

PUBLIC KNOWLEDGE, PRACTICES, AND PREDICTORS OF MEDICATION DISPOSAL: A MALAYSIAN CROSS-SECTIONAL STUDY USING SELF-ORGANISING MAP ANALYSIS

Ain Shafiqah Zaidi¹, Aina Amanina Abdul Jalil¹, Zakiah Mohd Noordin^{2,3}, Muhammad Firdaus Aziz⁴, Lee Pei Jia⁵, and Syarifah Syamimi Putri Adiba Syed Putera^{1,*}

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Abstract

The improper disposal of unused and expired medications poses significant environmental and health risks. This study assesses home medication disposal knowledge and practices among visitors to the discharge pharmacy at Hospital Raja Permaisuri Bainun (HRPB), Perak, Malaysia. A cross-sectional survey was conducted, with data analysed using descriptive statistics and Self-Organising Maps (SOM) to identify behavioural patterns. Findings revealed that over 60% of respondents lacked knowledge of proper disposal methods, with a concerning 50.8% resorting to unsafe disposal of household garbage. However, 82.1% expressed interest in learning safe disposal practices and identified pharmacists as their preferred source of information, highlighting opportunities for pharmacist-led public education. Advanced analysis using SOM revealed distinct patterns in disposal behaviours, with female respondents exhibiting greater awareness than males. Individuals with tertiary education were clustered in regions of lower awareness, a finding potentially explained by the Theory of Planned Behaviour (TPB), which suggests a perceived lower risk. Unemployed individuals and those storing large quantities of expired medications showed poorer disposal practices. These findings highlight significant knowledge gaps and opportunities for targeted interventions. Strengthening regulatory frameworks and the implementation of accessible, structured medication return systems nationwide could further address these challenges. This study offers evidence-based insights into public knowledge and behaviour regarding pharmaceutical waste disposal in Malaysia, supported by advanced analytical techniques. These findings also suggest potential directions for enhancing medication waste management strategies.

Keywords: Disposal Behaviours; Disposal Practices; Home Medication; Self-Organising Maps (SOM)

¹ Department of Clinical Pharmacy and Pharmacy Practice, Faculty of Pharmacy and Health Sciences, Universiti Kuala Lumpur, Royal College of Medicine Perak, 30450, Ipoh, Perak, Malaysia. E-mail: ain.zaidi01@s.unikl.edu.my; aina.amanina@unikl.edu.my; khalid.sunaidar@unikl.edu.my; syarifah.syamimi@unikl.edu.my

² Department of Pharmacy Practice, Faculty of Pharmacy, Universiti Teknologi MARA Cawangan Selangor, Malaysia. Email: zakiahmn@uitm.edu.my

³ Cardiology Therapeutics Research Group, Universiti Teknologi MARA, Bandar Puncak Alam, Malaysia. Email: zakiahmn@uitm.edu.my

⁴ Pusat Pengajian Citra Universiti, Universiti Kebangsaan Malaysia. Email: firdaus95aziz@ukm.edu.my

⁵ Department of Pharmacy, Hospital Raja Permaisuri Bainun, Perak, Ministry of Health, Malaysia. Email: peijia@gmail.com

* Corresponding author

Introduction

Medicines are essential for treating disease and improving health, which must be taken with care. The widespread use and storage of prescription and over-the-counter (OTC) medications has led to a significant accumulation of unused or expired drugs within households (Makki *et al.*, 2019). Factors such as non-adherence to treatment plans, changes in medical conditions and impulsive purchases of OTC medication exacerbated this issue (Alemu *et al.*, 2023). Additionally, the common practice of self-medication for minor ailments often leads to medication stockpiling (Mok *et al.*, 2021).

The surplus of pharmaceuticals in households has potential unintended impacts, notably improper disposal (Rogowska and Zimmermann, 2022). Globally, studies indicated that the most common method for disposing of unused medications in households is by dumping them as trash (Aryal *et al.*, 2023), leading to the sporadic release of pharmaceutical residues into the environment, contaminating soil and water bodies and posing risks to ecological balance and human health (Gwenzi *et al.*, 2022). Recognising this concern, Malaysia has implemented initiatives including the Return Your Medicines (RYM) programme, a national effort to provide a safe avenue for disposing of unwanted medications. Despite such efforts, consistent observation of improper disposal practices highlights the need for further research (Ong *et al.*, 2020). This issue is further exacerbated by a lack of public knowledge on safe disposal methods and the absence of comprehensive management strategies in many countries (Ariffin and Zakili, 2019).

