Pharmaceutical Waste Management in Healthcare: A Comprehensive Study on Environmental Implications, Current Practices and Strategies for Sustainable Solutions

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Abstract

The pharmaceutical industry, which is vital for healthcare, faces challenges in effective pharmaceutical waste management, impacting financial resources and healthcare quality. This study addresses these challenges by classifying waste, exploring community perceptions and assessing organisational practices. The study employs advanced waste management strategies and surveys community and organisational practices. It covers disposal methods, health concerns, regulatory effectiveness and organisational approaches to inventory management, procurement cycles, storage conditions and biomedical waste practices. Survey outcomes highlight diverse community perceptions with 35 respondents favouring returning pharmaceuticals to healthcare facilities.

Health concerns include contamination of drinking water (11 respondents), increased antibiotic resistance (22 respondents) and exposure to hazardous chemicals (27 respondents). 38 respondents think that regulatory effectiveness is good and 25 think that local communities are actively involved. Organisational practices show 35 respondents rating pharmaceutical inventory management as very effective. In conclusion, the study advocates for responsible disposal practices, increased awareness and location-specific solutions for pharmaceutical waste. Findings emphasize the importance of tailored communication, education and continuous training to ensure consistent adherence to safety protocols, recognizing the interconnection of environmental and health outcomes in pharmaceutical waste management.

Keywords: Pharmaceutical waste, Biomedical waste, Waste management, Hazardous waste, Non-hazardous waste, Health risks.

Introduction

Pharmaceutical waste can originate from various activities and locations within a healthcare facility. For instance, having a compounding pharmacy onsite lead to the generation of drug waste. Instances such as spills, partially used bottles and residual drugs in IV equipment can occur wherever medications are administered. Managing waste medicines or drugs poses unique challenges in treatment and disposal. Returning unused drugs in their original packaging to the provider from whom they were purchased, presents a beneficial solution for all parties involved. This practice eliminates the need to dispose of medications as garbage while providing others in need with access to potentially life-saving medication[8].

Pharmaceutical waste encompasses a diverse array of materials generated within hospital premises, with specific hazardous agents requiring specialized disposal methods such as incineration, as underscored by Dubey et al[6]. Wildlife also faces detrimental impacts, with concerns raised about the potential extinction of certain fish species due to reproductive issues as observed by Nyaga et al[22].

This entails adherence to regulations and the adoption of stringent disposal protocols to mitigate risks posed by pharmaceutical waste entering the environment through pathways such as landfill water seepage, wastewater and sewage pipes, as highlighted by Rogowska et al[27].

The latter encompasses various subcategories, each presenting unique challenges and requiring specialized disposal protocols[25]. Waste may include disposable towels, gowns, aprons, gloves, as well as tissues and materials utilized during medical procedures and autopsies[29]. Sharp objects like knives, broken glass, hypodermic needles and scalpels are also classified as deleterious waste due to their potential to cause injuries, regardless of infection. Proper disposal of these medications is crucial to prevent environmental contamination and potential health hazards[29]. Hazardous chemical waste generated from testing facilities or experimental units requires careful handling and disposal to prevent adverse effects on human health and the environment[29].

Wastes are highly hazardous and can contaminate soil with metals like lead, copper and zinc, necessitating proper management to mitigate environmental risks. Proper handling and disposal of these materials are essential to prevent radiation exposure and environmental contamination[29]. Packaging materials that come into contact with pharmaceuticals, such as glass containers and

aluminum packs, also constitute pharmaceutical waste, highlighting the importance of comprehensive management strategies[29]. As technologies evolve, it is essential to continue exploring innovative approaches to waste disposal that balance efficiency with environmental stewardship[8]. As healthcare facilities strive to maintain stringent infection control measures, autoclaving continues to be a valuable tool in ensuring the safe handling and disposal of biomedical waste[8].

With proper maintenance and skilled personnel, microwave technology can play a valuable role in biomedical waste management strategies, contributing to safer and more sustainable waste treatment practices[8]. However, strict adherence to safety protocols and environmental regulations is necessary to ensure the safe and responsible use of chemical disinfectants in healthcare settings. By implementing advanced technologies and adhering to best practices, secure landfills can minimize environmental risks and contribute to sustainable waste management efforts[8].

Through careful implementation and adherence to safety standards, this process contributes to sustainable waste management efforts. Utilizing sewers for the disposal of liquid medications offers a convenient and environmentally sound solution, provided that appropriate precautions are taken to safeguard against potential risks associated with sewer system integrity[8]. By employing appropriate waste management strategies such as recycling, composting and landfilling, communities can mitigate the adverse effects of non-hazardous waste on the environment and human health[26].

Improper disposal of pharmaceuticls: Improper disposal practices contribute significantly to the presence of pharmaceuticals in the environment[15,16]. However, as awareness grew regarding the environmental and public health risks associated with medicine flushing, guidelines for pharmaceutical disposal evolved[5]. Studies conducted in developing countries have highlighted a significant accumulation of unused or expired pharmaceuticals among the population[13].

Additionally, some individuals redistribute their prescription medications to family members or friends[19]. These substances find their way into streams, lakes and rivers through the sewer system when pharmaceuticals are flushed down toilets or drains[14].

Challenges of managing pharmaceuticals in the environment: Pharmaceutical waste represents a multifaceted challenge, originating from diverse sources including manufacturing, agricultural activities, patient use and disposal practices. These compounds, engineered to exert specific pharmacological effects, persist in the environment due to their slow degradation rates, posing risks to ecosystems and human health[11]. Despite their ubiquitous presence, wastewater treatment plants often lack the capability to detect and remove pharmaceutical residues effectively, perpetuating the cycle of environmental exposure[21].

Studies conducted across different contexts reveal common challenges including insufficient awareness, outdated disposal methods and the absence of comprehensive waste management strategies[31]. Methods used to control pharmaceuticals release in the environment are represented in the figure 2.

