

Improving sorting practices to accelerate the ecological transition and promote the circular economy in the healthcare system

Maitriser le tri pour accélérer la transition écologique et favoriser l'économie circulaire dans le système de santé

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Date submitted : 02/04/2026

Date of acceptance : 13/05/2026

To cite this article :

MOBALIGH M. & AIT BEN ALI S. (2026) «Improving sorting practices to accelerate the ecological transition and promote the circular economy in the healthcare system», Revue Internationale des Sciences de Gestion « Volume 9 : Numéro 2 » pp : 991 - 1006

Abstract

This study aims to assess the impact of the quality of the sorting process and ongoing training on the generation and management of healthcare waste at Sidi Hssain Bennaceur Provincial Hospital Ouarzazate.

The results demonstrate that over 60% of all waste produced is infectious healthcare waste, which is much higher than the national average. This inaccurate classification of infectious healthcare waste can be attributed to gaps in the sorting process resulting from a lack of healthcare waste management training ($\chi^2 = 7.24, p < 0.007$).

In conclusion, a waste reduction strategy based on rigorous improvements in waste sorting, ongoing staff training, the provision of appropriate equipment, and enhanced organizational coordination appears essential to ensuring staff safety, compliance with regulatory standards, and the sustainability of medical waste management within the hospital.

Keywords: healthcare waste, infectious medical waste, sorting, healthcare waste management training.

Résumé

Cette étude vise à évaluer l'impact de la qualité du processus de tri et de la formation continue sur la production et la gestion des déchets médicaux pharmaceutiques au niveau de l'hôpital Provincial Sidi Hssain Bennaceur Ouarzazate.

Les résultats montrent que plus de 60 % de l'ensemble des déchets produits sont des déchets d'activités de soins à risques infectieux, ce qui est bien supérieur à la moyenne nationale. Cette surqualification des déchets d'activités de soins à risques infectieux s'explique par la présence de lacunes dans le processus de tri majoritairement due au manque de formation en gestion des déchets médicaux pharmaceutiques ($\chi^2 = 7,24, p < 0,007$).

En conclusion, une stratégie de minimisation des déchets, reposant sur une amélioration rigoureuse du tri, une formation continue du personnel, la disponibilité de l'équipement approprié et un renforcement de la coordination organisationnelle, semble essentielle pour assurer la protection du personnel, le respect des normes réglementaires et la durabilité de la gestion des déchets médicaux pharmaceutiques au sein de l'hôpital.

Mots clés : déchets médicaux pharmaceutique, déchets d'activités de soins à risques infectieux, tri, formation en gestion des déchets médicaux pharmaceutiques.

Introduction

Recently, the healthcare sector has experienced a noticeable rise in waste generation, largely driven by population growth and the increasing demand for medical services (Yeoh et al., 2013). While healthcare is not always viewed as a highly polluting sector compared to industries such as manufacturing or energy, its environmental footprint is far from negligible. In fact, the significant quantity of waste produced by healthcare activities contributes meaningfully to environmental pollution (Lenzen et al., 2021).

Beyond its environmental impact, healthcare waste also poses serious risks to human health. Improper handling can lead to infections, contamination, and even toxic exposure, affecting both healthcare workers and the wider community (Padmanabhan & Barik, 2019). When waste is not managed effectively, these risks are amplified, potentially leading not only to public health concerns but also to reputational damage for healthcare institutions (Janik-Karpinska et al., 2024).

For these reasons, improving healthcare waste management has become an urgent priority. Healthcare facilities are increasingly expected to adopt more sustainable and environmentally responsible practices. This involves not only investing in appropriate infrastructure and treatment technologies but also rethinking processes to reduce waste generation and enhance resource efficiency. In this regard, moving toward a more circular approach where waste is minimized and materials are reused or recovered represents a promising pathway for the healthcare sector.

