ISSN: 2458-8989

Natural and Engineering Sciences

NESciences, 2025, 10 (1): 162-175 doi: 10.28978/nesciences.1642307

Design of Sustainable Approaches for Pharmaceutical Waste Management in Household Settings

Bhanu Juneja [1*], Shashikant Deepak [2], Dushyanth V Babu R [3], Arjit Tomar [4]

[1*] Assistant Professor, Chitkara University Institute of Engineering and Technology, Centre for Research Impact and Outcome, Chitkara University Institute of Engineering and Technology, Chitkara University, Rajpura, Punjab, India. E-mail: bhanu.juneja.orp@chitkara.edu.in

[2] Assistant Professor, Department of uGDX, ATLAS SkillTech University, Mumbai, Maharashtra, India. E-mail: shashikant.deepak@atlasuniversity.edu.in

[3] Assistant Professor, Department of Civil Engineering, Faculty of Engineering and Technology, Jain (Deemed-to-be University), Ramnagar District, Karnataka, India. E-mail: vb.dushyanth@jainuniversity.ac.in

[4] Assistant Professor, Department of Computer Science & Engineering, Noida International University, Greater Noida, Uttar Pradesh, India. E-mail: arjit.tomar@niu.edu.in

Abstract

Pharmaceutical waste plays a crucial role in treating illnesses and preventing diseases and it has become a significant environmental pollutant. Households, as a primary source of pharmaceutical waste, often contribute to improper disposal practices that harm both public health and the environment. This research investigates the current state of pharmaceutical waste management (PWM) in household settings, focusing on public perceptions and disposal practices. A questionnaire survey was conducted with 500 participants, selected through convenience sampling, to assess the environmental pollution impact of household pharmaceutical waste (HPW) and the disposal methods employed. Descriptive statistical analysis is applied to evaluate the data, with additional simulation models used to estimate the environmental pollution consequences of improper disposal, such as discarding waste in trash bins, sinks, and drains. The simulation incorporated local environmental factors, including waste collection rates, population density, and water flow models. The results revealed that while 80% of respondents were aware of the risks associated with HPW, 55% disposed in regular trash bins, 3.5% poured it down drains, 4.2% disposed in kitchen sinks, and 2.3% in toilet sinks. Additionally, 9.1% of participants flushed medicines directly down the toilet. Although 77% of respondents agreed that HPW should be separated from general waste, only 30% participated in medicine return programs. Furthermore, 85% of respondents reported that data on suitable discarding methods is insufficient, and 70% expressed a need for more accessible disposal options. The findings underscore the need for more sustainable and accessible disposal programs, as well as increased public awareness, to mitigate the environmental risks of improper pharmaceutical waste disposal.

Corresponding Author: Bhanu Juneja, E-mail: bhanu.juneja.orp@chitkara.edu.in

Keywords:

Pharmaceutical waste, waste management, environmental pollution, household settings, disposal methods.

Article history:

Received: 28/10/2024, Revised: 28/12/2024, Accepted: 16/01/2025, Available online: 31/03/2025

Introduction

Pharmaceuticals recognized as drugs, pharmaceuticals, or medicines are ever more acknowledged as ecological pollutants due to their pseudo-persistent nature, organicmotion and extensive usage in individual and veterinary drugs (West et al., 2020; Mousa, 2022; Shakir et al., 2024). Pharmaceutical goods' life cycle, from manufacture to individual use, leads to waste formation, discharging pharmaceutical particles into the surroundings via channels like excretion, inappropriate discarding, and waste from industrialized creation (Samal et al., 2022; Đeković-Šević et al., 2021). Insufficient PWM that is referred to as pharmaceutical waste management, particularly at the domestic level, is a serious worldwide risk that complicates ecological damage and community well-being hazards, especially in areas with poor transportation and communal knowledge (Mitiku et al., 2024). Figure 1 represents the drivers and causes of PW (Orhorhoro et al., 2016).