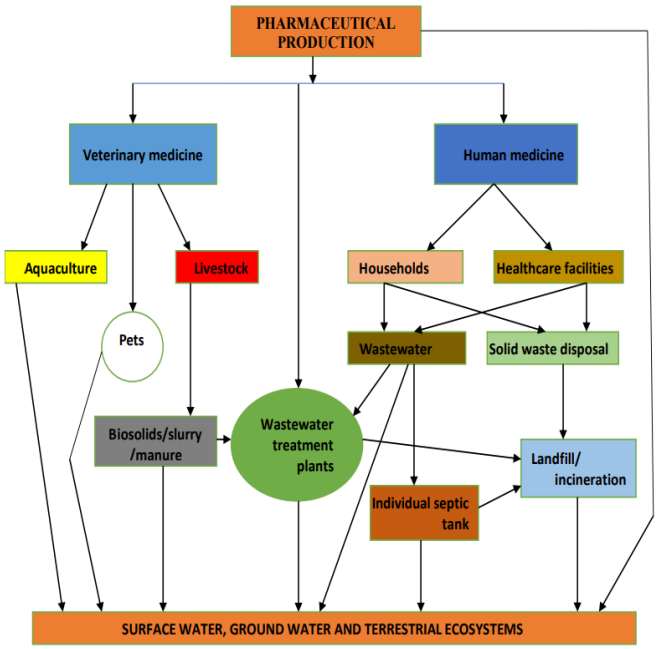


Figure 1: Sources and release of pharmaceuticals into the environment[21]

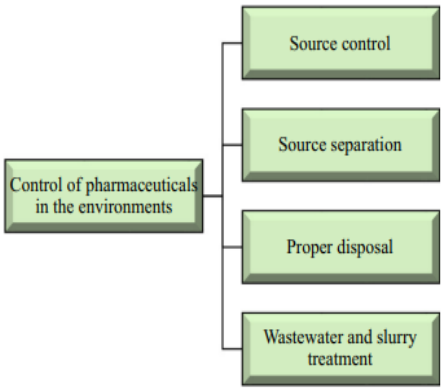


Figure 2: Methods used to control pharmaceuticals release in the environment[12]

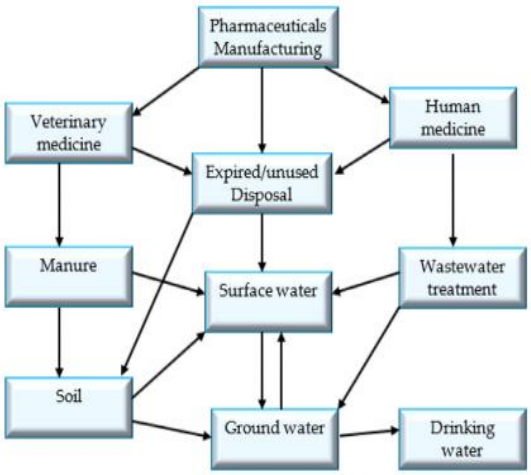


Figure 3: Potential sources of pharmaceuticals in the environment[12]

By fostering collaboration among stakeholders and prioritizing environmental stewardship, it is possible to mitigate the adverse impacts of pharmaceutical waste accumulation and safeguard both ecological integrity and human well-being[4]. Potential sources of pharmaceuticals in the environment are represented in the figure 3.

The improper disposal of the pharmaceutical waste presents a significant environmental and public health concern, particularly in developing countries with inadequate waste management infrastructure. Pharmaceuticals entering the environment through improper disposal methods such as flushing down toilets or discarding in the trash, pose risks to ecosystems and human health due to their persistence and potential toxicity. Despite increasing awareness of these issues, challenges persist in effectively managing pharmaceutical waste across various sectors including healthcare facilities and households.

The improper disposal of pharmaceutical waste contributes to environment contamination and health risks, especially in regions with limited waste management program. Factors such as incorrect inventory management, lengthy procurement cycles, poor storage practices and irrational drug use exacerbate pharmaceutical waste generation. In healthcare facilities, challenges related to biomedical waste management including the risk of disease transmission and environmental pollution, further compound the problem. Addressing these issues requires a comprehensive understanding of the environmental and health risks associated with pharmaceutical waste disposal and the identification of factors contributing to waste generation and inefficient waste management practices.

Material and Methodology

The methodology encompasses the structure of the survey, the number of participants and the locations where the survey was conducted. The survey was administered to 60 participants comprising of healthcare professionals, waste management personnel and stakeholders across various healthcare facilities and organizations. The survey was conducted in Visakhapatnam, colloquially known as Vizag, which is a rapidly developing metropolitan area located in the northeastern coastal region of Andhra Pradesh. Encompassing an area of approximately 545 square kilometers, the city is positioned between 17° 15' and 18° 32' Northern latitude and 18° 54' and 83° 30' Eastern longitude. Geographically, Visakhapatnam is bordered to the North by the Sate of Orissa and Vizianagaram District, to the South by East Godavari district, to the West by Orissa State and to the East by the Bay of Bengal.

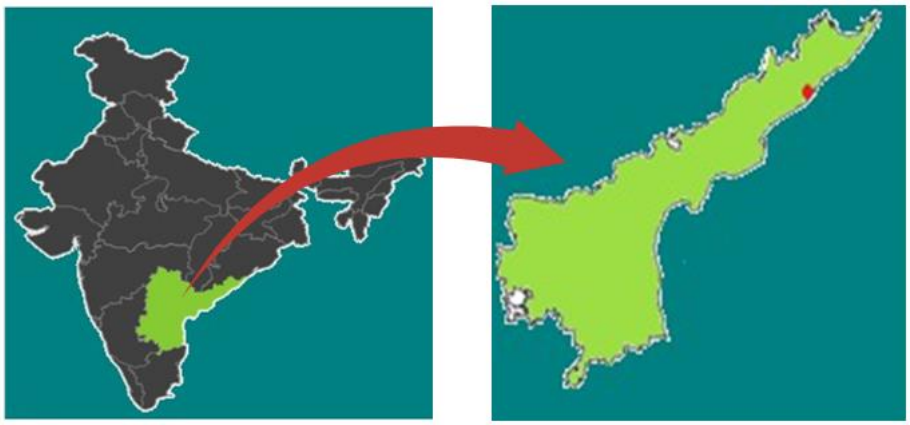
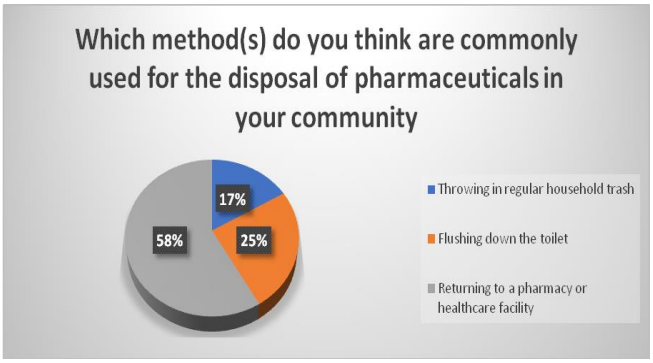


