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Original Research Article

Project green pharmacy: a pilot study in best practices for medicine waste disposal in households

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ABSTRACT

Background: Pharmaceutical waste disposal poses significant environmental and public health concerns, particularly in urban regions where improper practices result in ecosystem contamination and human health risks. In India, discarded or expired medicines, including antibiotics and painkillers, are commonly disposed of in landfills or flushed, exacerbating pollution. The Green Pharmacy initiative by RNisarg Foundation in Thane City was developed to address these issues through public education, secure disposal infrastructure, and waste segregation.
Methods: A cross-sectional study evaluated three-year campaign (2022-2024), which utilized digital (webinars, videos, flyers) and physical (on-ground sessions, live demonstrations) engagement strategies to promote safe disposal and responsible purchasing of pharmaceuticals. Initially, 30 tamper-proof bins were placed in commercial complexes, chemist shops, and residential societies for collection. Later, an additional 170 bins were deployed within a 1-kilometer radius across the city to improve participation and collection efficiency.
Results: The campaign successfully reached over 20,000 individuals. Structured interviews revealed that 100% of participants had previously engaged in unsafe disposal practices, with 90% discarding medicines in landfills and 10% flushing them. Over the study period, 1,979.1 kg of pharmaceutical waste was collected, comprising 67.72% active pharmaceutical ingredients (APIs) and 32.28% packaging waste. Waste contributions were 47% from commercial complexes, 37% from residential societies, and 16% from chemists.
Conclusions: The Green Pharmacy initiative demonstrated significant impact in improving public awareness and disposal practices. Sustained community engagement, policy reinforcement, and recycling measures are essential to mitigate pharmaceutical pollution and its associated health risks in India.

Keywords: Active pharmaceutical ingredients, Green pharmacy initiative, Pharmaceutical waste, Recycling, Safe disposal

INTRODUCTION

Pharmaceutical pollution threatens both environmental and human health nature.[1] Pharmaceuticals that are improperly disposed of in the environment are one of the leading threats to other species and ecosystems.[2] It can also be responsible for ill health of humans.[3,4]

Pharmaceutical wastes include antibiotics, medicines, used needles, syringes, bandages, empty vials or ampules, plastic bottles, tubes, and wastes generated from personal care products. The majority of individuals dispose expired or unused drugs at open landfill sites. Medicines, vials, ampules are getting dumped in dumping grounds, and other places because they do not aware of the

possible risks and consequences associated with improper disposal of it.[5]

The environmental impacts of pharmaceutical waste are substantial from the view of public health. The efficacy and safety of pharmaceutical products are guaranteed until the date of expiration printed on the medication container. After its expiration date, there is no assurance that a drug will lose all of its effectiveness or stop working altogether.[6] Humans and other ecological life forms are directly impacted by the growing body of research on the appropriate disposal of currently unused and expired pharmaceuticals.

The surrounding ecosystems become contaminated when these drugs are disposed of inappropriately, which has harmful effects on those biological systems. As the number of pharmaceutical substances contaminating the ecosystem increases and their potential detrimental effects on biological systems become a global concern, countries like India, which have high rates of population growth, will confront greater challenges. Genetic diversity, species and community diversity are all at risk when drugs are introduced into ecosystems and living organisms.[7]

Pharmaceutical waste from households has emerged as a significant environmental and public health challenge globally. The unsound disposal of medicines in landfills and water systems introduces contaminants into the environment, posing risks of poisoning, antimicrobial resistance, and ecological harm.[8] Improper disposal of antibiotics is particularly concerning, as it promotes the emergence and spread of AMR, recognized by the World Health Organization (WHO) as one of the top global public health threats.[9] Additionally, pharmaceutical contaminants such as NSAIDs have adverse ecological impacts, including threats to wildlife and water quality.[10,11]

Despite the guidelines under India's Solid Waste Management Rules (2016), compliance at the household level remains negligible.[12] To address this issue, RNisarg Foundation, NGO initiated Project Green Pharmacy on 15th August 2021. This initiative focuses on public education about safe use and disposal of pharmaceutical waste. Key findings highlight the need for stricter disposal regulations, improved packaging recyclability, and public awareness campaigns to mitigate the environmental and health impacts of pharmaceutical waste.

METHODS

A cross-sectional campaign was conducted in Thane City by RNisarg Foundation, NGO who initiated Project Green Pharmacy on 15th August 2021.