In 2021, Morocco generated approximately 38 000 tons of healthcare waste annually, with nearly one-third classified as dangerous (Sibley et al., 2021). Despite improvements in regulatory frameworks and treatment capacity, less than half of this waste is adequately treated. This gap highlights persistent issues related to infrastructure, monitoring systems, and operational efficiency.

Although Morocco has established a relatively structured regulatory system for healthcare waste management, significant challenges remain. These include limited coverage of treatment services, insufficient staff training, and gaps in awareness and implementation of best practices. Addressing these issues requires not only stronger systems but also continuous evaluation and research to ensure both environmental sustainability and public health protection.

In this context, the present study focuses on a critical yet often overlooked aspect of healthcare waste management: the quality of healthcare waste sorting practices and the role of staff

training. Specifically, it aims to assess how these factors influence the production and management of healthcare waste at the Sidi Hssain Bennaceur Provincial Hospital Ouarzazate.

1. Theoretical Framework

This research is grounded in the concept of the circular economy, which provides a key analytical lens for addressing sustainability challenges and improving the efficient use of resources within healthcare systems. The circular economy moves away from the traditional linear model by encouraging waste reduction, material reuse, and the continuous circulation of resources through closed-loop systems (Stahel, 2017).

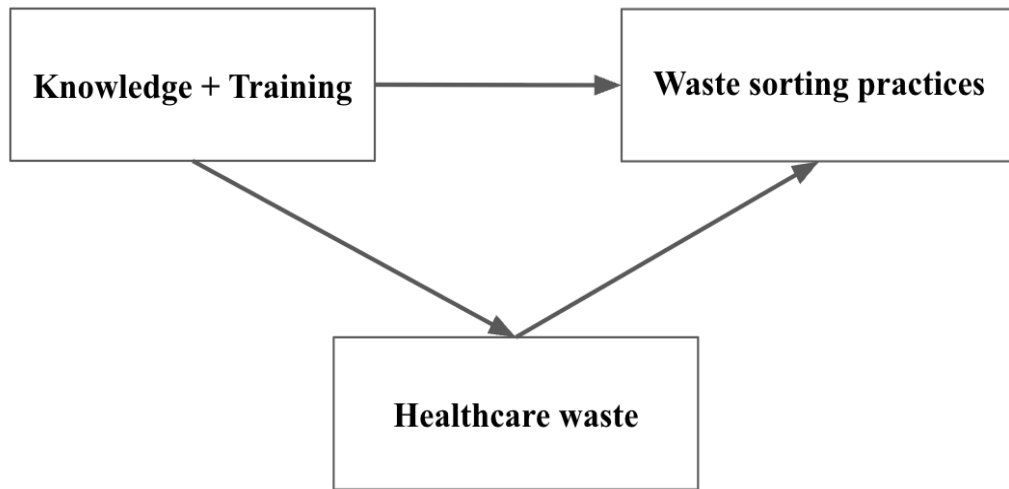
According to MacArthur (2013), the circular economy aims to preserve the value of products, materials, and resources for as long as possible while minimizing waste generation. Within healthcare systems, this approach is particularly relevant, as waste management remains a major challenge due to the large quantities produced and the potentially dangerous nature of a significant portion of this waste (Chartier et al., 2014).

In this context, healthcare waste sorting plays a crucial role. It allows for the proper separation of recyclable, recoverable, and dangerous waste streams, which is essential for any effective waste management strategy. When sorting practices are inadequate, valuable materials are often lost or contaminated, and opportunities for recycling and resource recovery are significantly reduced. As a result, improving healthcare waste sorting practices is not merely an operational concern but a fundamental prerequisite for implementing circular economy principles effectively within healthcare institutions.

To better understand the impact of training and waste sorting practices on waste quantities, we propose the following research hypothesis: Waste sorting practices have a positive impact on circular economy performance.

Based on the formulated hypothesis, the conceptual framework of this study is presented as follows:

Figure 1: Conceptual framework (Source: authors).