Figure 4: Study Area

Table 1
Frequency analysis on: Which method(s) do you think are commonly used for the disposal of pharmaceuticals in your community

Which method(s) do you think are commonly used for the disposal of pharmaceuticals in your community	**Frequency**
Throwing in regular household trash	10
Flushing down the toilet	15
Returning to a pharmacy or healthcare facility	35
Total	**60**



Results

Table 1 shows the results of a frequency analysis that was done to find out what people in the surveyed community thought were the most common ways to get rid of drugs. Among the respondents, 10 individuals identified the practice of throwing pharmaceuticals into regular household trash as prevalent. Additionally, 15 respondents indicated the belief that flushing medications down the toilet is a commonly adopted method. Interestingly, a significant majority of 35 participants reported that returning pharmaceuticals to a pharmacy or healthcare facility is a prevalent disposal practice in their community. This data provides insights into the community's perceptions regarding pharmaceutical disposal methods, with a total of 60 respondents contributing to the survey. The values obtained are represented in the table 1.

Table 2 presents the findings of a frequency analysis of the health concerns associated with the improper disposal of pharmaceutical waste in the surveyed community. Among the respondents, 11 individuals expressed apprehension about the contamination of drinking water as a consequence of inadequate disposal practices. Additionally, 22 participants associated improper disposal with an increased risk of antibiotic resistance. Notably, a significant majority of 27 respondents voiced concerns regarding exposure to hazardous chemicals resulting from improper pharmaceutical waste disposal. This data, derived from a total of 60 survey participants, underscores the diverse health concerns linked to the mishandling of pharmaceutical waste within the community.

Table 3 sheds light on the perceptions of the surveyed individuals regarding the effectiveness of current regulations governing pharmaceutical waste disposal in their country. Within the sample of 60 respondents, six individuals expressed the view that these regulations are ineffective. In contrast, 12 participants expressed a moderate level of

confidence in the regulations as being somewhat effective. Notably, a majority of 38 respondents held a positive outlook, describing the existing regulations as very effective. On the other hand, four respondents remained uncertain about the effectiveness of the regulations in place for pharmaceutical waste disposal. This data indicates a range of perspectives within the community, with a significant proportion expressing confidence in the regulatory framework, while others harbour doubts or perceive room for improvement in the current system.

Table 4 provides insights into the perceived extent of local community involvement in addressing the challenge of pharmaceutical waste disposal. Among the 60 respondents, 16 individuals indicated that there is limited involvement from local communities in tackling this issue. Another 15 participants noted that there is some level of community engagement in addressing pharmaceutical waste disposal. Notably, a majority of 25 respondents expressed the belief that local communities are actively involved in dealing with the problem. However, a minority of four respondents felt that there was no involvement from local communities in addressing the issue of pharmaceutical waste disposal. These findings underscore the diverse perspectives within the surveyed community regarding the level of engagement and participation of local communities in managing pharmaceutical waste.

Table 5 provides information on how the survey respondents perceived the effectiveness of the current pharmaceutical inventory management systems within organizations. Out of the 60 participants, eight individuals characterised their organisation's system as ineffective. Meanwhile, twelve respondents considered the system to be somewhat effective. A notable majority of 35 participants expressed confidence in the efficiency of their organisation's pharmaceutical inventory management system, rating it as very effective.

On the other hand, five respondents admitted uncertainty about the efficiency of their organisation's current pharmaceutical inventory management system. These results highlight varying perceptions within the surveyed organisations regarding the effectiveness of their pharmaceutical inventory management practices with a significant portion expressing satisfaction with the system's efficacy.

Table 2
Frequency analysis on: Which health concerns do you associate with the improper disposal of pharmaceutical waste

Which health concerns do you associate with the improper disposal of pharmaceutical waste	**Frequency**
Contamination of drinking water	11
Increased antibiotic resistance	22
Exposure to hazardous chemicals	27
Total	**60**

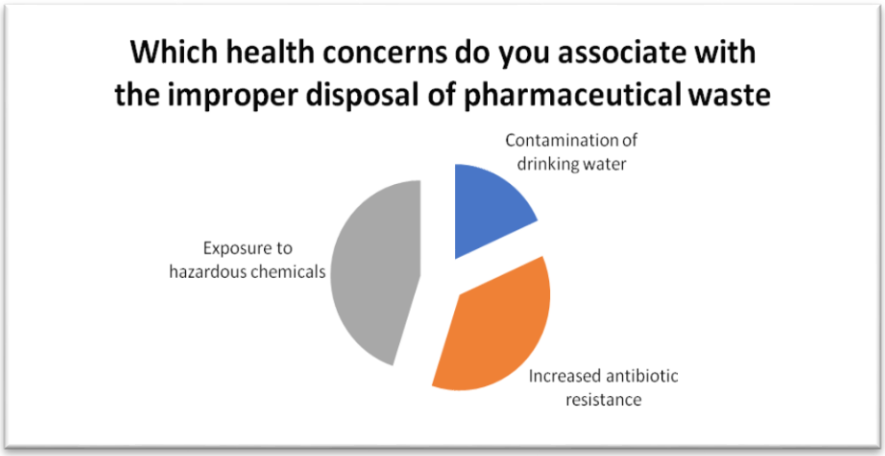


Table 3
Frequency analysis on: How would you rate the effectiveness of existing regulations on pharmaceutical waste disposal in your country

How would you rate the effectiveness of existing regulations on pharmaceutical waste disposal in your country	**Frequency**
Ineffective	6
Somewhat effective	12
Very effective	38
Not sure	4
Total	**60**