Figure 1: Treat your trash.

Under this project objective was to create awareness about 4S's like safe purchase, safe storage, safe consumption and safe disposal of household pharmaceutical waste.

Three innovative ideas like awareness campaigns for community, installation with collection of pharmaceutical waste through bins and segregation of collected pharmaceutical waste.

As part of the Green Pharmacy program, a multifaceted awareness campaign plan was put into place to encourage the safe and appropriate disposal of domestic pharmaceutical waste.

Figure 2: Green pharmacy program.

The approach included both digital and physical modes of engagement, ensuring a wide reach across various demographic and geographic segments. In this awareness campaigns, structured interviews have been conducted for

participants. Parameters like types of medicines purchased, storage, consumption pattern, disposed of, frequency of disposal and knowledge about the harmful effects of improper disposal were assessed through this questionnaire.

Further, NGO has successfully completed installation and collection of pharmaceutical waste through 30 ssecured, tamper-proof bins in different locations of metropolitan city includes commercial complexes, chemists' shops and residential societies. Every month, the whole amount of pharmaceutical waste is collected and separated into recyclable and non-recyclable items.

Collection of pharmaceutical waste

The collection bins utilized in the Green Pharmacy initiative are meticulously designed to ensure safe, secure, and environmentally responsible disposal of household pharmaceutical waste.

Figure 3: Collection of pharmaceutical waste.

The bin features are tailored to address risks associated with storage, handling, and transportation of expired, unused, or damaged medicines. The following specifications outline the key design elements:

Tamper-proof construction: The bins are built to be tamper-proof, ensuring that once medicines are deposited, they cannot be retrieved by unauthorized individuals. This feature plays a crucial role in preventing the misuse, theft, or illegal redistribution of pharmaceutical products.

One-way deposit mechanism: A one-way locking system is integrated into the design, allowing waste to be inserted while completely blocking any reverse access. This mechanism ensures unidirectional waste flow and secures the deposited contents until authorized collection.

Secure lock-and-key access: Only authorized personnel are provided with access to the bin via a lock-and-key mechanism. This measure upholds the integrity of the disposal process, preventing any unauthorized access during interim storage and transportation phases.

Puncture-proof material: The bins are manufactured using puncture-resistant materials to safeguard against accidental damage or leakage. This feature ensures the safe containment of sharp, pressurized, or otherwise hazardous items such as glass ampoules or blister packs.

Internal cushioning (sponge lining): To further protect the contents and prevent breakage, especially of glass bottles and fragile packaging, the interior of the bin is lined with a cushioning sponge layer. This helps absorb shocks during disposal and transport, reducing the risk of spills and exposure.

Awareness campaigns

Digital campaigns were carried out through a combination of online tools and social media platforms to reach a broad audience efficiently. The components of digital outreach included:

Circulation of online flyers: Informative and visually engaging flyers were disseminated via WhatsApp, email, and other social media platforms to raise awareness about the risks of improper pharmaceutical waste disposal and the benefits of using Green Pharmacy bins.

Awareness videos: Short educational videos explaining the importance of safe pharmaceutical waste management were shared through WhatsApp, Instagram, Facebook, and other commonly used channels.

Physical awareness campaigns

Offline or physical awareness sessions were also organized to reach communities with limited access to digital media or where personal interaction was deemed more effective.

Figure 4: Physical awareness campaigns.

These included on-ground sessions in residential societies, schools, and public spaces. These sessions

covered key topics such as pharmaceutical pollution, proper segregation practices, and the use of tamper-proof disposal bins. Practical demonstrations were carried out to show how medicines should be disposed of in the specially designed Green Pharmacy bins, emphasizing safety protocols.

Collection and segregation of waste

Total pharmaceutical waste further collected on monthly basis and segregation of waste into recyclable and non-recyclable materials has been done. Medicine waste was categorized based on its type (e.g., painkillers, antibiotics), packaging recyclability, and disposal practices. APIs incinerated; recyclable packaging sent to local recyclers; non-recyclable packaging used for co-processing

RESULTS

A multi-pronged awareness campaign under the Green Pharmacy initiative was implemented not only to promote safe disposal of household pharmaceutical waste bout also on safe purchase, in order to reduce the waste generation at households. This project helps bridge that gap through education. The campaign utilized both digital and physical engagement strategies. Digitally, 30 webinars, educational videos, and online flyers were disseminated via social media and messaging platforms. Physically, 20 on-ground sessions and live demonstrations were conducted in residential areas and public spaces. As a result, over 20,000 individuals were reached and educated on safe disposal practices.

