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Original Article

Survey to Solutions: A Digital Health Platform to Promote Safe Drug Disposal Practices in India

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ABSTRACT

Background: Improper disposal of unused or expired medicines poses serious risks to both public health and the environment. In India, limited awareness of official guidelines and the absence of systematic collection mechanisms contribute to unsafe practices, such as discarding medicines in household trash. **Objectives:** This study aimed to assess the knowledge, attitudes, and practices of the public regarding drug disposal in India and to develop a digital platform, PillBin, to promote safe and accessible disposal practices. **Materials and Methods:** A cross-sectional survey was conducted with 383 participants from varied professional backgrounds between December 2024 and January 2025. A structured questionnaire was used to collect data on participants' knowledge, attitudes, and practices related to drug disposal. Insights from the survey informed the design of PillBin, a multilingual mobile and web-based platform that provides educational resources and interactive disposal guidance. **Results:** Awareness of official drug disposal guidelines was limited, while the commonest drug disposal method was found to be through the household trash. Awareness was higher among healthcare professionals. Most respondents expressed a need for additional information, with websites and mobile applications preferred as educational channels. Technology preferences did not differ by location. Analgesics, cough syrups, and antacids were the most commonly reported leftover medicines. **Conclusion:** The study highlights critical gaps in drug disposal awareness and practice in India, emphasizing the need for scalable solutions. PillBin addresses these gaps by offering accessible, multilingual digital education and disposal guidance, thereby contributing to safer pharmaceutical waste management and public health protection.

Keywords: Digital health intervention, Drug disposal, Health knowledge, Mobile application, Public health.

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INTRODUCTION

Drug disposal refers to the safe and responsible process of discarding unused, expired, or unwanted pharmaceutical products to minimize harm to humans, animals, and the environment (OECD, 2022). Implementing proper disposal methods helps prevent misuse and abuse of pharmaceuticals while reducing the risk of environmental contamination from residual drugs entering ecosystems (World Health Organization, 2011). The presence of pharmaceuticals in the environment due to human use has been widely documented, highlighting both current knowledge and emerging challenges (Kümmerer, 2009). Global analyses have detailed the occurrence and persistence of pharmaceutical contaminants across water, soil, and sediments, emphasizing the urgent need for coordinated policy action (Aus der Beek *et al*., 2016).

In most of the Asian and African nations, medications are commonly discarded in household waste, leading to accumulation at landfills without proper containment or treatment (Ayalew *et al*., 2021). A study in USA reported acetaminophen concentrations as high as 117,000 ng/L in landfill leachate, the highest among measured pharmaceuticals (Lubick, 2010). Similar environmental findings include widespread detection of pharmaceuticals in rivers worldwide (Khan *et al*., 2023), with over 25% of sampled rivers containing pollutants at toxic concentrations, particularly in Sub-Saharan Africa, South Asia, and South America (Wilkinson *et al*., 2022).

Such environmental contamination fosters the emergence of resistant microorganisms, including third-generation cephalosporin-resistant *Escherichia coli*, methicillin-resistant *Staphylococcus aureus*, multidrug-resistant *Candida auris*, and carbapenem-resistant *Klebsiella pneumoniae* (Martinez, 2009; World Health Organization, 2021). Diclofenac residues have been linked to catastrophic declines in vulture populations

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in South Asia (Oaks *et al.*, 2004; Prakash *et al.*, 2007), and endocrine-disrupting compounds such as estradiol and ethinyl estradiol have been shown to feminize male fish and impair reproductive function (Kolpin *et al.*, 2002; Jobling *et al.*, 2002).

Globally, more than half of all medications are prescribed or sold inappropriately (Ogunshe and Adinmonyema, 2014), contributing to unnecessary accumulation in households due to factors such as poor adherence, prescription changes, and recovery from illness (Vuong and Marriott, 2006; Glassmeyer *et al.*, 2009; Seehusen and Edwards, 2006). In India, studies have shown that more than 90% of consumers dispose of medicines via household waste, with limited awareness of safe disposal guidelines or access to take-back programs (Abahussain and Ball, 2007; Manocha *et al.*, 2020; Sonowal *et al.*, 2016). National guidelines for safe disposal were introduced in May 2025 (CDSCO, 2025), but they focus primarily on large-scale manufacturers and healthcare facilities, with limited guidance for household-level drug disposal.

