferation, improper disposal, and illegal dumping, ultimately contaminates soil and water sources. Such environmental contamination has been documented in studies showing water pollution near medical waste sites, posing a direct threat to surrounding communities [15–18]. The knowledge gaps identified among waste handlers are consistent with findings from comparable settings in the MENA region, where frontline workers with direct waste exposure often receive the least systematic training [19].

Similarly, gaps in practical implementation are equally critical. Inconsistent use of the color-coding system and low rates of correct waste collection frequency undermine the entire segregation process. When waste is not properly segregated at the source, the management chain is compromised. This leads to a larger volume of waste being treated as hazardous, increasing disposal costs and environmental burden. Worse still, hazardous waste may be mixed with general municipal waste, ending up in landfills and leaching harmful substances into the environment [20, 21]

The most striking finding with severe environmental consequences is the inadequate treatment of liquid chemical waste. Only 32.99% of waste handlers report pre-treating this waste before disposal, a dangerously low rate. Untreated chemical waste disposed of down the drain can directly contaminate aquatic ecosystems, harm biodiversity, and potentially enter the water supply [22–24].

3.3 Occupational health implications

Beyond environmental risks, the findings highlight a severe occupational health crisis. Overall, 28.7% of healthcare workers reported sharps injuries, a rate that rises to 50% among waste handlers. The situation is exacerbated by a critically low reporting rate of 15.7%, which masks the true scale of exposure and prevents timely post-exposure prophylaxis. This systematic under-reporting significantly increases the risk of blood-borne pathogens infections, such as Hepatitis B, Hepatitis C, and HIV, endangering both healthcare workers and the broader community [25].

3.4 Satisfaction and recommendation

The low staff satisfaction and the specific recommendations provided by professionals are strongly supported by scientific evidence. Studies have established that targeted training, consistent availability

of PPE, and effective monitoring systems are foundational pillars for improving compliance, safety, and overall efficacy in BMW management [19, 26, 27].

The inverse relationship between professional knowledge and satisfaction observed in this study is particularly noteworthy. Medical biologists, who demonstrated the highest levels of knowledge and policy awareness, reported the lowest satisfaction rates (28.6%). In contrast, waste handlers, despite exhibiting the most significant knowledge and practice gaps, were the most satisfied (70.8%). This paradox may be explained by the concept of informed dissatisfaction : professionals with greater technical expertise are more acutely aware of discrepancy between established standards and actual on-the-ground practices, making them more critical of existing systems. Similar patterns have been reported in other healthcare settings, where higher education levels correlate with greater awareness of systemic deficiencies and, consequently, lower satisfaction with institutional practices [1, 12]. These findings suggest that satisfaction scores alone are insufficient proxies for quality of waste management and should be interpreted alongside objective knowledge and practice indicators.

3.5 Methodological strengths

The inclusion of diverse professional groups in this study enabled a nuanced understanding of role-specific gaps and needs. Furthermore, the mixed-method approach, combining quantitative assessments qith open-ended suggestions, provided actionable insights directly from frontline workers, enhancing the practical relevance of the findings.

3.6 Limitations

This study has several limitations. First, the reliance on self-reported data may introduce social desirability bias, whereby participants may overstate their adherence to waste management protocols. This is particularly relevant for practice-related items, where the gap between declared and actual behavior is well documented in KAP studies. Second, the cross-sectional design captures a single point in time, limiting our ability to establish causal relationships or track changes over time. Third, the study was conducted exclusively in Casablanca, the largest urban and economic center of Morocco, which may limit the generalizability of findings to other regions characterized by different resource levels, laboratory infrastructure, and regulatory enforcement. Future studies should adopt a multicentric design encompassing both urban and rural settings across Morocco to provide a more comprehensive national picture.

Conclusion

This study uncovers significant deficiencies in BMW management among healthcare professionals in Casablanca. These include inadequate of chemical waste, poor storage protocols, and alarmingly high rates of underreported sharps injuries. Crucially, healthcare workers have identified key solutions, including comprehensive training, better access to PPE access, and stronger monitoring systems. Implementing these evidence-based recommendations represents both an operational necessity and an

ethical obligation. Such actions are essential to enhance occupational safety, protect public health, and promote environmental sustainability in BMW management.

Abbreviations

BMW	Biomedical waste
COVID	Corona Virus Disease
HIV	Human Immunodeficiency Virus
KAP	Knowledge, Attitudes, and Practices
MENA	Middle East and North Africa
POPs	Persistent organic pollutants
PPE	Personal Protective Equipment.
WHO	World Health Organization

Declarations

Ethical consideration

All methods were performed in accordance with the ethical principles outlined in the Declaration of Helsinki and in compliance with national research ethics guidelines for academic research. Ethical clearance was obtained from Mohammed VI University of Sciences and Health (UM6SS), Casablanca. Administrative authorizations were obtained from the respective public and private laboratory directors in Casablanca prior to data collection. Informed consent was obtained from all participants after a clear explanation of the study's objectives, and participants were informed of their right to withdraw at any time without penalty. Confidentiality was strictly maintained throughout the research process, and all data were anonymized during analysis to ensure no personally identifiable information was disclosed.

Consent to participate

Written informed consent was obtained from all participants.

Consent for publish

All authors read and approved the publication of the final version of the manuscript.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

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Author Contribution

O.E. conceived and designed the study, carried out the statistical analysis, and prepared the first draft of the manuscript. S.S and MA.L. contributed to the statistical analysis and to the interpretation of the findings. F.A , H.B and H.D. contributed to the interpretation of results and provided critical revisions of the manuscript. H.H. contributed to the study design and to the revision. R.F. contributed to the study design, interpretation of results, and revision of the manuscript. All authors read and approved the final version of the manuscript.

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Data Availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

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