Survey data collection tools included structured interviews, questionnaires, and quantitative assessments. Findings revealed that 100% of respondents previously engaged in unsafe disposal methods, with 90% discarding unused medicines in landfills and 10% flushing them. 64% individuals shared that they discarded Painkillers and antibiotics. Notably, 50% of households were unaware of the environmental and health risks associated with improper disposal, while 95% indicated a willingness to adopt safer methods if appropriate facilities were accessible.

Secure, tamper-proof 30 bins have been kept at different types of locations in a metropolitan city which includes 09 commercial complexes, 5 chemists' shop and 16 Residential societies including 2602 flats. Total weight of collected waste from these 30 bins was 1979.1 kgs for the period of three years from 2022 to 2024. On monthly basis, on an average 60.52 kg waste has been collected from commercial complexes and 21.kg from chemists and 40.62 kg from residents (Table 1).

Out of this total 1979 kg waste, 47% waste has been deposited at bins kept at commercial complexes followed by residential societies (37%) and 16% by chemists (Table 1).

Table 1: Collection of pharmaceutical waste.

Drop-off locations	Count	Total waste collected in kgs	No. of collections	Avg waste collected in kgs
Commercial complex	9	934.64 (47.22)	127	60.52
Chemists	5	310.1 (15.67)	68	21.67
Residential societies	16	734.36 (37.10)	213	40.62
Total	30	1979.1	408	122.81

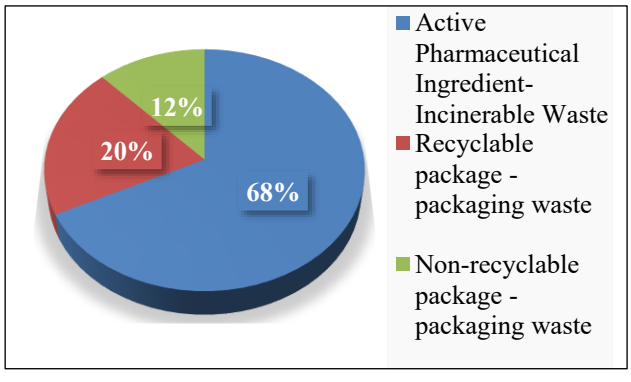

Figure 5: Distribution of pharmaceutical waste.

From last 03 years, out collected pharmaceutical waste (1979.1 kgs), 1341.15 kgs (67.72%) were found as active pharmaceutical ingredient (API) and 638.95 kgs (32.28%) were of packaging waste form. Out of 638.95 kg of packaging waste, 62.9% (402 kg) waste was found to be recyclable and 37.1% (236 kg) were of non-recyclable form (Figure 5).

The study quantified incinerable pharmaceutical waste by active pharmaceutical ingredient (API) type, amounting to a total of 1340.15 kilograms. Among the various categories, multivitamins constituted the highest proportion of the waste, accounting for 34% (455.65 kg). Painkillers represented the second-largest share at 16% (214.42 kg), followed by blood thinners at 9.16% (122.76 kg) and antibiotics at 8.2% (109.89 kg).

Pharmaceuticals associated with chronic conditions, including blood pressure/hypertension (BP/HT) and diabetes mellitus (Sugar/DM), contributed 5.2% (69.69 kg) and 5.6% (75.05 kg) of the total waste, respectively. Medications for acidity and cold/cough accounted for 3.3% (44.22 kg) and 1.4% (18.76 kg), respectively. The

"Others" category comprised a significant 17.14% (229.70 kg), indicating the presence of a diverse range of pharmaceutical compounds not individually classified. These findings highlight the dominant contribution of multivitamin and painkiller categories to the overall incinerable pharmaceutical waste profile.

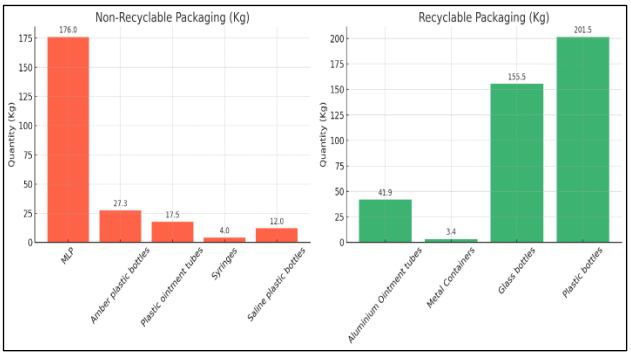

Figure 6: Generates packaging waste distribution.