Considering India's estimated 750-886 million active internet users in 2024, with significant rural smartphone penetration (IAMAI and Kantar, 2024), digital health tools represent a scalable opportunity to improve public awareness and adoption of safe drug disposal practices.

This study aimed to evaluate public knowledge, attitudes, and practices regarding drug disposal and to develop PillBin, a multilingual mobile and web-based platform to promote safe pharmaceutical waste management in India.

MATERIALS AND METHODS

Selection and Description of Participants

The questionnaire was developed following an extensive literature review on public health awareness and drug disposal practices (Kanyari *et al.*, 2024; Patel *et al.*, 2019). Participants were recruited from various backgrounds, including students and teaching faculties, healthcare professionals (doctors, pharmacists, nurses), paramedical staff (physiotherapists, lab technicians), and members of the public from both urban and semi-urban areas. Inclusion criteria were: age ≥18 years, recent exposure to medicines within the past three months (through personal use, prescription, or handling). The number of participants (n) was estimated using a single-proportion formula:

$$n=\{Z^2p(1-p)\}\div d^2\times DEFF$$

Which came out to be 383.14≈383.

Technical Information

The questionnaire was structured in simple English for clarity and comprised four sections: section 1-informed consent, section 2-demographic details (gender, age), section 3- questions assessing knowledge, attitudes, and practices regarding drug disposal and section 4- suggestions for improving disposal practices. Content validity was established through assessment of survey questionnaire by five medical experts, and suggested amendments were incorporated. Face validity was tested with 10 participants, whose data were excluded from final analysis. Distribution channels included institutional circulation, direct outreach, and online platforms (Google Forms, WhatsApp). The survey contained yes/no, multiple-choice (single and multi-select), Likert scale, and categorical questions, with open-ended fields for participant suggestions.

Statistics

Demographic data were recorded, and chi-square tests were used to assess associations between demographic variables and participant knowledge or attitudes toward drug disposal. Variables analyzed included professional category (medical or non-medical) and location (urban, semi-urban, rural). Statistical significance was set at $p<0.05$. Data were analyzed using SAS 9.4 software, with statistical assistance from Claude AI.

Ethics

The study adhered to ethical principles outlined by the Indian Council of Medical Research for research involving human participants (ICMR, 2017). Participation was voluntary, informed consent was obtained, and no personally identifiable information was collected. Permission for conducting the study was granted by the Chairperson of Ethics Committee, C.U. Shah College of Pharmacy, SNDT Women's University.

RESULTS

A total of 383 participants participated in the survey. The participants consisted of majority of female (53.5%), in the age range of 18-40 years (78.6%), and resided in urban areas (74.2%). Detailed demographic characteristics are summarized in Table 1.

Based on their professional experience, the participants were categorized into medical (34.5%) and non-medical (65.5%), ensuring adequate representation from both healthcare and general public groups for comparative analysis. Distribution of participants from healthcare background is shown in Figure 1.

The guidelines with regards to household drug disposal have come into existence in India in May 2025. Until recently, India lacked specific national guidelines addressing household-level pharmaceutical disposal, leading to inconsistent and unsafe practices such as discarding medicines in household waste or drains. This regulatory gap contributed to widespread environmental contamination and public unawareness about safe disposal methods. This was reflected in results, as approximately one third of participants reported being aware of such guidelines (Table 2). Awareness of existing medicine take-back facilities was similarly low, with only 19.3% reporting knowledge of any NGO, pharmacy, or organization facilitating safe disposal.

Despite limited awareness, participants were found to have willingness to learn about correct disposal practices was observed. A significant majority of participants (78.3%) expressed interest in learning more about proper drug disposal methods, and 45.4% indicated they would be very likely to use formal disposal services if such facilities were easily accessible (Table 2).