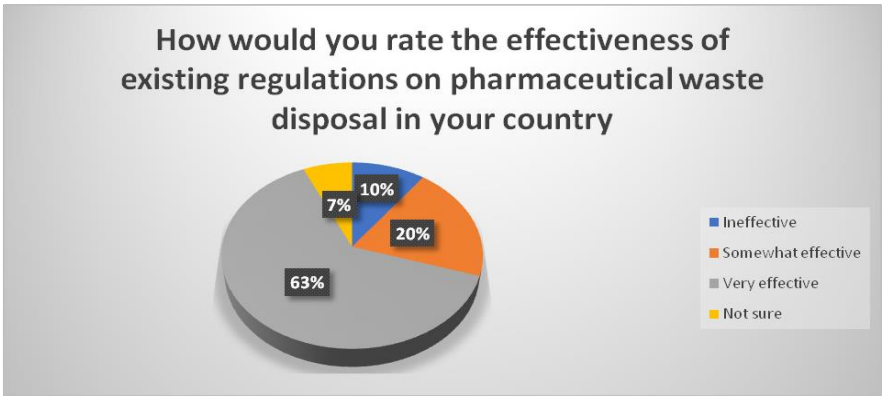


Table 4
Frequency analyses to: What extent are local communities involved in addressing the issue of pharmaceutical waste disposal

How would you rate the effectiveness of existing regulations on pharmaceutical waste disposal in your country	**Frequency**
Limited involvement	16
Some involvement	15
Active involvement	25
No involvement	4
Total	**60**

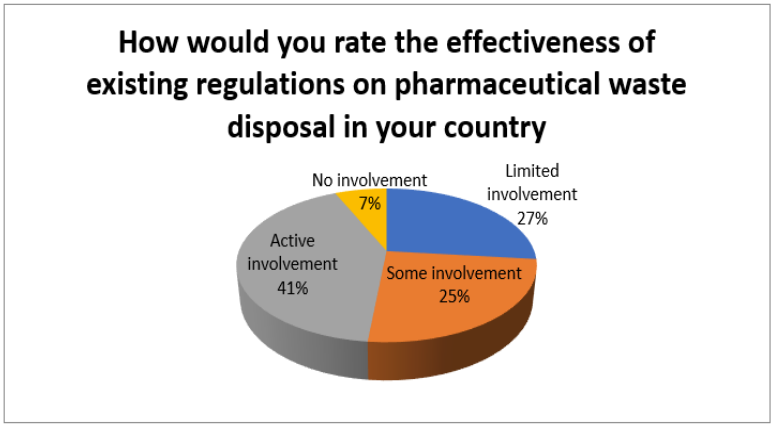


Table 6 shows the results of a frequency analysis of respondents' reports of the perceived length of pharmaceutical procurement cycles within organizations. According to the 60 participants, 10 individuals described their experience with short procurement cycles, typically taking less than a month. A majority of 32 respondents reported moderate-length procurement cycles, falling within the range of 1 to 3 months. In contrast, a smaller group of six participants indicated experiencing long procurement cycles, extending beyond 3 months. Additionally, 12 respondents expressed uncertainty about the duration of procurement cycles in their organizations. This data signifies diverse experiences within the surveyed organisations regarding the timelines associated with the procurement of pharmaceuticals, reflecting variations in operational practices and processes.

According to the survey respondents' reports, table 7 provides insights into the assessment of pharmaceutical storage conditions within organizations. Out of the 60 respondents, 30 individuals expressed satisfaction with the storage conditions, deeming them adequate. This adequacy is often associated with controlled temperatures and proper shelving.

In contrast, 10 participants indicated that the storage conditions in their organisations were only moderately adequate. A larger group of 14 respondents reported inadequate storage conditions for pharmaceuticals, reflecting issues with the existing facilities.

Additionally, six respondents admitted uncertainty about the current storage conditions in their organizations. This data highlights the diverse perspectives within surveyed organisations regarding the adequacy of pharmaceutical storage conditions, emphasising the importance of maintaining controlled environments to ensure the integrity and efficacy of pharmaceuticals.

Table 5
Frequency analysis on: How would you rate the efficiency of the current pharmaceutical inventory management system in your organization

How would you rate the efficiency of the current pharmaceutical inventory management system in your organization	Frequency
Ineffective	8
Somewhat effective	12
Very effective	35
Not sure	5
Total	**60**

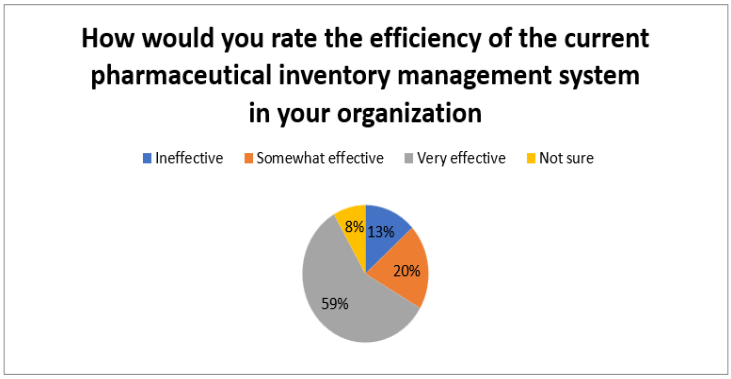
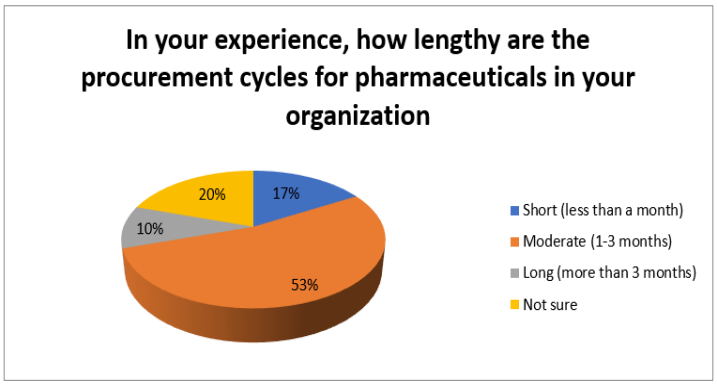


Table 6
Frequency analysis on: Your experience, how lengthy is the procurement cycles for pharmaceuticals in your organization

In your experience, how lengthy are the procurement cycles for pharmaceuticals in your organization	Frequency
Short (less than a month)	10
Moderate (1-3 months)	32
Long (more than 3 months)	6
Not sure	12
Total	**60**



According to survey respondents' reports, table 8 provides insights into the perceived impact of irrational drug use on pharmaceutical waste within organizations. Among the 60 respondents, eight individuals indicated that they believe irrational drug use is not a significant factor contributing to pharmaceutical waste in their organizations.