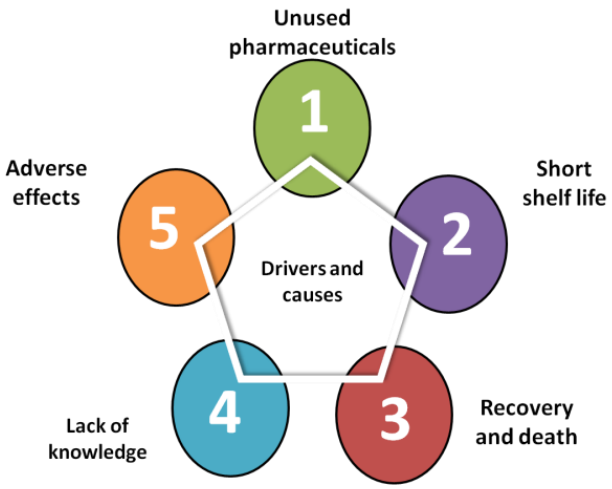

Figure 1. PW drivers and causes

Households contribute significantly to the release of PW into the atmosphere, including unused, expired, and available drugs. Noncompliance with instructions, alterations in treatment, early healing, or faults in recommending and buying are common causes of this waste (Liu et al., 2020). In many countries dealing with elderly residents and poor PW disposal techniques, this topic provides significant ecological and communal well-being challenges. The incorrect removal of domestic PW, like flushing pills or dumping them in common garbage, transfers Active Pharmaceutical Ingredients (APIs) into usual environments, affects dangers to water bodies, and causes drug struggle (Toe et al., 2023). Many places lack efficient waste management practices to reduce these concerns. Specifically in these areas with PWM addressing, like HPW is critical for minimizing contamination and protecting community wellbeing (Ewunetei et al., 2021). Figure 2 denotes the various procedures for PW disposal.

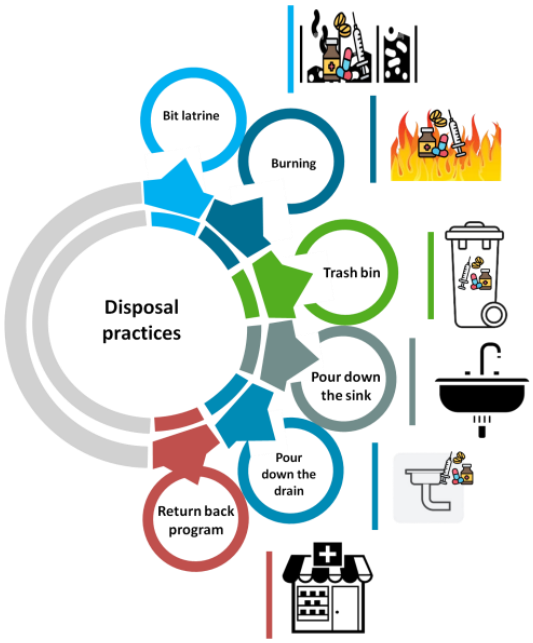

Figure 2. Disposal procedures

Medication is offered from a variety of resources, including municipal and private healthcare, pharmacies, and private hospitals, and categorized as instruction or non-instruction pharmaceuticals. Doctors prescribe prescriptions, and pharmacists dispense them. Non-pharmacists, like drugstore helpers, who need professional well-being requirements at hospitals or pharmacies, distribute drugs, incorporating instruction-only treatments. Drugs for self-care are commonly accessible in drug shops, grocery stores, and internet platforms (Funk et al., 2021). Although worldwide understanding of pharmaceutical toxic waste problems, handling unwanted pharmaceuticals is crucial due to the lack of explicit rules and directives for accurate discarding. The 4th national tactical scheme on chemical administration and the national master scheme, which are associated with global agendas, like sustainable improvement purposes and the tactical techniques for worldwide chemicals organization, have begun to tackle this concern at the state level (Luo et al., 2021). These activities seek to fight pharmaceutical pollution by encouraging sustainable waste managing practices, like altering manufacturing and utilization habits, to limit the liberation of atmospherically determined pharmaceutical pollutants and promote community understanding (Asghari, 2019). Figure 3 represents the hazards of PW (Hussain & Taimooz, 2024).

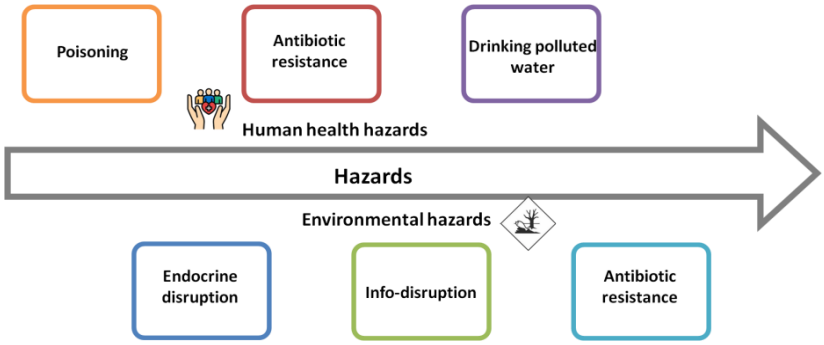

Figure 3. Hazards of pharmaceutical waste

The department of health has also developed society recommendations for the organization of unwanted drugs, urging secure disposal at approved snooze places, like hospitals for expired pharmaceuticals. In the deficiency of a systematic withdrawal scheme, individuals have no selected venues to revisit unneeded

medicines (Chen et al 2023). Various hurdles prevent the secure disposal of unwanted pharmaceuticals in domestics, resulting in the widespread use of incorrect disposal procedures. The prevalence and effects of pharmaceuticals stay unknown, emphasizing the need for further research to update successful measures (Azmi Hassali &Shakeel 2020). Figure 4 represents the mitigation procedures for safe disposal.