The survey also tried to deduce the classes of drugs which are predominantly left at domestic level, leading to improper disposal. It was found that, analgesics were highest in leftover category (Figure 2). The top-most reason for having leftover medication shown in Figure 3 was observed to be 'change in prescription by doctor (44.4%), followed by 39% of patients stopping the treatment after symptomatic relief, also indicating patient non-compliance. This also reflects the high prevalence of over the counter and symptomatic medicines in daily use.

The predominant disposal practice was found to be through household dustbins reported by 89.2% of respondents. Only 11.4% returned unused or expired medicines to pharmacies or take-back programs, reflecting minimal adoption of environmentally safe disposal methods (Figure 4) (Table 3).

Significant differences were observed between medical and non-medical participants regarding awareness and disposal practices (Table 4). Awareness of drug disposal guidelines was significantly higher among medical professionals (40.2%) compared to non-medical respondents (30.7%; p=0.004). Medical respondents were also less likely to dispose of medicines in household dustbins (84.1%) than non-medical participants (91.6%; p=0.025).

Checking expiry dates before medicine use was significantly more common among medical respondents (94.7%) compared to non-medical participants (90.8%; p=0.037). Although, preferences for receiving disposal information through mobile applications or websites did not differ significantly between the two groups (p>0.05).

Websites (59.0%) and mobile applications (55.4%) were the most preferred sources for drug disposal information. These preferences were consistent across urban, semi-urban, and rural participants, with no statistically significant variation by location (Table 3), suggesting broad feasibility of digital interventions for public education.

DISCUSSION

The CDSCO guidance emphasizes that improper disposal of pharmaceuticals can lead to contamination of soil and water, posing significant risks to human, animal, and environmental health. It highlights the need for systematic collection, segregation, and disposal through approved biomedical waste channels to ensure regulatory compliance and public safety. Improper household disposal like throwing in dustbins or drains is identified as a primary cause of environmental pollution. It recommends that State Governments, local bodies, and chemist associations establish "drug take-back sites or programs" where people can drop their expired or unused medicines for safe collection and disposal under the Biomedical Waste Management Rules (2016) (CDSCO, 2025).

This study highlights critical gaps in public knowledge and practices regarding the disposal of unused and expired medicines among the 383 respondents surveyed. There was a limited awareness of the disposal guidelines issued by regulatory authorities like the WHO or FDA. The participants from healthcare profession background were observed to have notable awareness, indicating the professional training is playing a role in disposal behavior.

Disposal of medicines in household trash was reported as common practice, despite contributing to environmental pollution and antimicrobial resistance. Although, participants from healthcare background were less likely to perform these practices, dustbin disposal was significantly more common yet this method is unsafe and environmentally harmful; medicines should be securely packed and mixed with inert materials such as soil or coffee grounds before disposal to prevent misuse, accidental exposure, and environmental contamination.

Table 1: The demographic characteristics of the study participants (n=383).

Demographic Parameters		Number	Percentage
Gender	Male	178	46.5
	Female	205	53.5
Age	18-20 years	149	38.9
	21-40 years	152	39.7
	41-60 years	72	18.8
	60+ years	10	2.6
Location	Urban	284	74.2
	Semi-Urban	63	16.4
	Rural	36	9.4

Table 2: Responses of Questions related to Knowledge based questions such as Awareness, Practices and Suggestions.

Domain	Questions	Responses (%)
Awareness	Are you aware about drug disposal guidelines given by WHO or Indian Regulatory Authorities?	Yes (33.9), No (66.1%).
	Are you aware of any NGO, Chemist, which takes back unused/expired medications?	Yes (19.3%), No (75.5%), Maybe (5.2%).
Willingness	If such facilities were available, how likely are you to use them?	Very likely (45.4%), Very unlikely (13.1%).
Experience	Have you ever returned unused medications to a pharmacy or medicine take-back program?	Yes (33.9%), No (58%), Maybe (8.1%).
Need of information	Would you like to be informed about drug disposal awareness programs or related initiatives?	Yes (78.3%), No (12.5%) Maybe (9.1%).
Initiative	How would you like to be informed about Drug Disposal Guidelines?	Through Apps (55.4%) Through Website (59%) Through Pharmacist (47%) Through personal communication (43.3%).
Encouraging factors	What would encourage you to adopt proper drug disposal practices?	Awareness Campaigns (66.8%) Nearby Disposal Facilities (59.8%) Home disposal Kits (48.6%) Government Regulations (38.9%).
Disposal practices	How do you normally dispose your medicines?	Household dustbins (89.2%), Pharmacy returns (11.4%), Flushing in toilet/sink (11.8%), Burning or burying (4.4%).