To better understand factors influencing medication accumulation and disposal behaviours, this study attempts to assess the knowledge and practices of home medication disposal among visitors at the discharge pharmacy of Hospital Raja Permaisuri Bainun (HRPB), Malaysia, by combining surveys with data-driven analysis. Specifically, this study aims to examine public knowledge and disposal practices in Malaysia, identify predictive factors and provide actionable intervention insights.

Materials and Methods

Study design

This single-centred study employed a quantitative research methodology through a cross-sectional design to assess medication disposal practices and associated demographic factors. Data analysis was enhanced by Self-Organising Maps

(SOM), an artificial neural network technique, to identify clusters and patterns in disposal behaviours. SOM was chosen over traditional regression analysis owing to its ability to identify non-linear relationships, reduce data dimensionality for visualisation of complex patterns and its exploratory capabilities in uncovering distinct behavioural groups based on multiple variables simultaneously. With SOM-based cluster analysis, this study provides a data-driven understanding of medication disposal behaviours, enabling the identification of distinct behavioural groups and informing targeted interventions.

Study Setting

This study was conducted at the discharge pharmacy of HRPB, Ipoh, Perak, a tertiary public hospital serving a diverse population. The discharge pharmacy was selected as the data collection site thanks to its strategic status in capturing individuals who are in the process of managing medications post-hospitalisation. However, it is important to acknowledge that the use of hospital visitors as the study sample may limit the generalisability of the findings to the broader community, as their medication management behaviours might differ due to recent health events or ongoing treatment.

Study Sample

The study sample comprised 252 visitors to the HRPB discharge pharmacy, aged 18 years old and older, who had used at least three medications in the past six months. Inclusion criteria were established to ensure that participants had sufficient experience with medication management. Individuals who had not used medications for the past six months were excluded. A convenience sampling method was employed whereby participants were recruited based on their ease of accessibility and willingness to provide consent. Before their involvement in this study, participants were required to meet the predetermined inclusion criteria. This sample size was determined based on a calculated estimate considering a non-response rate of 10% and a previous Malaysian study reporting that 84% of individuals have unused medications (Wang and Ji, 2020; Wang *et al.*, 2021).

The sample size (n) was calculated according to the formula:

$$n = \frac{z^2 p \left(\frac{1-p}{e^2} \right)}{1 + z^2 p \left(\frac{1-p}{e^2 N} \right)}$$

Where:

$z = 1.96$ for a confidence level (α) of 95%

p = Proportion (expressed as a decimal)

N = Population size

e = Margin of error

$z = 1.96$, $p = 0.826$, $N = 20000$, $e = 0.05$

Study Instruments

A self-administered questionnaire was utilised as the primary data collection tool for the quantitative phase. It captured demographic information (five questions) and medication disposal methods (five questions) through a combination of closed-ended and Likert-scale items. To delve deeper into medication disposal behaviours, the questionnaire incorporated specific questions related to knowledge (five questions), patient (four questions) and medication-related (three questions) factors. This questionnaire was adapted from Al-Qerem *et al.* (2021), with necessary permissions obtained.

The English version was translated into Malay using the standard forward-backwards translation method to ensure linguistic and conceptual equivalence. Face validity of the translated version was assessed by a panel of experts in pharmacy practice. A pilot test was conducted with 30 participants sharing similar characteristics with the target population. The purpose was to evaluate clarity, comprehensibility and feasibility. Minor wording adjustments were made based on feedback.

The reliability of the questionnaire was assessed using Cronbach's alpha to determine internal consistency, yielding an overall Cronbach's alpha of 0.76. Domain-specific values were as follows: Knowledge domain ($\alpha = 0.677$), Patient-related factors ($\alpha = 0.651$) and Medication-related factors ($\alpha = 0.821$) indicating acceptable to good internal consistency.