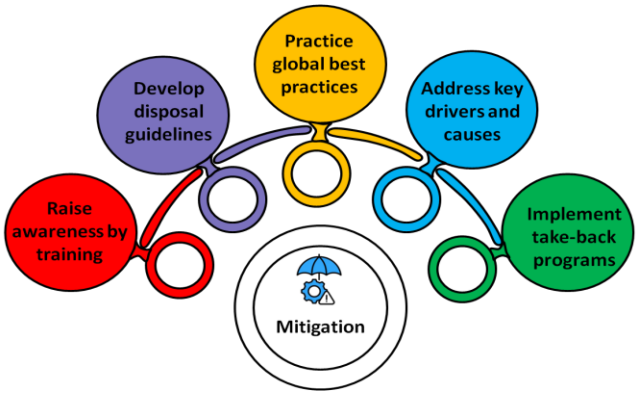

Figure 4. Mitigation procedure

Magagula et al., (2022) examined PWM in Johannesburg, assessing handling, storage, and disposal practices. Using an online survey, data from 286 respondents revealed that 77% knew about household pharmaceutical waste, mainly painkillers (73%) and cold medications (52%). Education influenced proper disposal willingness. The findings highlighted the need for targeted waste management initiatives.

Benítez-Rico et al., (2023) investigated the removal of unused remedies and the occurrence of pharmaceutical remains in Mexico City's water bodies. A cross-sectional survey of 719 residents and survey reports were conducted as a part of two-phase investigation. The findings found that 83.5% used incorrect disposal methods, with 51 medication residues detected. Limited policy implementation impeded mitigation.

Watkins et al., (2022) investigated HPW, storage, and discarding patterns using a cross-sectional investigation of 663 individuals. Multiple regressions were used to demonstrate that age, knowledge, activity, and purpose had an impact on disposal behavior. Limitations include reliance on self-reported data and the need for a greater understanding of correct disposal practices to improve outcomes.

Lima et al. (2020) examined risk perceptions of pharmaceutical pollution, focusing on trust, knowledge, intention, and disposal behavior. Assessment results from 509 individuals in Portugal, Spain, and France revealed that France had higher recycling rates but no increased hazard awareness. The outcomes demonstrated that hazard awareness has an indirect effect on behavior modulated by environmental identity. Limitations include sample variability.

Xu et al., (2023) investigated the factors that influence home pharmaceutical waste (HPW) recycling intentions utilizing the extended Theory of Planned Behavior (TPB). According to the survey results, subjective norms, recycling attitudes, economic incentives, and information publicity have a major impact on recycling intention. There was less trust in the government or the retail industry. The use of self-reported data was one of its limitations.

Aluko et al., (2022) examined the disposal of fallow, damaged, and expired drugs in metropolitan homes. A cross-sectional, comparative research of 404 females was conducted utilizing multi-stage sampling. The findings revealed that the people have strong knowledge and attitudes, they have inadequate disposal behaviors. Limitations include potential sample bias and a regional focus.

Amoabeng et al., (2022) examined the discarding of fallow and expired drugs. A descriptive cross-sectional method examined 400 families and 35 pharmacies using structured interviews. The findings revealed illegal disposal techniques, such as dumping in garbage and incineration. The report emphasized the need for improved educational and disposal guidelines.

Kharaba et al., (2022) assessed community pharmacists' strategies for disposing of expired medications and identified ways to reduce waste. A cross-sectional research of 418 pharmacists in the UAE discovered that more than one-third employed unlawful disposal methods. The research emphasized the importance of specialized disposal facilities and inventory management.

Kahsay et al., (2020) examined the awareness, attitudes, and discarding methods for expired pills. A qualitative poll of 359 people found that half had adequate knowledge, the majority had favorable views, and incorrect disposal techniques were widespread. There was a need for knowledge and practice regarding suitable disposal.

Begum et al., (2021) investigated medicine disposal methods in Dhaka metropolitan homes. A diverse-system approach, including surveys and interviews, was utilized. The results suggested a lack of awareness about drug disposal, with many homes inappropriately disposing of prescriptions. Limitations included a lack of widespread public awareness and conventional laws for safe disposal techniques.

Tegegne et al., (2024) examined knowledge, attitudes, and awareness of unneeded pharmaceutical disposal in Gondar. A population-based cross-sectional investigation revealed low knowledge (42.6%) and attitudes (42.9%) were influenced by age, education, and prior knowledge. One limitation was a need for responsiveness (46.9%) to the hazards connected with discarding.

Althagafi et al., (2022) assessed Saudi Arabian knowledge and awareness of safe pharmaceutical disposal practices. A poll of 1105 participants revealed that 49.1% kept unwanted drugs at home, while 79.5% disposed of them in household trash. There was a lack of education regarding disposal methods. Awareness campaigns were recommended.

Alnsour & Moqbel, (2023) assessed stakeholders' engagement in ascertaining a pharmaceutical extract course. Surveys and interviews with officials, producers, and the general public were done using qualitative cross-sectional methodologies as well as force field analysis. The findings revealed a lack of awareness and opposition among pharmaceutical producers. Limitations include inadequate logistical support and public participation.