A majority of 35 participants expressed the view that irrational drug use is somewhat significant in contributing to pharmaceutical waste. In contrast, a smaller group of five respondents deemed irrational drug use to be very significant in contributing to pharmaceutical waste.

Additionally, 12 participants admitted uncertainty regarding the extent to which irrational drug use contributes to pharmaceutical waste in their organizations. This data underscores the varied perspectives within organisations regarding the role of irrational drug use in contributing to pharmaceutical waste, highlighting the need for awareness and strategies to address this issue.

Table 7
Frequency analysis on: How would you assess the storage conditions of pharmaceuticals in your organization

How would you assess the storage conditions of pharmaceuticals in your organization	Frequency
Adequate (controlled temperature, proper shelving)	30
Moderately adequate	10
Inadequate	14
Not sure	6
Total	**60**

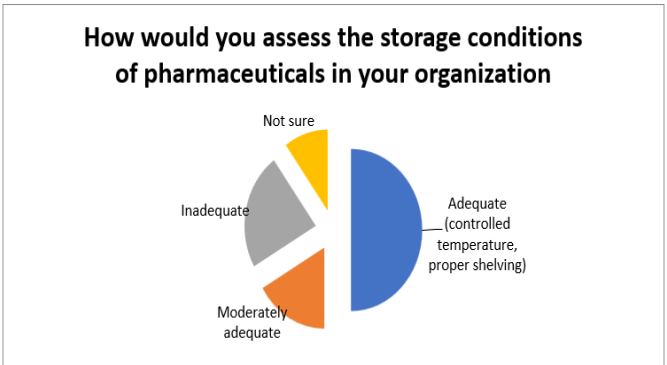
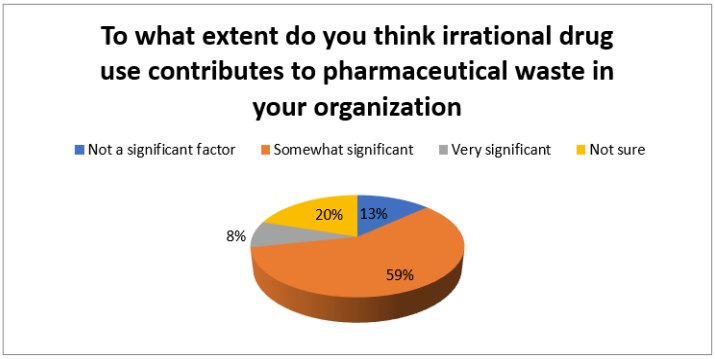


Table 8
Frequency analysis on: To what extent do you think irrational drug use contributes to pharmaceutical waste in your organization

To what extent do you think irrational drug use contributes to pharmaceutical waste in your organization	Frequency
Not a significant factor	8
Somewhat significant	35
Very significant	5
Not sure	12
Total	**60**



According to survey respondents' reports, table 9 shows results from a frequency analysis on the efficacy of segregating biomedical waste at the source within healthcare facilities. Among the 60 respondents, 23 individuals expressed satisfaction with the segregation process, deeming it very effective. An additional 17 participants reported that the segregation of biomedical waste at the source in their healthcare facility is moderately effective. On the other hand, 16 respondents indicated that the segregation process is ineffective, suggesting room for improvement in waste management practices. Furthermore, four participants admitted uncertainty about the effectiveness of the segregation of biomedical waste at the source in their healthcare facility. This data underscores the diverse perspectives within healthcare facilities regarding the effectiveness of waste segregation practices, emphasising the importance of continuous evaluation and improvement in biomedical waste management protocols.

Table 10 provides insights into the availability and clarity of designated and secure areas for the collection and temporary storage of biomedical waste within healthcare facilities, as reported by the survey participants. Out of the 60 respondents, 32 individuals affirmed the presence of well-defined areas for such purposes, indicating a proactive approach to biomedical waste management. In contrast,

eight participants reported that their healthcare facilities have only somewhat defined areas for the collection and temporary storage of biomedical waste, suggesting a need for more clarity in the waste management infrastructure. 13 respondents stated that their healthcare facilities lack specific areas designated for this purpose, indicating potential gaps in biomedical waste management practices.

Additionally, seven participants expressed uncertainty about the existence of designated and secure areas for biomedical waste collection and temporary storage in their healthcare facility. This data highlights variation in the infrastructure and practices related to biomedical waste management across healthcare facilities, underscoring the importance of clear guidelines and designated areas to ensure safe and effective waste handling.

Table 11 presents findings from a frequency analysis on the adherence to infection control measures during the handling and disposal of biomedical waste within healthcare facilities, as reported by survey participants. Among the 60 respondents, 23 individuals noted strict adherence to infection control measures, reflecting a commitment to maintaining a high standard of safety during waste management processes. Additionally, 17 participants reported partial adherence, suggesting areas where improvements or reinforcement of infection control measures may be needed.

13 respondents indicated minimal adherence to infection control measures during biomedical waste handling and disposal, signaling potential concerns in safety practices.