Source: Authors

2. Methods

Our study was conducted at Sidi Hssain Bennacer Provincial Hospital Ouarzazate from March to June 2025. This descriptive study aims to present current healthcare waste management practices, identify the challenges encountered, and propose recommendations to optimize healthcare waste management at the hospital under study. This research was conducted among 122 healthcare professionals, including 5 doctors, 78 nurses, 12 technicians, 17 interns, 3 nursing assistants, and 7 cleaning staff.

2.1. Data Collection

We chose to adopt an investigation based approach targeting healthcare professionals to collect our data, using a questionnaire as the foundation. This questionnaire was designed to gather information regarding the various types of waste generated in the departments, established sorting procedures, training received in healthcare waste management, and the challenges encountered. In addition, we used a weighing device (digital scale) to measure the weight of bags containing waste from the various hospital departments. The study was conducted in accordance with the ethical and professional standards established for this type of research.

2.2. Inclusion and exclusion criteria

In our study, we focused on:

- Healthcare professionals, including nurses and doctors,
- Professionals responsible for hygiene,
- Nursing assistants and Interns.

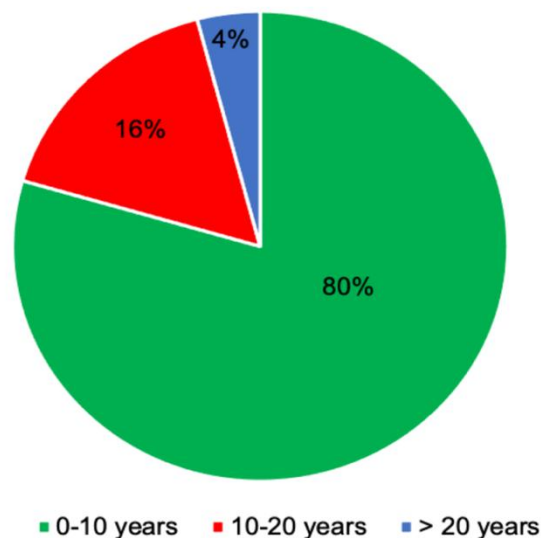
Our research does not include: Staff not involved with healthcare waste management, employees who were absent due to leave or administrative holidays during the data collection period, and those who declined to participate.

3. Results

3.1. Characteristics of the study population

According to the data (Figure 2), the largest group consists of professionals with less than 10 years of professional experience, accounting for 79.51% of the total. They are followed by those with between 10 and 20 years of experience and those with more than 20 years of professional experience, accounting for 16.39% and 4% respectively.

Figure 2: Distribution of medical staff by years of service



Source: Authors

3.2. Rate of healthcare waste generation

According to the results (Table 1), the hospital under study generates nearly 167.18 kg of healthcare waste daily. Of this total, approximately 39.15% consists mainly of municipal solid waste, 60.64% of infectious healthcare waste, and 0.21% of chemical and pharmaceutical

waste. The maximum healthcare waste generation rate by department was calculated at 11.38% in the operating room and 0.49% in the pharmacy for the minimum generation rate.

Table 1: Daily quantity of healthcare waste generated by the various departments at Sidi Hssain Bennaceur Provincial Hospital Ouarzazate