Kusturica et al., (2020) explored the HPW disposal habits and inhabitants' willingness to engage in a collecting program in Serbia. A poll of patients from large cities revealed that 80% were probable to contribute, but less than half were eager to forfeit. Environmental pollution awareness and income were key elements determining involvement. Most participants' disposal of their waste was one of the limitations.

McRae et al., (2021) investigated public views regarding medical waste and pharmaceutical recycling in Wales liberated instruction healthcare method. A quantitative online poll of 5,584 respondents demonstrated substantial worries about medical waste, as well as a high level of support for medicine reuse. One limitation was that healthcare workers were biased in their responses.

There was a gap in the research regarding the efficacy of current PWM policies and processes in areas with limited infrastructure and resources. While studies have looked at public attitudes, disposal methods, and awareness across different locations, there was a scarcity of research on targeted interventions, regional

variances, and the implementation of sustainable disposal systems in underserved areas. More research into the impact of education, policy enforcement, and waste management initiatives was needed to close this gap and improve waste disposal practices, particularly in areas with underdeveloped healthcare systems. The research objective is to examine the present condition of PWM in household backgrounds, with a particular concentration on community awareness and disposal procedures. The research also utilizes simulation models to evaluate the ecological impacts of offensive disposal, considering confined ecological features.

Highlights of the Research

The research sheds light on the important ecological hazards caused by offensive pharmaceutical waste disposal in households, emphasizing the requirement for enhanced managing procedures. The research highlights are given below.

The research objective is to examine the present condition of PWM in household situations, with a particular focus on community insights and discarding practices.

The data is gathered from 500 individuals to offer an inclusive thought of communal insights and actual disposal practices, informative gaps among awareness, and dependable exploits.

The research initiates a simulation model to evaluate the ecological impact of offensive disposal and provides valuable perceptions into how various disposal methods contribute to environmental degradation.

The findings designate a strong requirement for improved disposal preferences and public instruction and underline the significance of developing more available and sustainable pharmaceutical waste disposal programs.

The outcomes promote better engagement with drug return programs and more suitable disposal methods, helping diminish the public well-being and ecological hazards connected with PWM.

Methodology

The data is gathered from 500 individuals utilizing a structured questionnaire that focused on sociodemographic features, disposal activities, and environmental pollution knowledge. The research also developed clear inclusion and exclusion principles to ensure those participants' offerings are pertinent. Furthermore, simulation models are utilized to measure the ecological consequences of offensive disposal, and data is evaluated with SPSS software to understand the outcomes and offer realistic insights.

Data Collection

The data is gathered from 500 participants utilizing a structured questionnaire through convenience sampling, focusing on a range of households. The questionnaire collected sociodemographic information, disposal methods for expired drugs, and an understanding of the ecological effect of improper pharmaceutical discarding. All of the questions are closed-ended, with some allowing respondents to record their views if the options are not appropriate.

Selection Criteria

The selection criteria ensure the significance of the sample for the investigation. There are both exclusion and inclusion measures.

Inclusion Criteria

- Respondents' participation in this survey is completely voluntary.
- No specific medical conditions are required, but participants must be familiar with common pharmaceutical products in their households.
- Participants residing in areas with accessible waste collection services and water systems for environmental modeling.
- Participants expressed concerns about environmental pollution or those actively seeking information on sustainable disposal methods.

Exclusion Criteria

Pharmaceutical waste from businesses, healthcare facilities, or hospitals is not considered.

Individuals with a background in the healthcare profession have different disposal practices, so the individual are excluded to avoid bias.

Households that do not use any pharmaceuticals or medications would be excluded, as they do not contribute to pharmaceutical waste.

Participants who report highly irregular disposal practices are excluded to maintain typical disposal behavior focus.

These criteria ensure that the research contains a broad but relevant sample of individuals who are likely to contribute valuable insights on pharmaceutical waste disposal in household settings.

Simulation Models

Simulation models are used to assess the environmental pollution impact of improper HPW disposal, like discarding it in trash bins, pouring it down drains, or flushing it down toilets. These models integrate real-world features and issues that manipulate how waste is disposed of and how it affects the atmosphere.

Key Environmental Factors

- Waste collection rate denotes how rapidly waste is composed of households, impacting the revelation time of HPW to the surroundings.
- Population density is the density of the residents in a particular region that influences the amount of pharmaceutical waste produced and how prevalent the disposal procedures are.
- Water flow models suggest how pharmaceuticals, when disposed of offensively, move through the water bodies. They help to evaluate the hazard of contaminating water sources, disturbing both restricted ecosystems and human wellbeing.

Simulation models forecast the effects of improper pharmaceutical waste disposal, saving time and resources. They offer precious perceptions for decision makers to design effectual waste management programs and evaluate the scale of ecological damage. This technique aids in analyzing the impact of home trash disposal, directing measures for improvement, and encouraging better waste management practices.

Data Analysis

The survey reactions are erratically disguised using integers in Microsoft Excel and then established into the IBM Statistical Package for the Social Sciences (SPSS 20) program for the last investigation. When individuals report unrequited, they are classified as missing values and do not contribute to the investigation results. Demographic information from the survey is summarized using frequencies and percentages.