Table 9
Frequency analysis on: How effective is the segregation of biomedical waste at the source in your healthcare facility

How effective is the segregation of biomedical waste at the source in your healthcare facility	Frequency
Very effective	23
Moderately effective	17
Ineffective	16
Not sure	4
Total	**60**

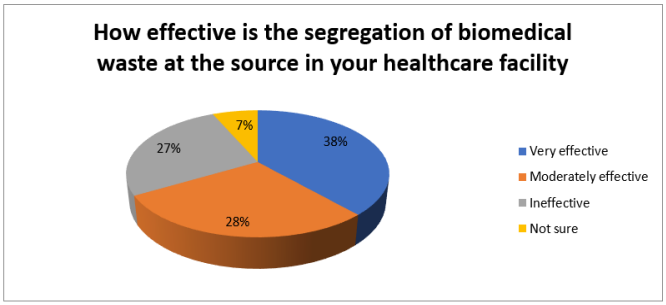


Table 10
Frequency analysis on: Are there designated and secure areas for the collection and temporary storage of biomedical waste in your healthcare facility

Are there designated and secure areas for the collection and temporary storage of biomedical waste in your healthcare facility	Frequency
Yes, well-defined areas	32
Somewhat defined areas	8
No specific areas	13
Not sure	7
Total	**60**

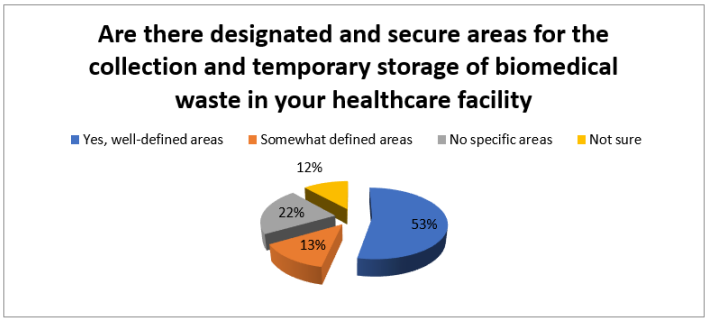


Table 11
Frequency analysis on: How strictly are infection control measures followed during the handling and disposal of biomedical waste in your healthcare facility

How strictly are infection control measures followed during the handling and disposal of biomedical waste in your healthcare facility	Frequency
Strict adherence	23
Partial adherence	17
Minimal adherence	13
Not sure	7
Total	**60**

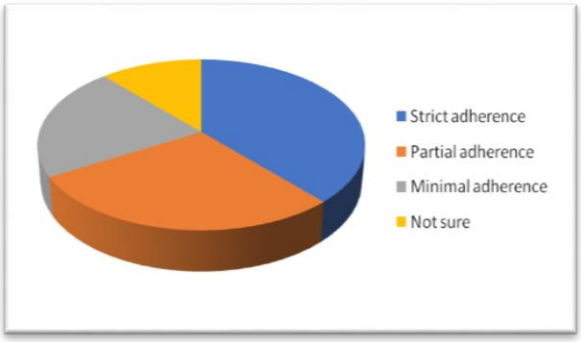


Table 12
Frequency analysis on: To what extent do healthcare staff use appropriate PPE when handling biomedical waste

To what extent do healthcare staff use appropriate PPE when handling biomedical waste	Frequency
Always	31
Sometimes	9
Rarely	11
Not sure	9
Total	**60**

Furthermore, seven participants expressed uncertainty about the extent of adherence to infection control measures in their healthcare facility. This data underscores the varied practices within healthcare facilities regarding infection control measures during biomedical waste management, emphasizing the importance of consistent training and monitoring to enhance safety protocols.

Table 12 provides insights into the extent to which healthcare staff use appropriate personal protective equipment (PPE) when handling biomedical waste, as reported by the survey participants. Thirteen out of the sixty respondents said that medical personnel always utilised the proper PPE when handling biomedical waste, demonstrating their dedication to safety procedures.

Nine participants, on the other hand, stated that healthcare personnel only occasionally utilised the proper PPE, highlighting opportunities for safety measure reinforcement or enhancement. Eleven respondents also pointed out that there may be inconsistencies in the adherence to safety procedures since medical personnel seldom wore the proper PPE when handling biomedical waste. Nine participants also expressed scepticism regarding the healthcare staff's continuous use of the proper PPE in their facility. The aforementioned data highlights the discrepancies in the compliance of healthcare personnel with safety protocols when handling biomedical waste, underscoring the significance of continuous education and oversight to guarantee the regular use ofappropriate PPE.

Discussion

The data presented across multiple tables offers valuable insights into various aspects of pharmaceutical and biomedical waste management practices, perceptions and challenges within communities and healthcare facilities. These findings shed light on disposal methods, health concerns, regulatory effectiveness, storage conditions, biomedical waste segregation etc. Each aspect contributes to our understanding of the current state of waste management and highlights areas where improvements can be made to mitigate environmental and health risks associated with improper waste disposal.

In the surveyed community, returning pharmaceuticals to pharmacies or healthcare facilities is perceived as the most common disposal method, followed by throwing them in regular household trash and flushing them down the toilet. These perceptions reflect community attitudes towards convenient and accessible disposal options, with a significant emphasis on returning medications to designated facilities for proper disposal, indicating awareness of environmental and safety concerns. As per the study of Mohammed et al[18], segregated pharmaceuticals stored in 35.6% dispensing units waited for removal and 68.1% used cartons as a sort of container for segregation. Moreover, 66.7% of respondents revealed that pharmaceuticals wastes were disposed of within health facilities compounds and the usual (63.7%) methods of disposal were burning in the open air.

Respondents expressed various health concerns related to improper disposal practices, including exposure to hazardous chemicals, contamination of drinking water and increased antibiotic resistance. As per the Marwa et al[17], in Tanzania, 91.4% of respondents were not aware of the existence of proper medicine disposal methods. This is due to the fact that patients were not educated in this area or the methods of education were ineffective. These concerns highlight the potential risks posed by improper waste disposal methods and underscore the importance of implementing effective waste management strategies to safeguard public health and the environment.

The majority of respondents expressed confidence in the effectiveness of existing regulations governing pharmaceutical waste disposal, with only a small proportion viewing them as ineffective. As per the Naser et al[21], most of the individuals are aware that throwing unwanted medications into the trash or pouring them into the sewage system has a negative impact on the environment and health. For example, in Jordan, 72.5% of participants said they knew that the improper disposal of medications could harmfully affect the environment and health and 0.86% of households in the US said that flushing unwanted medications down the toilet or sink may result in medications contaminating the water supply or negatively impacting the environment. This indicates a general belief in the regulatory framework's ability to address waste management issues, although there may be room for improvement or concerns about enforcement in certain areas.