Services	Quantity of municipal solid waste (kg/day)	Quantity of infectious healthcare waste (kg/day)	Quantity of chemical and pharmaceutical waste (kg/day)	Percentage of municipal solid waste compared to infectious healthcare waste
Operating room	5.20 kg	13.80 kg		11.39%
Radiology	3.35 kg	4.60 kg		4.76%
Hemodialysis	5.10 kg	11.97 kg		10.23%
Psychiatry	6.90 kg	2.00 kg		5.34%
Pharmacy	0.80 kg	0kg		0.48%
Emergency	3.25 kg	9.42 kg		7.59%
Resuscitation	6.16 kg	10.50 kg		9.98%
Medical and surgical pediatrics	2.43 kg	6.78 kg		5.52%
Surgery	2.76 kg	7.90 kg		6.39%
Medicine	2.10 kg	4.65 kg	0.33 kg	4.05%
Delivery room	3.41 kg	7.23 kg		6.38%
Postpartum unit	2.60 kg	1.80 kg		2.64%
Laboratory	1.20 kg	12.10 kg	-	7.97%
Kitchen	16.00 kg	0kg	-	9.59%
Blood center	4.20 kg	8.64 kg	-	7.69%
Percentage	39.15 %	60.64 %	0.21 %	100%
	65.465kg	101.39 kg	0.329 kg	
Total			167.187 kg	

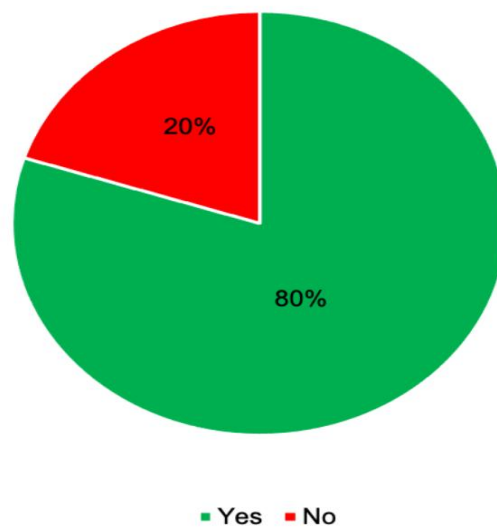
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3.3. Healthcare waste management process

3.3.1. Healthcare waste reduction initiatives

The results (Figure 3) show that most of the surveyed healthcare executives 80% are unaware of the various regulations governing the management of healthcare waste implemented by their hospital. Meanwhile, 20% of the surveyed healthcare executives are aware of these regulations.

Figure 3: Awareness of healthcare waste management regulations among surveyed staff at Sidi Hssain Bennaceur Hospital Ouarzazate

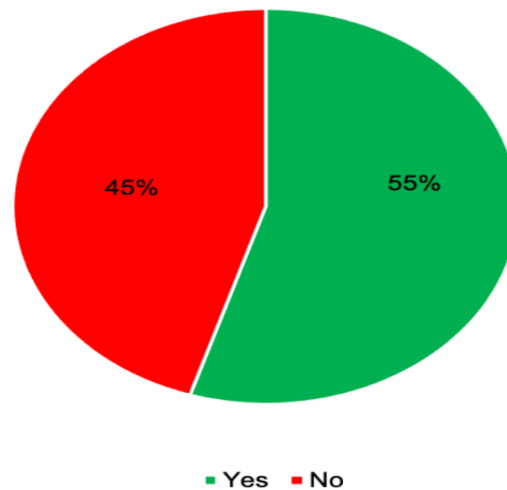


Source: Authors

3.3.2. Waste sorting and the availability of a color-coding system

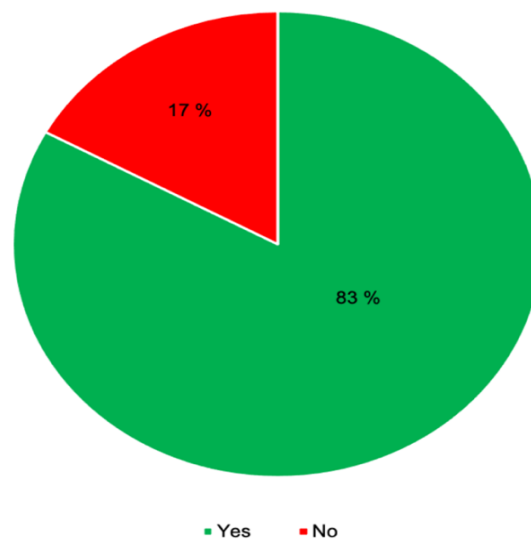
The results (Figure 4) indicate that a large proportion of the surveyed professionals 54.70% believe that the medical staff complies with waste sorting rules. For nearly 45.30% of respondents, professionals do not comply with source separation standards. To ensure sorting in accordance with standards, the various departments must have a sufficient number of recycling bins and use a color-coding system to identify different types of waste based on different color codes. All respondents (83%) confirmed the availability of a color-coding system for each type of waste in their department. Only 17% of them believe that the quantity is insufficient (Figure 5).