Result

The goal of this project is to investigate home methods for disposing of pharmaceutical waste (HPW) and raise awareness of its environmental pollution consequences. The evaluation metrics include demographic information, disposal habits, and willingness to participate in return programs or use alternate disposal strategies. The findings are used to identify knowledge and behavior gaps to enhance disposal processes and raise public awareness.

Participant's Information

A participant's information offers major features and data of the research population, categorizing them with features. Significant factors like age, gender, and number of households are evaluated in HPW management practices. Table 1 demonstrates the traits of individuals.

Table 1. Traits of individuals

Variables	Categories	Number of individuals (n=500)	Percentage (%)
Age	20-35	319	63.8
	36-50	113	22.6
	Above 50	68	13.6
Gender	Male	268	53.6
	Female	232	46.4
Educational Qualification	Primary education	92	18.4
	Secondary education	125	25
	Diploma	146	29.2
	Graduated	137	27.4
Number of households	1-2	37	7.4
	3	182	36.4
	4	140	28.0
	5 and above	141	28.2
Medicine consumption	Every day	180	36
	Weekly	93	18.6
	Monthly	31	6.2
	Yearly	103	20.6
	Infrequently	93	18.6

The demographic data of 500 participants show a wide range of features. The majority (63.8%) are between the ages of 20 and 35, with fewer elderly individuals. The gender distribution is generally balanced, with 53.6% females and 46.4% males. In terms of education, 29.2% have a diploma, followed by those who have completed secondary (25%) and primary (18.4%). Household size varies, with the largest group (36.4%) including three people. In terms of medication intake, 36% of individuals take it regularly, whereas 18.6% use it infrequently. These data reveal a variety of educational backgrounds, family sizes, and drug consumption behaviors that influence pharmaceutical waste disposal procedures and awareness levels.

Environmental Consequences of Incorrect HPW Disposal

It is used to raise awareness about how inappropriate disposal endangers ecosystems, water quality, and human health. It examines public attitudes using survey responses to identify gaps between awareness and action. Table 2 represents the individual's response to environmental consequences.

Table 2. Awareness regarding the environmental risks

Queries	Strongly agree	Agree	Neutral	disagree	Strongly disagree
Drug disposal by garbage, sinks, or toilets causes an environmental impact.	123	265	58	33	21
Unsafe medicine disposal methods contribute to increased antibiotic resistance.	104	237	82	51	26
Unsafe drug disposal methods contribute to the development of hormone-dependent malignancies.	94	238	103	41	24
Make ensuring that outdated medications are appropriately segregated and organized.	122	249	74	32	23
I must protect the security of all living genera in the world.	153	204	95	25	23
Were you aware of the risks associated with HPW	172	228	42	38	20

The majority (388 out of 500) agreed that disposing of drugs in the garbage, sinks, or toilets harms the environment. Similarly, a sizable proportion acknowledged the dangers of improper disposal that contribute to antibiotic resistance (341 respondents) and hormone-dependent cancer (332 respondents). However, while 371 participants agreed that expired pharmaceuticals should be appropriately segregated, personal responsibility for environmental safety received significantly less support (357 respondents). The results revealed that while 80% of respondents are aware of the risks associated with HPW. These findings demonstrate a widespread grasp of pharmaceutical waste dangers, but they also indicate the need for greater action-oriented legislation and education to support correct discarding habits.

Disposal Practices for Pharmaceutical Waste in Households

Pharmaceutical waste disposal habits in households refer to how people dispose of expired or unused prescriptions, like tossing them away, flushing them down the toilet, or returning them through programs. This research examines disposal habits using survey data to measure environmental effects and find gaps in responsible behavior, highlighting the need for improved disposal methods and public education campaigns. Table 3 and Figure 5 show the different disposal procedures for HPW.

Table 3. Disposal procedures for HPW

Disposal methods	Percentage (%)
Pour down the drain	3.5
Throw into the trash bin	55
Pour down the sink	4.2
Pour down the toilet sink	2.3
Use separate bin	6.1
Flush down the toilet	9.1
Return program	5.2
Burn	3.3
Keep in store	9.1
Others	2.2

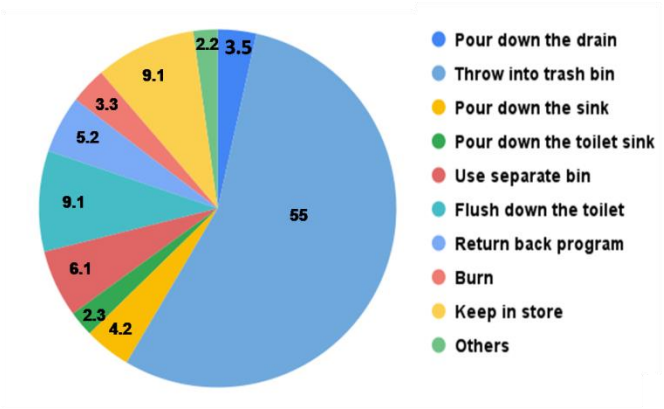

Figure 5. Disposal procedures for HPW

The findings show that incorrect pharmaceutical waste disposal is common, with 55% of respondents throwing drugs in trash cans and 9.1% flushing them down the toilet. Despite 6.1% using separate bins and 5.2% participating in return programs, there remains a substantial disparity in safe disposal methods. The outcomes emphasize the significant necessity for improved public knowledge, enhanced disposal methods, and prolonged return programs to decrease environmental distress and ensure sustainable PWM.