The final questionnaire was distributed to eligible participants at the study site between March and April 2023. Participants completed it independently, with researchers available to provide clarification if needed.

Data Analysis

Descriptive statistics (means, frequencies and standard deviations) were employed using SPSS version 22.0 to summarise demographic data and medication disposal practices. Each item in the knowledge-related, patient-related and medication-related domains was measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Mean scores were calculated for each domain to assess the overall level of agreement.

A scoring index was developed for the knowledge domain by summing the five individual item scores, following the method described by Fang *et al.* (2021), with higher scores indicating greater knowledge of safe medication disposal. Similarly, composite scores were calculated for the patient-related (four items) and medication-related (three items) domains by summing their respective item scores. In both domains, higher scores reflected stronger agreement with perceived barriers or beliefs influencing medication disposal behaviour, as adapted from Al-Qerem *et al.* (2021).

Data cleaning was performed in SPSS. Among the 254 individuals approached, 252 fully completed the questionnaire. There were no missing values or incomplete responses for any of the variables analysed. As such, no imputation or additional missing data handling procedures were required. Beyond descriptive statistics, the SOM algorithm was applied using MATLAB (version 16b) as the primary technique for clustering and identifying behavioural patterns. The selection over other clustering methods came from its ability to preserve topological relationships and provide intuitive visual maps of high-dimensional data. This makes it particularly suitable for exploratory behavioural pattern analysis in public health contexts (Agboka *et al.*, 2025). However, it is important to acknowledge certain limitations of the SOM approach. While visually appealing, the interpretation of the resulting maps can sometimes be subjective and requires experts to fully understand the topological relationships and the representation of high-dimensional data on a lower-dimensional grid.

Before applying the SOM algorithm, data were pre-processed to ensure comparability across variables. First, as no incomplete, corrupted, or duplicate data points were identified during the cleaning phase in SPSS, no data points were removed. Subsequently, since SOM is primarily used for exploratory analysis and clustering, the entire dataset was utilised to train the model. This approach enabled the algorithm to capture the full structure and distribution of the input data without the need for splitting it into training and validation subsets. To standardise the range of values across variables and prevent those with larger scales from disproportionately influencing the SOM formation, z-score normalisation was applied. This method transformed each variable to have a mean of 0 and a standard deviation of 1.

Ethical Approval

This study was approved by the Malaysian Medical Research Ethics Committee (Reference

No: NMRR ID-22-02584-NQL). Written informed consent was obtained from all participants before their inclusion in the study.

Privacy and Confidentiality

Participants' confidentiality and data security were strictly maintained. All collected data was securely stored, with personal information protected from unauthorised access. Meanwhile, digital data was password-protected and had inactivity timeouts. Physical records were locked securely. Data had been retained for two years before secure destruction. Participant anonymity was ensured in all reporting. Access to data was limited to the research team, with potential review by monitors and auditors as required for ethical compliance.

Results

Part 1: Quantitative study

Respondent demographics revealed a predominantly young female population (mean age of 30.16 years old, SD 12.34). Educational attainment was primarily at the bachelor's level (44.0%), with a majority belonging to lower-income households ($n=97$, 38.5%). The household size centred around 5-9 members ($n=178$, 70.06%). (Figure 1).

Knowledge regarding medication disposal was limited, with over 60% of participants lacking information on proper disposal methods (Figure 2). Despite this gap, the majority expressed interest in learning more about safe disposal practices. While improper disposal, such as throwing medications in the garbage (Figure 3), was prevalent, participants identified pharmacists as a primary source and preferred source for obtaining information on medication disposal (Figure 4).

Present findings (Table 1) suggested that respondents perceived system-level barriers (Q22-24) as significant obstacles to proper medication disposal. High agreement with knowledge-related items indicated that participants were both aware of the knowledge gap (Q21) and willing to act responsibly if structural supports like accessible disposal sites are available (Q29). In contrast, patient-driven reasons for medication accumulation were less strongly endorsed, suggesting that while individual behaviours do contribute, participants viewed the absence of convenient, well-integrated disposal options (Q29) and inconsistent guidance from healthcare providers (Q22) as more influential in shaping disposal practices. Additionally, strong agreement with medication-related triggers (Q310-31) showed a reactive approach to disposal driven