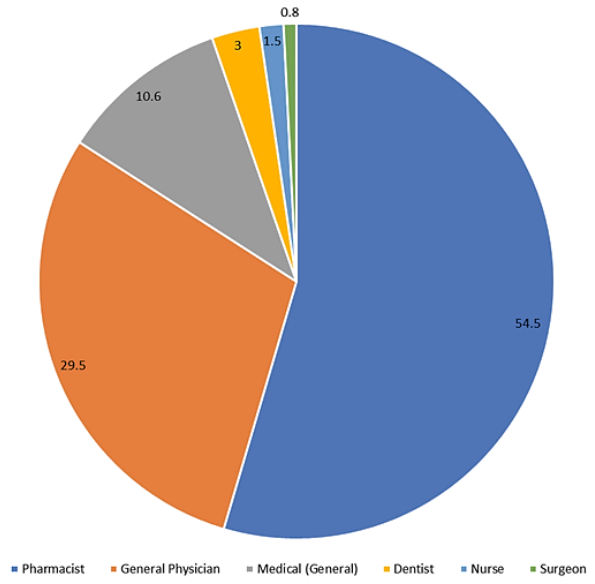

Figure 1: Distribution of Participants from Healthcare Background (*n*=132).

Discontinuing medications after symptomatic relief or following changes in prescriptions, were resulting in leftover medicines at home, for considerable number of participants. These findings also highlight the practices related to patient compliance. The accumulation of unused medicines not only increases the risk of improper disposal but may also contribute to accidental exposure, misuse, and environmental contamination. Strengthening patient counseling and reinforcing adherence education may help reduce medicine wastage at the household level. There is a significant infrastructural gap in safe disposal mechanisms as denoted by limited awareness and availability of pharmacy-based or organized medicine take-back services. Despite this, participants expressed a strong willingness to adopt proper disposal practices if accessible options were made available. This suggests that the absence of easy and approachable disposal pathways limits safe practices.

Polypharmacy also negatively affects patient care by increasing the risk of therapeutic duplication, unnecessary drug exposure, adverse drug events, and poor adherence, all of which may leave patients with unused medicines, leading to improper disposal (Nguyen *et al.*, 2020). Also, in geriatric populations, the concurrent use of five or more drugs has been strongly associated with potentially inappropriate medications, highlighting the need for improved awareness patient friendly disposal options (Sandesh *et al.*, 2024).

From a public health communication perspective, digital platforms can play an imperative role for information dissemination on drug disposal practices. Preferences for mobile applications and websites were consistent across urban, semi-urban, and rural populations, indicating broad acceptability of digital health interventions. The findings of this study provide

Table 3: Preference for digital sources of drug disposal information by location.

Information source	Overall (%)	Urban (%)	Rural (%)	Semi-Urban	*p*-value
App	55.4	56.7	50.0	53.2	>0.05
Website	59	61.3%	61.1	61.3	>0.05

Table 4: Association between professional background and drug disposal knowledge and practices.