Household Perceptions of the Environmental Impact of HPW

This is an outline of how household participants observe the influence of HPW on the surrounding environment, namely the outcomes of improper pharmaceutical waste disposal on ecosystems, water quality, and public wellbeing. The respondents' opinions are gathered through survey questions, demonstrating great concern about environmental pollution harm and emphasizing the need for better disposal techniques and public education. Table 4 and Figure 6 show the willingness of the household in PWM.

Table 4. Willingness of the households

Household willingness	Agree	Disagree
I planned to take the unused medication and return to the pharmacy.	30	70
HPW should be isolated from ordinary garbage to reduce environmental harm.	70	30
There is plenty of data about the proper disposal of pharmaceutical waste.	85	15
More convenient disposal alternatives for pharmaceutical waste are required.	70	30

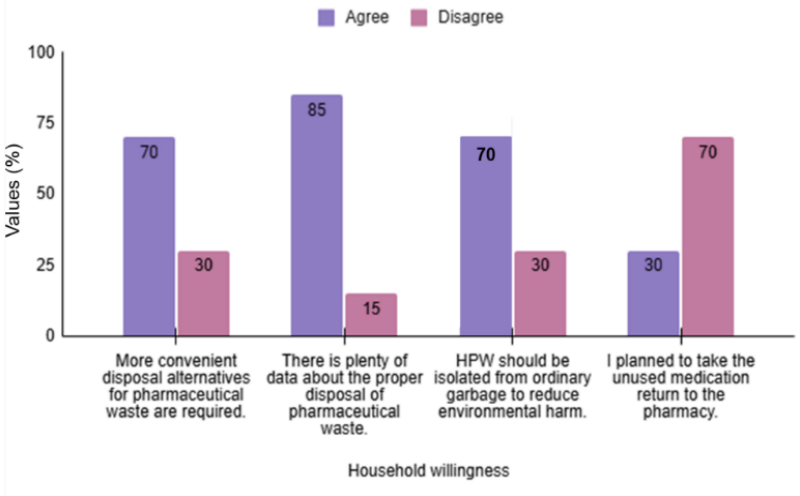

Figure 6. Estimation of household’s willingness

However, 70% of respondents believe that HPW should be separated from regular garbage to avoid environmental harm, and just 30% intend to return unwanted medication to the pharmacy. Furthermore, 85% agree that there is enough information on proper disposal, yet 70% say more convenient disposal options are required. These findings highlight the need for more accessible disposal choices and increased public participation in sustainable practices.

Discussion

This research evaluated domestic insights, discarding habits, and willingness to participate in PWM, with a concentration on the environmental repercussions. The findings showed that 80% of individuals were responsive to the ecological concerns connected with improper discarding, such as the impact on ecosystems and public health. Despite this understanding, many respondents continued to dispose of pharmaceutical waste incorrectly, with 55% throwing it away and 9.1% flushing it. While 77% believed HPW should be separated from ordinary trash, only 30% planned to return unwanted drugs to pharmacies. Furthermore, 85% believe there was enough information on proper disposal, yet 70% expressed a need for more convenient disposal methods. These findings indicated a large gap between knowledge and action, and emphasized the need for improved infrastructure, accessible return programs, and increased public engagement in addressing environmental pollution concerns. The findings highlighted the significance of promoting convenience, public knowledge, and engagement in sustainable PWM procedures.

Conclusion

Evaluating HPW management strategies was critical for understanding the environmental pollution and health consequences of inappropriate disposal. It identified gaps in public awareness and directed actions, such as improved disposal infrastructure, educational campaigns, and easily accessible return programs. This evaluation guided sustainable activities while protecting ecosystems and human health. This research objective was to analyze household beliefs, disposal methods, and readiness to adopt sustainable behaviors. The findings found that, despite widespread awareness of the environmental concerns of HPW, inappropriate disposal is common, with significant gaps in safe disposal behaviors. Despite widespread recognition of the issue, only a tiny fraction of respondents participates in return programs, and many of them continue to dispose pharmaceutical waste in trash cans or toilets. The research's limitations include its dependence on self-reported information and the use of convenience sampling that limits the findings' generalizability. Future research should look into ways to enhance participation in return programs, make disposal options that is more accessible, and implement public education campaigns to close the knowledge-action gap, ultimately leading to more sustainable HPW management practices.