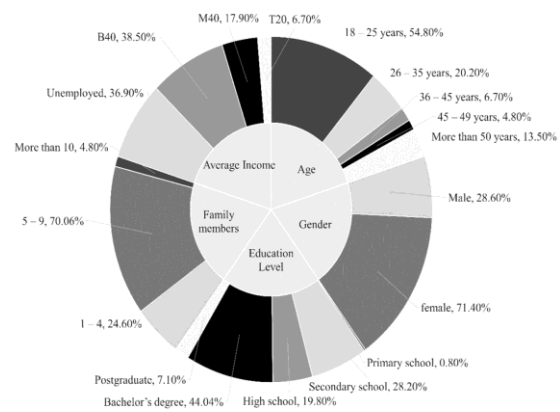


Figure 1. Respondents' demographic characteristics

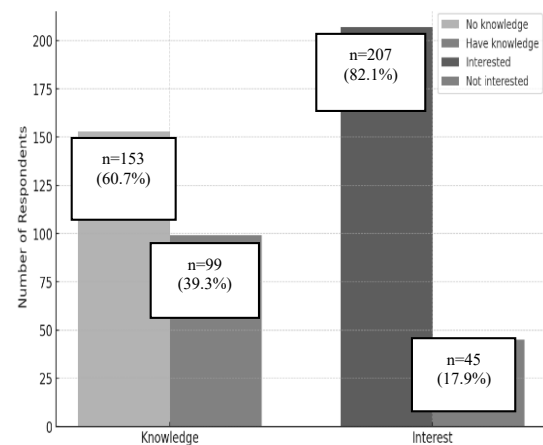


Figure 2. Respondents' knowledge and interest in medication disposal method

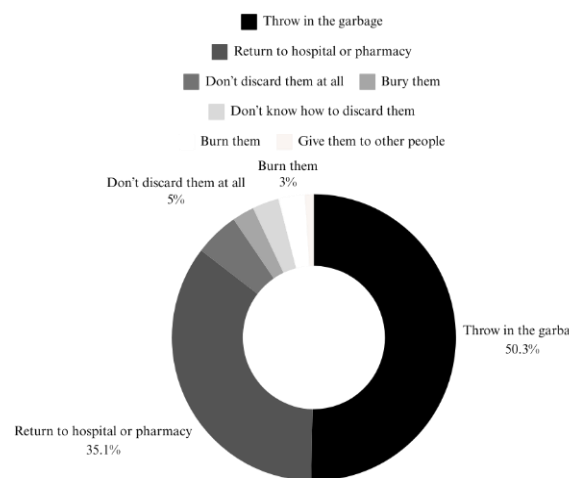


Figure 3. Respondents' preferred methods of medication disposal

Table 1. Practice towards home medication disposal

N = 252 Factors	Questions	Total Mean
Knowledge-need	Q21. There is a lack of knowledge among the population about the appropriate ways to discard medications.	4.16
	Q22. Doctors and healthcare providers must take a more active role in counselling patients about the correct methods of discarding medications.	
	Q23. The government is responsible for the enactment of strict policies on the returning of unused medications to their sources and providing a suitable place to discard unused medications.	
	Q24. There is a need for more awareness and orientation about the proper ways to discard medications.	
	Q29. I will discard my medications in a suitable place if it is available.	
Patient-related	Q25. I have unused medications because I stop taking them when I feel better.	3.45
	Q26. I have unused medications because I experience unwanted side effects.	
	Q27. I have unused medications because I do not feel better as I have expected.	
	Q28. I have unused medications because I have not taken the medications as instructed/prescribed.	
Medication-related	Q30. I dispose of my medications when the medications have expired.	4.17
	Q31. I dispose of my medications when they smell, taste, or look bad.	
	Q32. I dispose of my medications when I have not stored them correctly or when they turn bad.	

by circumstances such as expiration rather than initiative-taking planning.