Behavior	Medical (*n*=132)	Non-Medical (*n*=251)	'*p*' Value
Check Expiry Date (Yes)	125 (94.7%)	228 (90.8%)	0.037 (Significant)
Aware of Guidelines (Yes)	53 (40.2%)	77 (30.7%)	0.004 (Highly Significant)
Use Dustbin Disposal	111 (84.1%)	230 (91.6%)	0.025 (Significant)
Prefer Apps	75 (56.8%)	137 (54.6%)	0.523 (Not Significant)
Prefer websites	82 (62.1%)	144 (57.4%)	0.523 (Not Significant)

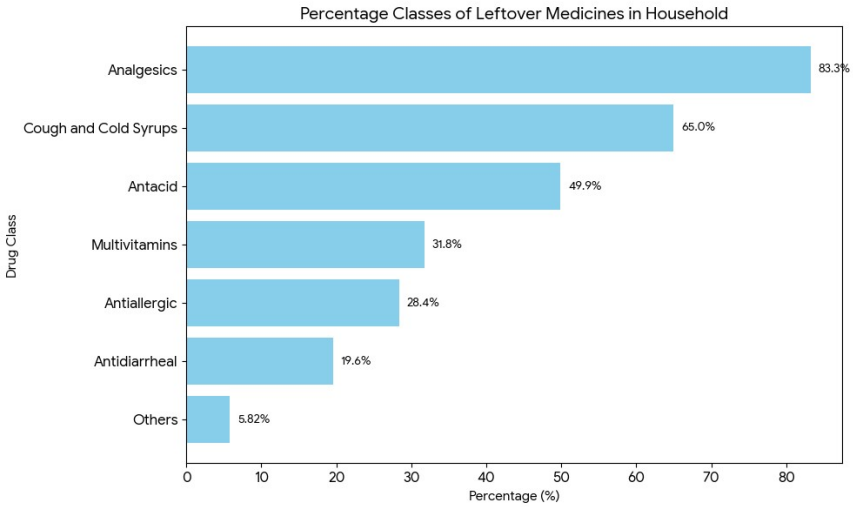

Figure 2: Common Leftover Medicines Classes.

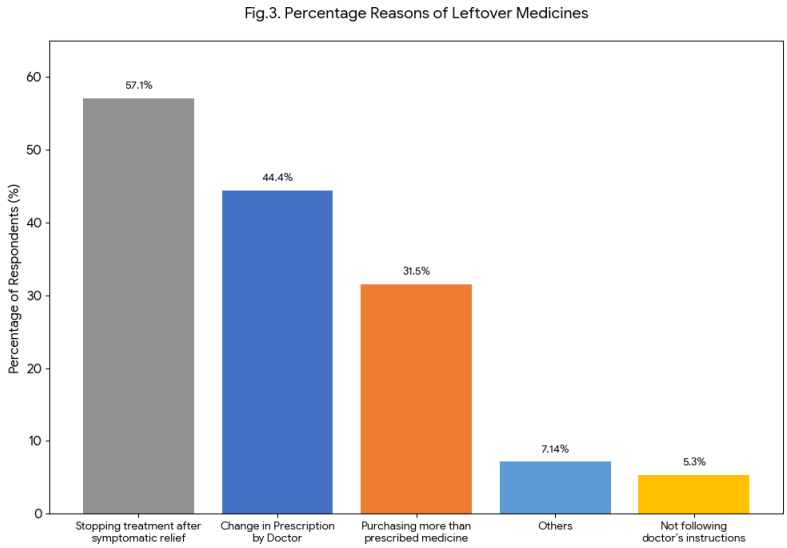

Figure 3: Reasons for leftover medicines at home. Multiple reasons were allowed.