Figure 4: Participation rate of medical staff in sorting healthcare waste in the hospital studied



Source: Authors

Figure 5: Availability rate of a color-coding system for healthcare waste records at the hospital studied



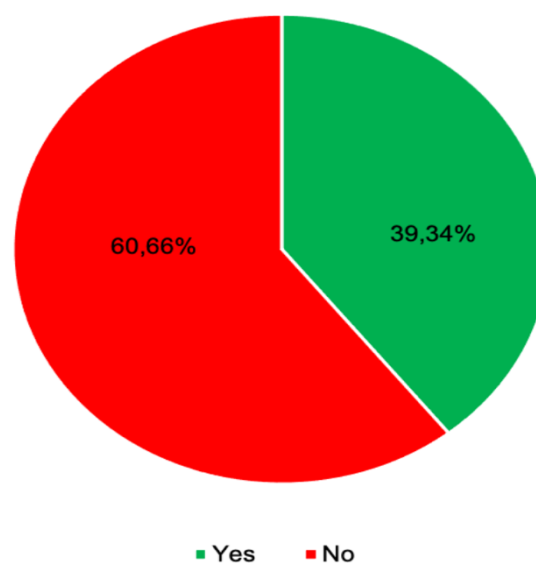
Source: Authors

3.3.3. Healthcare waste management training

The data (Figure 6) indicate that there is a lack of training (60%) among medical staff regarding healthcare waste management. Only 39.34% of respondents reported having received training on healthcare waste management.

Figure 6: Percentage of medical staff who have received training on the management of healthcare waste at the Sidi Hssain Bennaceur Provincial Hospital

Ouarzazate



Source: Authors

3.3.4. Association between healthcare waste management training and the practice of sorting

Statistical analyses show a significant association between continuing training and compliance with the sorting process ($\chi^2 = 7.24, p < 0.007$). This suggests that continuing training contributes to improved sorting. Healthcare personnel with greater knowledge are more apt to sort healthcare waste in accordance with the standards.

3.3.5. Key challenges in healthcare waste management

To identify all the obstacles to reducing hospital waste, we asked respondents to select any constraints they faced in managing healthcare waste within their institution. The Table 2 below lists the suggested improvements identified.

Table 2: Key Challenges in healthcare waste management

Challenges	Rate (%)
Inadequate training	31%
Unavailability of appropriate equipment	25%
Failure to comply with protocols	29%
Staff shortage	14%

Source: Authors

4. Discussion

Based on the study results, the majority of participants had less than 10 years of professional experience, indicating a relatively young workforce. This finding is particularly relevant, as recent research (Bouchama et al., 2026) has shown that knowledge of waste management and sorting practices tends to improve with professional experience. However, the competencies of younger professionals in proper waste sorting can be significantly strengthened through regular and targeted continuing education programs.

The healthcare facility under study generates a considerable amount of healthcare waste, exceeding the national average. Infectious healthcare waste represents a substantial proportion of the total waste produced, thereby posing significant risks to both healthcare personnel and the environment.

These results may be explained by the specific nature of the hospital, which provides a wide range of healthcare services. However, the high proportion of infectious healthcare waste may also reflect insufficient training in hospital waste management. Such deficiencies can lead to an increase in dangerous waste production, including infectious waste, while negatively affecting the quality of waste segregation (Bannour et al., 2024). In the absence of adequate continuous training and under conditions of high workload and occupational stress, healthcare staff may confuse municipal solid waste with dangerous waste, thereby artificially increasing the reported quantity of infectious healthcare waste. In reality, a significant portion of this waste could be classified as municipal solid waste or redirected toward recycling through proper sorting practices (Yang et al., 2024).