Part 2: SOM Analysis

Figure 5 presents the SOM analysis, which explores the relationship between demographic, socioeconomic and behavioural factors and participants' medication disposal habits. The SOM achieved a final quantisation error (QE) of 0.33 and a topographic error (TE) of 0.12. The QE reflects the average distance between input data and their best-matching units (BMUs), with lower values indicating a better fit of data to the map. The TE assesses how well the map preserves the topological structure of the data. According to prior studies, a QE below 0.5 and a TE below 0.2 are generally considered acceptable for health behaviour data (Kohonen, 2001; Vesanto and Alhoniemi, 2000). Therefore, the obtained values indicated a robust representation of the data with minimal distortion and strong topological preservation.

The U-matrix (Figure 5(a)) illustrated the cluster boundaries, while component planes (Figure 5(b-s)) revealed the distribution of individual variables across the SOM grid. The SOM analysis identified three distinct behavioural clusters (Figure 6): Cluster B (High Awareness, Responsible Disposers), Cluster A (Low Awareness, High Willingness to Learn) and Cluster C (Low Awareness, Low Engagement).

Cluster B demonstrated proper disposal knowledge and a proactive approach to discarding unused medications. A higher proportion of female respondents occupying this cluster aligns with broader trends of greater health engagement among

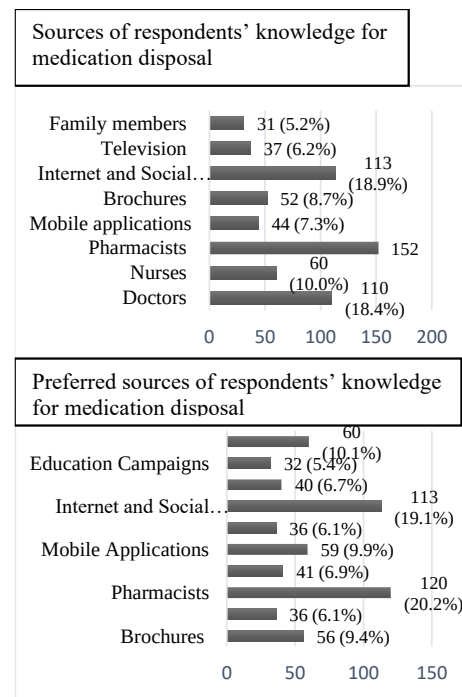


Figure 4. Respondents' knowledge sources and preferences for medication disposal

women. Sociodemographically, they were often employed and educated beyond the secondary level.

Component plane visualisation confirmed systematic knowledge gaps across clusters regarding proper disposal methods and environmental risks while differentiating Cluster A's unique combination of low awareness with high

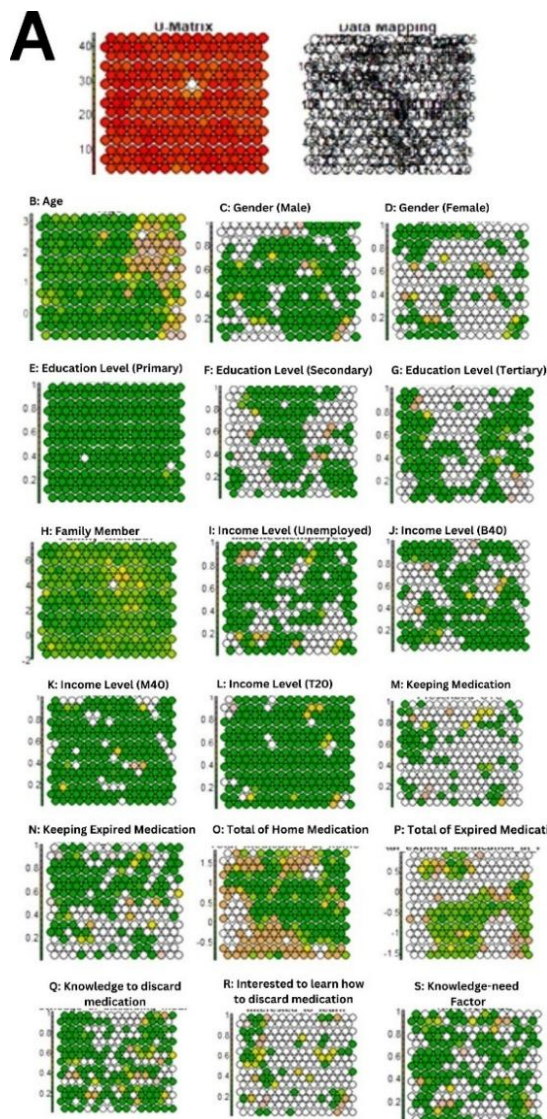


Figure 5. SOM representing the relationship of all variables against the medication disposal behaviour. The relationship between SOM component plane forms and clusters is represented in the (A) U-matrix. Each component plane in the SOM represents the variables used in this study

receptivity to education. The cluster comprised a significant proportion of individuals with tertiary education, further emphasising the counterintuitive finding of a disconnect between educational attainment and disposal of knowledge observed in the overall analysis.