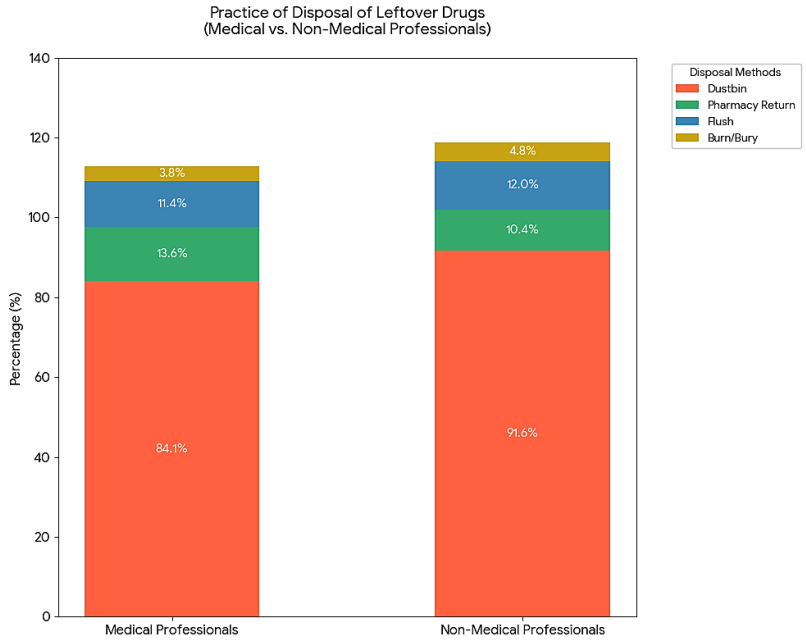

Figure 4: Practice of disposal of leftover drugs. X axis: Medical Vs Non-Medical. Y axis: % Segments: Dustbin, Pharmacy Return, Flush, Burn/Bury.

a strong rationale for the development of digital educational tools to promote safe drug disposal practices. Such interventions will be extremely useful particularly in countries like India, as they are cost friendly. They can be a powerful tool for achieving the goal of sustainable and environment friendly practices starting at household levels.

Based on the identified gaps in public awareness and the expressed preference for digital information sources, a conceptual digital platform, PillBin, was developed to support education on safe medicine disposal practices. The platform is designed to deliver concise, evidence-based guidance through web and mobile interfaces, with multilingual support to enhance accessibility. PillBin illustrates the potential role of digital health tools in bridging knowledge gaps, reinforcing environmentally responsible behavior, and complementing existing pharmaceutical waste management efforts.

CONCLUSION

Improper disposal of medicines poses significant environmental and public health risks. This study identified substantial gaps in awareness and safe disposal practices among the Indian public. PillBin, a multilingual digital platform, was developed to address these gaps through accessible education, interactive guidance, and potential integration with take-back services. By leveraging the high penetration of mobile and internet technologies in India, PillBin offers a scalable, sustainable approach to improving pharmaceutical waste management and reducing associated hazards.

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ABBREVIATIONS

CDSCO: Central Drugs Standard Control Organization; **FDA:** Food and Drug Administration; **ICMR:** Indian Council of Medical Research; **NGO:** Non-Governmental Organisation; **OECD:** Organisation for Economic Co-operation and Development; **WHO:** World Health Organisation.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTIONS

Ms. Mayuri Ghadge: Study conception and design, survey preparation, data collection, manuscript drafting, website development, and app front-end design.

Mr. Nikhil Yadav: Data analysis and back-end development of the mobile application.

Dr. Tanmayee Joshi: Project supervision, manuscript review, critical revisions, and final approval of the work.

SUMMARY

This cross-sectional study assessed drug disposal knowledge, attitudes, and practices among 383 participants across India (December 2024-January 2025) and introduced PillBin, a multilingual digital platform addressing pharmaceutical waste management gaps. Key findings revealed that 66.1% of participants were unaware of official disposal guidelines, and 89.2% disposed of medicines via household dustbins. Medical professionals demonstrated significantly higher awareness (40.2%) compared to non-medical participants (30.7%, p=0.004) and were less likely to use dustbin disposal (84.1% vs 91.6%, p=0.025). Despite limited awareness, 78.3% expressed interest in learning proper disposal methods, with strong preference for digital platforms websites (59%) and mobile applications (55.4%) across all geographic locations. Analgesics (83.6%), cough syrups (65.3%), and antacids (50.4%) were the most common leftover medicines, primarily due to prescription changes (44.4%) and treatment discontinuation after symptom relief (57.2%). PillBin was developed as a response to these findings, offering accessible, evidence-based disposal guidance through web and mobile interfaces with multilingual support (English, Hindi, Marathi). The platform addresses critical gaps in India's pharmaceutical waste infrastructure by providing interactive educational resources, location-based disposal point mapping, and integration potential with take-back programs. This study demonstrates the feasibility and necessity of digital health interventions for promoting safe drug disposal practices in resource-limited settings with high mobile penetration.

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