References

Alnsour, M., & Moqbel, S. (2023). Enhancing environmental sustainability through a household pharmaceuticals take-back program in Jordan. *Environmental Monitoring and Assessment*, *195*(12), 1424. https://doi.org/10.1007/s10661-023-12050-7

Althagafi, A., Alshibani, M., Alshehri, S., Noor, A., Baglagel, A., & Almeleebia, T. (2022). Assessment of knowledge and awareness of safe disposal of unused or expired medication in Saudi Arabia: A cross-sectional study. *Saudi Pharmaceutical Journal*, *30*(11), 1672-1678. https://doi.org/10.1016/j.jsps.2022.09.012

Aluko, O. O., Imbianozor, G. T., Jideama, C. O., Ogundele, O. V., Fapetu, T. E., Afolabi, O. T., & Odewade, O. L. (2022). The perception and disposal practices of unused and expired medicines by households in an urban municipality, southwest Nigeria: a comparative cross-sectional study. *Waste Management*, *140*, 121-132.https://doi.org/10.1016/j.wasman.2022.01.022

Amoabeng, I. A., Otoo, B. A., Darko, G., & Borquaye, L. S. (2022). Disposal of Unused and Expired Medicines within the Sunyani Municipality of Ghana: A Cross-Sectional Survey. *Journal of environmental and public health*, *2022*(1), 6113346.https://doi.org/10.1155/2022/6113346

Asghari, M. (2019). Pollution Haven Effect and Water Quality. *International Academic Journal of Economics, 6(1), 91–109.* https://doi.org/10.9756/IAJE/V6I1/1910007

Azmi Hassali, M., & Shakeel, S. (2020). Unused and expired medications disposal practices among the general public in Selangor, Malaysia. *Pharmacy*, *8*(4), 196.https://doi.org/10.3390/pharmacy8040196

Begum, M. M., Rivu, S. F., Hasan, M. M. A., Nova, T. T., Rahman, M. M., Alim, M. A., ... & Rahman, M. S. (2021). Disposal practices of unused and leftover medicines in the households of Dhaka metropolis. *Pharmacy*, *9*(2), 103.https://doi.org/10.3390/pharmacy9020103

Benítez-Rico, A., Pérez-Martínez, A., Muñóz-López, B. I., Martino-Roaro, L., Alegría-Baños, J. A., Vergara-Castañeda, A., & Islas-García, A. (2023). Medical household waste as a potential environmental hazard: an ecological and epidemiological approach. *International Journal of Environmental Research and Public Health*, *20*(7), 5366.https://doi.org/10.3390/ijerph20075366

Chen, M., Hong, Y., Jin, X., Guo, C., Zhao, X., Liu, N., ... & Xu, J. (2023). Ranking the risks of eighty pharmaceuticals in surface water of a megacity: A multilevel optimization strategy. *Science of the Total Environment*, *878*, 163184.https://doi.org/10.1016/j.scitotenv.2023.163184

Đeković-Šević, M., Malešević, Z., & Jovović, M. (2021). RECYCLING OF WASTE SLUDGE FROM WWTP" GORIĆ" VALJEVO USING THE PROCESS OF STABILIZATION AND SOLIDIFICATION. https://doi.org/10.7251/afts.2021.1325.059M

Ewunetei, A., Yisak, H., & Kefale, B. (2021). Household Level Drug Utilization and Associated Factors in South Gondar Zone, North Western Ethiopia. *Drug, Healthcare and Patient Safety*, 47-58. https://doi.org/10.2147/DHPS.S297354

Funk, O. G., Yung, R., Arrighi, S., & Lee, S. (2021). Medication storage appropriateness in US households. *Innovations in pharmacy*, *12*(2), 10-24926.https://doi.org/10.24926/iip.v12i2.3822

Hussain, L. I., & Taimooz, S. H. (2024). Measuring the Levels of Heavy Metal Pollution in Al-Diwaniyah River Water Using Oomycetes Fungus. *International Academic Journal of Science and Engineering*, *11*(1), 312-316.https://doi.org/10.9756/IAJSE/V11I1/IAJSE1136

Kahsay, H., Ahmedin, M., Kebede, B., Gebrezihar, K., Araya, H., & Tesfay, D. (2020). Assessment of knowledge, attitude, and disposal practice of unused and expired pharmaceuticals in community of Adigrat City, Northern Ethiopia. *Journal of environmental and public health*, *2020*(1), 6725423. https://doi.org/10.1155/2020/6725423

Kharaba, Z., Khasawneh, L. Q., Aloum, L., Ghemrawi, R., Jirjees, F., Al Bataineh, N., ... & Alfoteih, Y. (2022). An assessment of the current practice of community pharmacists for the disposal of medication waste in the United Arab Emirates: A deep analysis at a glance. *Saudi Pharmaceutical Journal*, *30*(12), 1773-1780.https://doi.org/10.1016/j.jsps.2022.10.006