Employment status also emerged as a differentiating factor, with unemployed individuals being concentrated within Cluster C, potentially reflecting barriers to accessing health information and resources. The analysis also revealed

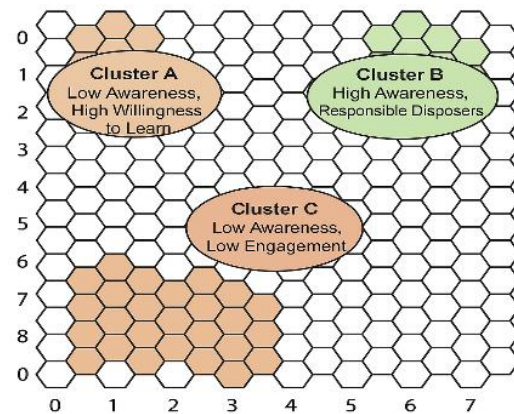


Figure 6. Participants' Clusters from SOM Analysis

associations between unemployment, medication stockpiling behaviours and limited risk recognition in Cluster C, suggesting a passive approach to medication management. The U-matrix (Figure 5(a)) visually supported the separation of these three clusters with clear inter-cluster distances.

Discussion

Improper disposal behaviours, including flushing and discarding medications with household waste, are a shared concern across Southeast Asia, with similar practices documented in Indonesia and Thailand (Insani *et al.*, 2020; Srijuntrapun and Maluangnon, 2024). However, while these studies provide valuable insights into the extent of the issue, their reliance on general population surveys often limits their ability to capture the complex interplay of factors driving these behaviours at an individual level. Moving beyond these general trends, the use of SOM analysis in this study offered a behavioural segmentation. This data-driven approach yielded several transformative insights with significant theoretical implications for the understanding of health behaviour models and practical implications for designing targeted educational interventions.

The counterintuitive finding of tertiary-educated individuals cluster in low-awareness groups contrasts with the widely held assumption in the literature that formal education inherently promotes responsible health behaviours (Liu *et al.*, 2023). This paradox indicates that educated populations may develop false confidence in self-knowledge of disposal, supported by the Extended Theory of Planned Behaviour (TPB) (Foon *et al.*, 2020). This study's findings emphasise that knowledge does not inherently translate to action unless accompanied by behavioural intention and

social reinforcement. This highlights the need to move beyond simply increasing awareness and to focus on strategies that foster intention and leverage social norms within specific population segments.

Additionally, unemployed individuals were identified as a critical risk group. This population tends to retain expired medications and exhibits the lowest levels of environmental concern. The behavioural pattern revealed through SOM analysis offers a compelling explanation for the persistent underutilisation of Malaysia's RYM programme compared to traditional surveys (Saharuddin *et al.*, 2024). These insights highlight a critical limitation of general awareness campaigns, which fail to address the specific cognitive and motivational barriers prevalent within distinct behavioural clusters (Samkange-Zeeb *et al.*, 2022). Consequently, a paradigm shift is needed, moving away from generic awareness-raising towards targeted, cluster-specific behaviour change strategies. To effectively bridge the gap between awareness and action, programmes must simultaneously address the "how" and "why" of proper disposal, tailoring approaches for different clusters (Binu *et al.*, 2024). This necessitates grounding interventions in behavioural science principles, with a specific focus on factors such as perceived susceptibility, environmental responsibility and social norms, particularly within high-risk clusters (Foon *et al.*, 2020).