While a significant number of respondents believe that local communities are actively involved in addressing pharmaceutical waste disposal, there are also indications of limited involvement in some cases. A survey conducted by Alhomoud et al[3] in the Kingdom of Saudi Arabia among undergraduate or postgraduate pharmacy students indicated that more than half (60%) had never received any information during their studies or training on how to store or dispose of medications. Moreover, 89% reported previously disposing of unused medicines mainly in household garbage.

On the other hand, as per the Alghadeer et al[2], between 73.3 and 75.3% (depending on the dosage form) of community pharmacists in Saudi Arabia returned unused drugs to the pharmaceutical distributors and only between 1.1 and 4.4% poured them down the sink or toilet. These findings underscore the importance of community engagement and awareness initiatives to promote responsible waste disposal practices and to enhance overall environmental stewardship.

Overall, respondents reported high levels of satisfaction with their organization's pharmaceutical inventory management systems, with the majority rating them as very effective. However, there were also indications of inefficiencies in certain cases, suggesting the need for ongoing evaluation and improvement of inventory management practices to optimize resource allocation and minimize waste. As per Hidayat et al[7], efficient inventory management enhances gross profits and net profits by reducing the cost of procured pharmaceutical products and associated operational expenses. In addition, cash flow will improve upon saving on purchasing and storing less costly products. Such cash flow can be used to pay operational expenses and to invest in other services.

In addition to the negative impacts on financial outcomes from the pharmacy's business perspective, inventory mismanagement could have deleterious corollaries on patient safety. Such outcomes can be attributed by the availability of expired, counterfeit, substandard, or spoiled products, unavailability of essential products, unclaimed prescriptions and not updating formularies. From both financial and operational perspectives, efficient inventory management plays a great role in pharmacy practice. Thus, both methods of inventory management and methods of evaluating inventory management should be integrated into the curriculum of pharmacy programs, in addition to including them in the continuing education courses for registered pharmacists.

While many respondents reported adequate storage conditions for pharmaceuticals in their organizations, concerns were raised about moderate adequacy or inadequacy in some cases. As per Akingeneye et al[1], in

Rwanda, they had warehouse premises but designed as residential houses for habitation, so space is insufficient and they are not well equipped as required by the pharmaceutical warehouse. They are not ventilated, pharmaceutical products are exposed to direct sunlight, devices in cold rooms are not calibrated, temperature monitoring is not done during holydays and weekend at district pharmacies, others have been trained long time ago, products in cartons are stacked not respecting good storage practices.

At district pharmacies they do not monitor relative humidity, there is a lack of cool storage condition, dispatching area is not separated with receiving area in all district pharmacies, there is lack of equipment for rifting heavy loads at district pharmacies, there is easy access to pharmaceutical products in the warehouse because there are no security precautions. Ensuring proper storage conditions, including controlled temperature and adequate shelving, is essential for maintaining the integrity and efficacy of medications and reducing the risk of waste due to degradation or spoilage.

While many respondents viewed the segregation of biomedical waste at the source as effective, there were also concerns about moderate effectiveness or ineffectiveness in some cases. As per Tank et al[30], they developed an instrument which segregates biomedical waste effectively and dispose it having minimum human exposure. They start with a matrix constructed using switches and LED lights of different colors which indicate the respective color code of the dustbins. The rows and columns describe the different properties of the waste material. Each of the dustbins has an ultrasonic distance sensor attached in front of them followed by a microcontroller and servo motor.

The distance sensor circuit controls the lid of the dustbin when person goes near/away from the dustbin. This is how hospital waste segregation is done fruitful and disposed in such a way that chances of spreading infection through medical waste decrease.

Later, it can be discarded in bigger bins for storing and transporting it to waste management companies. Improving waste segregation practices and infrastructure within healthcare facilities can help to minimize the risk of cross-contamination and to ensure safe handling and disposal of biomedical waste.

While many respondents reported strict adherence to infection control measures during biomedical waste handling and disposal, there were also indications of partial or minimal adherence in some cases. As per Padmanabhan et al[24], policies should be framed to avoid spread of infections by providing specification for handling waste for generation, segregation, collection, storage, transportation and treatment. Awareness should be created at all levels of society through various means of communication and education, so that the risks of spreading the health hazards could be minimized. Continuous training and monitoring are critical in maintaining high standards of safety and minimizing the risk of infections among healthcare workers and patients.

Ensuring the regular and appropriate use of PPE by healthcare staff during biomedical waste handling is essential for preventing occupational hazards and minimizing the risk of exposure to infectious agents.

As per Rose et al[28], lead glasses were consistently used 10.2% and never used 61.1% of the time. All forms of PPE were inconsistently used by 92.6% of participants. Women were 4.3 times more likely to report that PPE was not available. PPE compliance was related to fit and availability. Ongoing education, access to adequate supplies and enforcement of safety protocols can help to promote consistent PPE usage and to enhance overall workplace safety.

Conclusion

In conclusion, the pharmaceutical sector, which is essential to healthcare, has a significant problem with pharmaceutical waste management. The study emphasises how urgent it is for everyone to embrace systematic waste management practices, particularly in areas with inadequate waste management initiatives. The various origins of biomedical and pharmaceutical waste require a sophisticated strategy that takes into account both hazardous and non-hazardous categories. The survey results demonstrate various community viewpoints, underscoring the significance of ongoing evaluation and development of waste management practices and legal frameworks.

The study promotes the use of effective waste treatment techniques, raises awareness and encourages appropriate disposal. To reduce the hazards to the environment and public health posed by the disposal of pharmaceutical waste and to create a more sustainable and accountable healthcare system, location-specific solutions are essential.