It is also important to emphasize that deficiencies in healthcare waste sorting processes contribute to an increase in infectious waste, which subsequently raises management costs. A study cited in Zeynep (2026) demonstrated that improved sorting practices can significantly reduce the total quantity of infectious healthcare waste by redirecting appropriate waste streams toward recycling and recovery. Consequently, reducing the quantity of infectious healthcare waste directly lowers treatment costs, as the treatment of one ton of infectious healthcare waste is approximately three to five times more expensive than one ton of municipal solid waste, representing a substantial financial benefit of effective waste sorting (D'Aranda et al., 2021).

Our study also revealed that respondents were not sufficiently informed about initiatives implemented within the hospital to reduce healthcare waste generation. This lack of awareness directly limits the hospital's capacity to reduce infectious healthcare waste while also undermining occupational safety, regulatory compliance, and the overall quality of healthcare waste management practices (Abdallaoui et al., 2023).

Furthermore, the discrepancies observed between healthcare professionals' waste management practices, the lack of training, and the availability of equipment highlight the need to improve professional attitudes through structured and targeted continuing education. Such interventions are essential to ensure systematic waste segregation in accordance with established healthcare waste management standards (Dunbar et al., 2023).

Overall, the barriers reported by participants appear consistent with those identified in the literature. Despite differences in study populations, similar challenges were observed, suggesting a shared understanding of the factors hindering the effective implementation of healthcare waste reduction strategies. This convergence between the literature and the present findings indicates that these challenges are perceived in a similar way by both healthcare professionals and waste management staff (Quttainah et al., 2024).

These findings highlight the importance of investing in continuous training programs to improve waste sorting practices and support the transition toward a more sustainable healthcare system (Figure 7).

At the same time, the results of this study provide useful insights into healthcare waste management practices, but they also invite a more nuanced and critical reflection. To begin with, the predominance of a relatively young workforce is an important aspect to consider. On the one hand, younger professionals are often more open to change and may adapt more easily to new practices. On the other hand, their limited experience may partly explain some of the