Pharmacists, as accessible healthcare providers, are well-positioned to lead public medication return initiatives and educate the public on safe disposal. However, their involvement remains limited due to a lack of formal mandates, insufficient incentives and inadequate training in environmental health (Chong *et al.*, 2022). While Malaysia's RYM campaign offers a foundational platform, lessons from international models underscore that scalable success depends on embedding not just infrastructure but also financial, regulatory and operational incentives (Alfian *et al.*, 2024). For instance, the US federally regulated pharmacy dropbox system established under the 2014 DEA policy illustrates how centralised funding and streamlined logistics can alleviate the operational burdens on pharmacists. In contrast, the UK "Take Action for Inhaler Recycling (AIR)" scheme revealed that even with industry-sponsored logistical support, voluntary pharmacy participation plateaued at 65%, highlighting that participation may stagnate without formal incentive mechanisms (Murphy *et al.*, 2023). Although direct evidence on pharmacists-specific incentives remains scarce, relevant mechanisms from patient and industry-focused models offer transferable insights. Buffington *et al.* (2019) found that the public

perceived modest incentives, such as cash US\$1 from prescription costs, loyalty points or charity donation options, as effective motivators for returning unused medications. These behavioural nudges could be reframed into service-linked incentives for pharmacists, such as reimbursements per unit returned, per counselling session or based on patient engagement outcomes. Additionally, regulatory incentives such as tax exemptions and grants for sustainable pharmaceutical practices, as proposed by Jairoun *et al.* (2025), could be extended to pharmacies investing in take-back infrastructure or seeking green certification. Embedding such strategies into a nationally coordinated, pharmacist-led framework would strengthen the RYM programme while supporting long-term scalability and engagement (Muhamad *et al.*, 2023).

Limitations

While this study provides valuable insights into medication disposal practices within a specific hospital setting, several limitations warrant consideration. This study was conducted on visitors to a single hospital, potentially limiting the generalisability of the findings to other populations. As a cross-sectional study, it cannot establish causality, while the use of self-reported data introduces potential recall and social desirability biases. Furthermore, the absence of qualitative data constrains the understanding of the underlying reasons why certain behavioural clusters persist in unsafe disposal practices despite having the capacity for better choices. The use of convenience sampling in recruiting participants may have further limited the representativeness of this study's sample, as those more willing or available to participate might not reflect the broader population.

While the study setting within a hospital discharge pharmacy provides a valuable opportunity to investigate medication disposal practices in a specific patient population, it is important to acknowledge potential limitations to the external validity of the present findings. Patients utilising a discharge pharmacy may be more acutely ill and likely have better access to prescribed medications compared to the general population. This increased interaction with the healthcare system and potentially greater awareness of medication management could influence their disposal behaviours. Therefore, generalising these findings to broader community settings should be done with caution.

Besides, this study was conducted in Ipoh, the capital city of Perak, which likely benefits from a higher concentration of healthcare facilities and pharmacies compared to the state's more rural districts. This urban-centric sample may not fully

capture the challenges and experiences related to medication disposal faced by individuals in less urbanised areas of Perak, where access to disposal information and facilities might be more limited.

Future Directions

Future research should include a more diverse and representative sample across multiple healthcare facilities and community settings to enhance the validity and applicability of findings. Investigating the motivations behind unsafe disposal behaviours in well-educated individuals is warranted, focusing on risk perception, trust in healthcare systems and prevailing cultural norms. Expanding the scope to include underrepresented groups, such as rural residents and unemployed individuals, will also be crucial for developing inclusive public health strategies.

On top of that, qualitative methods such as focus group discussions or in-depth interviews could be employed to validate and enrich the SOM-derived behavioural clusters, providing context-specific insights that support tailored messaging. Future studies should also explore the impact of pharmacist-led educational interventions on public disposal practices, particularly within high-risk behavioural segments, to identify scalable, evidence-based solutions.

Conclusions

Addressing improper medication disposal requires a comprehensive, multi-pronged approach, integrating public education, policy-driven interventions and improved accessibility to disposal facilities. Targeted interventions for at-risk groups (such as the unemployed and households with stockpiled medications) and mandatory pharmacist engagement are critical next steps. By leveraging data-driven insights such as those from SOM analysis and adopting successful international models, policymakers could prioritise structured, accessible disposal systems supported by continuous public education.

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