Kusturica, M. P., Golocorbin-Kon, S., Ostojic, T., Kresoja, M., Milovic, M., Horvat, O., ... & Tomas, A. (2020). Consumer willingness to pay for a pharmaceutical disposal program in Serbia: A double hurdle modelingapproach. *Waste Management*, *104*,246-253. https://doi.org/10.1016/j.wasman.2020.01.029

Lima, M. L., Luís, S., Poggio, L., Aragonés, J. I., Courtier, A., Roig, B., & Calas-Blanchard, C. (2020). The importance of household pharmaceutical products disposal and its risk management: Example from SouthwesternEurope. *Waste Management*, *104*,139-147. https://doi.org/10.1016/j.wasman.2020.01.008

Liu, N., Jin, X., Feng, C., Wang, Z., Wu, F., Johnson, A. C., ... & Giesy, J. P. (2020). Ecological risk assessment of fifty pharmaceuticals and personal care products (PPCPs) in Chinese surface waters: a proposed multiplelevelsystem. *EnvironmentInternational*, *136*, 105454.https://doi.org/10.1016/j.envint.2019.105454

Luo, Y., Reimers, K., Yang, L., & Lin, J. (2021). Household drug management practices of residents in a second-tier city in China: Opportunities for reducing drug waste and environmental pollution. *International Journal of Environmental Research and Public Health*, *18*(16), 8544. https://doi.org/10.3390/ijerph18168544

Magagula, B. K., Rampedi, I. T., & Yessoufou, K. (2022). Household pharmaceutical waste management practices in the Johannesburg Area, South Africa. *International journal of environmental research and public health*, *19*(12), 7484.https://doi.org/10.3390/ijerph19127484

McRae, D., Gould, A., Price-Davies, R., Tagoe, J., Evans, A., & James, D. H. (2021). Public attitudes towards medicinal waste and medicines reuse in a 'free prescription'healthcare system. *Pharmacy*, *9*(2), 77. https://doi.org/10.3390/pharmacy9020077

Mitiku, A., Bekele, A., Siraj, J., & Hasen, G. (2024). The magnitude and associated factors of unused medications storage practice among households in Jimma city, southwest of Ethiopia: Community-based cross-sectional study. *Exploratory Research in Clinical and Social Pharmacy*, *15*, 100459. https://doi.org/10.1016/j.rcsop.2024.100459

Mousa, T. U. (2022). The Role of the Accounting Profession in Controlling Environmental Pollution According to Requirements of Social Responsibility in Industrial Companies. *International Academic Journal of Social Sciences*, *9*(1), 29-42. https://doi.org/10.9756/IAJSS/V9I1/IAJSS0904

Orhorhoro, E. K., Atuma, E. V., & Adeniyi, A. S. (2016). Design and fabrication of compression molding machine for plastic waste recycling in Nigeria. *Int. Acad. Inst. Sci. Technol*, *3*(11), 1.

Samal, K., Mahapatra, S., & Ali, M. H. (2022). Pharmaceutical wastewater as Emerging Contaminants (EC): Treatment technologies, impact on environment and human health. *Energy Nexus*, *6*, 100076. https://doi.org/10.1016/j.nexus.2022.100076

Shakir, M., Kumaran, U., & Rakesh, N. (2024). An Approach towards Forecasting Time Series Air Pol-lution Data Using LSTM-based Auto-Encoders. *Journal of Internet Services and Information Se-curity*, *14*(2), 32-46. https://doi.org/10.58346/JISIS.2024.I2.003

Tegegne, A. A., Genet, G., Workie Limenh, L., Yohannes, L., Mohammed Seid, A., Alemayehu, T. T., ... & Simegn, W. (2024). Public awareness, knowledge, and attitude regarding proper disposal of unused medicines and associated factors in Gondar city, northwest Ethiopia. *Frontiers in Public Health*, *12*, 1372739. https://doi.org/10.3389/fpubh.2024.1372739

Toe, J., Orok, E., & Erah, P. (2023). Assessment of knowledge and disposal practices of unused and expired household medicines in a community in Liberia. *Exploratory Research in Clinical and Social pharmacy*, *12*, 100369.https://doi.org/10.1016/j.rcsop.2023.100369

Watkins, S., Barnett, J., Standage, M., Kasprzyk-Hordern, B., & Barden, R. (2022). Household disposal of pharmaceuticals: attitudes and risk perception in a UK sample. *Journal of Material Cycles and Waste Management*, *24*(6), 2455-2469.https://doi.org/10.1007/s10163-022-01494-7

West, L. M., Stewart, D., & Cordina, M. (2020). Mixed-methods approach to determine adherence, knowledge and behavioral determinants associated with medication wastage. *Research in Social and Administrative Pharmacy*, *16*(5), 654-662.https://doi.org/10.1016/j.sapharm.2019.08.003

Xu, B. X., Liu, Z., & Rustam, A. (2023). Application of extended theory of planned behavior to explore household pharmaceutical waste recycling intentions: a case study of China. *Journal of Material Cycles and Waste Management*, *25*(5), 2870-2886.https://doi.org/10.1007/s10163-023-01721-9