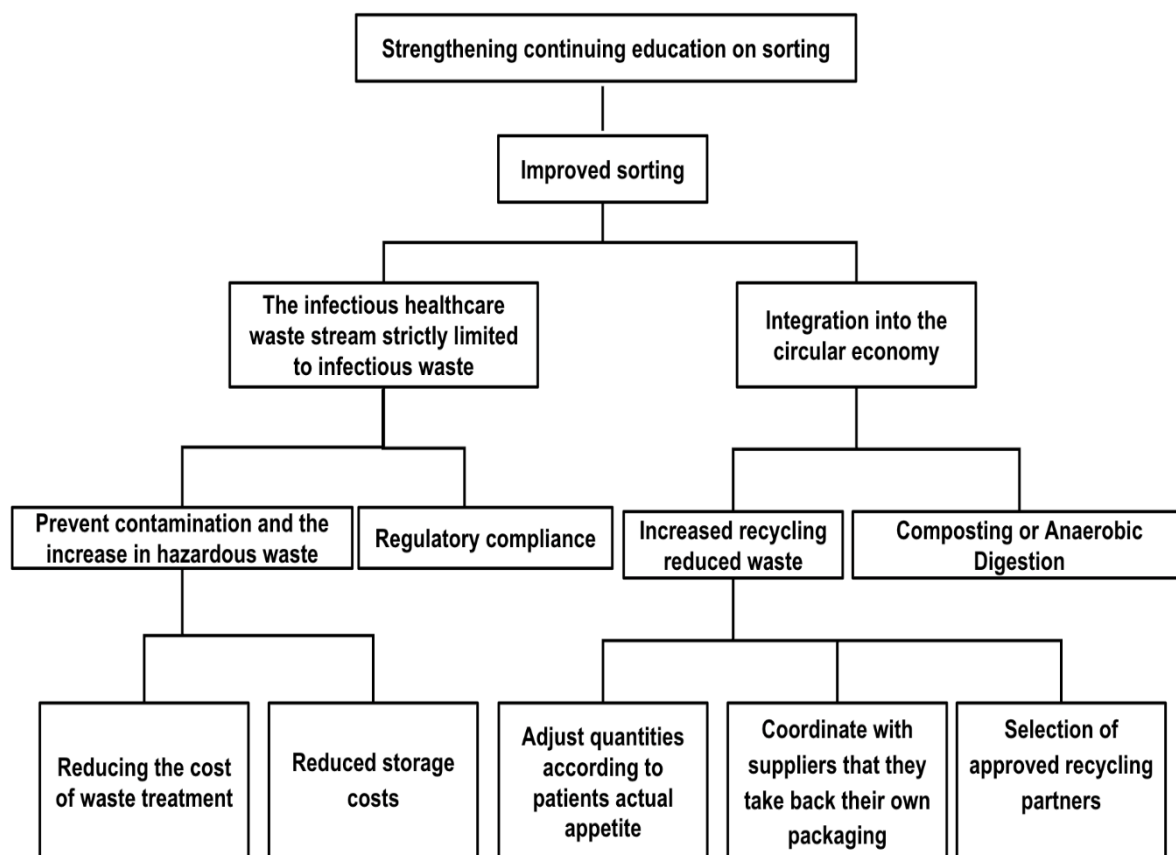
difficulties observed in properly applying waste sorting procedures. This suggests that continuous and practical training is essential to bridge this gap.

Another point that deserves attention is the high proportion of infectious healthcare waste reported in the facility. While this may be partly linked to the wide range of services provided by the hospital, it may also indicate issues in the sorting process. In practice, some non-hazardous waste may be incorrectly classified as infectious healthcare waste. This kind of misclassification not only increases environmental risks but also leads to unnecessary costs, as dangerous waste is much more expensive to treat.

Although the study highlights the importance of training, it is important to recognize that training alone is not enough. Waste management practices are also influenced by everyday working conditions. Factors such as workload, availability of appropriate equipment, clarity of procedures, and support from management all play a crucial role. Without a supportive environment, even well-trained staff may struggle to consistently apply proper sorting practices. In addition, the limited awareness among staff about existing waste reduction initiatives within the hospital points to a gap in internal communication. When professionals are not fully informed or involved, it becomes difficult to ensure their engagement and commitment to these initiatives.

Finally, while the findings are generally consistent with existing literature, they should be interpreted with caution. The study relies on self-reported data, which may not always reflect actual practices. Moreover, since the research was conducted in a single hospital, the results may not fully represent other healthcare settings. Future studies including multiple institutions and direct observations would provide a more comprehensive understanding of these issues.

Figure 7: Illustration of the benefits of enhancing the strengthening continuing training on healthcare waste sorting



Source: Authors

Conclusion

An analysis conducted at the Sidi Hssain Bennacer Provincial Hospital Ouarzazate reveals that by adopting a strategy focused on clinical assessment and optimization, healthcare system can minimize the economic and environmental costs associated with waste management.

To maintain a high level of health safety, implementing this strategy requires enhanced training for professional and adjustments to their organizational structures. This study demonstrates that the hospital generates a high quantity of healthcare waste and infectious healthcare waste due to lack of training and often inadequate sorting. These factors increase management costs, infection risks, and environmental impact. A waste reduction policy focused on improving waste sorting, providing ongoing professional training, and implementing an appropriate organizational plan can reduce the quantity of infectious healthcare waste, lower treatment costs, and improve professional and environmental safety.

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