References

1. Akingeneye C., Assessment of storage conditions of pharmaceutical products in Rwanda: case of Rwanda biomedical center, Medical procurement andproduction division and district pharmacies, Doctoral dissertation, University of Rwanda **(2019)**

2. Alghadeer S. and Al-Arifi M.N., Community pharmacists' practice, awareness and beliefs about drug disposal in Saudi Arabia, *Healthcare*, **9(7)**, 823 **(2021)**

3. Alhomoud F.K., Alsadiq Y., Alghalawin L., Alhifany A. and Alhomoud F., Pharmacy students' knowledge and practices concerning the storing and disposal of household medication in Saudi Arabia, *Currents in Pharmacy Teaching and Learning*, **13(1)**, 5-13 **(2021)**

4. Alnahas F., Yeboah P., Fliedel L., Abdin A.Y. and Alhareth K., Expired medication: Societal, regulatory and ethical aspects of a wasted opportunity, *International Journal of Environmental Research and Public Health*, **17(3)**, 787 **(2020)**

5. Dar M.A., Maqbool M. and Rasool S., Pharmaceutical wastes and their disposal practice in routine, *Int J Inf Comput Sci*, **6**, 76-92 **(2019)**

6. Dubey R. and Upmanyu N., Role of pharmacist in pharmaceutical waste management, *World*, **6(2)**, 1-3 **(2017)**

7. Hidayat R. and Saleh I., The importance of inventory management in pharmaceutical practice, *Open Access Indonesia Journal of Social Sciences*, **3(1)**, 80-84 **(2020)**

8. Jaseem M., Kumar P. and John R.M., An overview of waste management in pharmaceutical industry, *The Pharma Innovation*, **6(3, Part C)**, 158 **(2017)**

9. Jero Mathu Albert, Jayalekshmi Sunil, Neethu Hari, Vishnu S. Sanjeev and Ananthakrishnan Jayakumaran Nair, Evaluation of bioactivities and importance of indole-3-carbinol in the Brassica oleracea L. var. capitata f. alba extracts, *Res. J. Biotech*., **19(3)**, 20-30 **(2024)**

10. Kadam A., Patil S., Patil S. and Tumkur A., Pharmaceutical waste management an overview, *Indian Journal of Pharmacy Practice*, **9(1)**, 2-8 **(2016)**

11. Kalaji H.M. and Rastogi A., Pharmaceutical compounds: an emerging pollutant (a review on plant-pharmaceuticals interaction), *Chiang Mai J Sci*, **44**, 287-297 **(2017)**

12. Karungamye P., Rugaika A., Mtei K. and Machunda R., The pharmaceutical disposal practices and environmental contamination: A review in East African countries, *Hydro Research*, **5**, 99-107 **(2022)**

13. Kassahun H. and Tesfaye D., Disposal practices of unused medications among patients in public health centers of Dessie town, northeast Ethiopia: a cross-sectional study, *Current Drug Safety*, **15(2)**, 105-110 **(2020)**

14. Kinrys G., Gold A.K., Worthington J.J. and Nierenberg A.A., Medication disposal practices: increasing patient and clinician education on safe methods, *Journal of International Medical Research*, **46(3)**, 927-939 **(2018)**

15. Kusturica M.P. et al, Consumer willingness to pay for a pharmaceutical disposal program in Serbia: A double hurdle modeling approach, *Waste Management*, **104**, 246-253 **(2020)**

16. Madikizela L.M., Ncube S. and Chimuka L., Analysis, occurrence and removal of pharmaceuticals in African water resources: A current status, *Journal of Environmental Management*, **253**, 109741 **(2020)**

17. Marwa K.J., Mcharo G., Mwita S., Katabalo D., Ruganuza D. and Kapesa A., Disposal practices of expired and unused medications among households in Mwanza, Tanzania, *PloS One*, **16(2)**, e0246418 **(2021)**

18. Mohammed S.A., Kahissay M.H. and Hailu A.D., Pharmaceuticals wastage and pharmaceuticals waste management in public health facilities of Dessie town, North East Ethiopia, *PloS One*, **16(10)**, e0259160 **(2021)**

19. Mondal Sudip, Saha Rituparna, Mal Bijoy, Acharya Krishnendu and Biswas Gunjan, Comparative study of phytochemicals, antioxidant and anti-inflammatory activity of infusion and decoction extracts from Pycnoporus sanguineus (L.) Murril collected in West Bengal, *Res. J. Biotech*., **18(12)**, 7-13 **(2023)**

20. Muddu Krihna C., Jayaprakash N.K., Asha S. and Sravan Kumar Reddy T., Biological Potential of Ethyl Gallate, *Res. J. Biotech*., **19(1)**, 122-125 **(2024)**

21. Naser A.Y., Amara N., Dagash A. and Naddaf A., Medications disposal and medications storage in Jordan: A cross-sectional study, *International Journal of Clinical Practice*, **75(3)**, e13822 **(2021)**

22. Nyaga M.N., Nyagah D.M. and Njagi A., Pharmaceutical waste: Overview, management and impact of improper disposal, *Journal of Peer Scientist*, **3(2)**, e1000028 **(2020)**

23. Nyaga M.N., Nyagah D.M. and Njagi A., Expired drugs: statistics, factors and mitigation strategies, *Journal of Advanced Education and Sciences*, **2**, 09-11 **(2022)**

24. Padmanabhan K.K. and Barik D., Health hazards of medical waste and its disposal, Energy from toxic organic waste for heat and power generation, Woodhead Publishing, 99-118 **(2019)**

25. Pal P., Treatment and disposal of pharmaceutical wastewater: toward the sustainable strategy, *Separation & Purification Reviews*, **47(3)**, 179-198 **(2018)**

26. Paudel E., Choi E. and Shrestha N., Pharmaceutical Waste Management in Private Pharmacies of Kaski District, Nepal, *International Journal of Innovative Science and Research Technology*, **4(8)**, 543-565 **(2019)**

27. Rogowska J. and Zimmermann A., Household Pharmaceutical Waste Disposal as a Global Problem—A Review, *International Journal of Environmental Research and Public Health*, **19(23)**, 15798 **(2022)**

28. Rose A. and Rae W.I.D., Personal protective equipment availability and utilization among interventionalists, *Safety and Health at Work*, **10(2)**, 166-171 **(2019)**

29. Talele C.R., Talele D.R. and Shah N., Pharmaceutical waste management: critical for the future and the health of nature, *Frontiers In Pharmaceutical Sciences*, 65(2), 85-93 **(2023)**

30. Tank A. and Khambhati D., A New Approach for Effective Biomedical Waste Segregation and Disposal, *International Journal of Innovative Technology and Exploring Engineering*, **4l**, 236-238 **(2021)**

31. Yasir A.A., Environmental impact of pharmaceuticals and personal care products, *Journal of Global Pharma Technology*, **9(9)**, 58-64 **(2017)**.

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