The data represents (Figure 6) the quantity of packaging waste generated, categorized into non-recyclable and recyclable materials. Non-recyclable packaging accounted for a total of 236.8 kilograms. Among these, Multilayer Plastic (MLP) was the highest contributor at 176 kg, making up over 74% of the non-recyclable waste. Other contributors included amber plastic bottles (27.3 kg), plastic ointment tubes (17.5 kg), saline plastic bottles (12 kg), and syringes (4 kg). In contrast, recyclable packaging had a significantly higher total of 402.15 kilograms. The largest portion came from plastic bottles, which contributed 201.5 kg, nearly half of all recyclable waste (50.11%). Glass bottles followed with 155.5 kg, then aluminium ointment tubes (41.9 kg), and metal containers (3.35 kg).

To further advance the campaign objectives, 170 additional waste bins were installed within a 1-kilometer radius throughout the Corporation jurisdiction, aiming to increase community engagement and optimize waste collection processes. The logistical management of waste collected from a total of 200 bins is facilitated through a dedicated software system. This system utilizes QR code tracking affixed to each bin, enabling real-time monitoring and automated alerts to both end-users and administrators in cases of bin damage, required maintenance, or instances of overfilling. The program is currently operating in autonomous mode for a projected duration of 2 to 3 years under the management of Rnisarg.

DISCUSSION

The lack of awareness as highlighted in our findings (50% of households unaware) is consistent with another study by Daughton.[13] It discusses how consumers and even healthcare professionals are often uninformed about the risks of improper disposal. A study by Sah and Rao explored public awareness regarding the safe disposal of pharmaceuticals in urban and rural areas of India.[14] They found that awareness about the environmental and health impacts of improper disposal is low, especially in rural areas. There is an urgent need for education on proper disposal methods to reduce environmental contamination.

Painkillers and antibiotics comprising 64% of discarded pharmaceuticals reflects a broader trend. Certain classes of drugs, particularly painkillers (NSAIDs) and antibiotics, are frequently discarded improperly. A study by Patel et al found that antibiotics and analgesics make up the majority of improperly disposed pharmaceuticals in urban households.[15] The study also indicated a correlation between high rates of antibiotic misuse and improper disposal practices, further contributing to antibiotic resistance and environmental contamination. A study by Mandel and Scott shows that painkillers, especially opioids, are often improperly discarded.[16] This has become an urgent issue in the context of the opioid crisis, as improper disposal of prescription painkillers contributes to their misuse. In our study, 64% of individuals shared that they discarded painkillers and antibiotics. Also, collection of incinerable pharmaceutical waste, in which multivitamins emerged as the most prevalent category (34%) followed by painkillers at 16%. Similar results were presented by Zorpas et al, who surveyed a group of 184 adults and showed that painkillers were the most used by the respondents (65.8%).[17]

The Indian Ministry of Health and Family Welfare conducted a national survey to assess the willingness of the Indian public to adopt safer pharmaceutical disposal methods.[18] They found that although the majority of participants expressed willingness to change their habits, the lack of accessible disposal facilities and infrastructure in many areas (particularly rural regions) is a significant barrier to proper disposal. This finding aligns with the results from our study, indicating a high level of willingness (95%) to adopt safe disposal methods if appropriate facilities were available.

The collection of 67.72% of APIs from the total pharmaceutical waste raises serious concerns regarding environmental and public health. Improper disposal of APIs can contribute to contamination of water sources, which is a growing concern in India. A study by Nayak and Suryawanshi found that APIs like antibiotics contribute to the rise in antibiotic resistance and water pollution in Indian rivers.[19] Improper disposal and the discharge of API waste into water systems are not only affecting aquatic ecosystems but also endangering human health.

From packaging waste, 402 kg was recyclable, while 37.1% was non-recyclable. In India, packaging waste from pharmaceuticals often consists of materials like plastic, aluminium and paper. Kumar et al conducted a study in urban areas and found that pharmaceutical

packaging waste, particularly plastic and foil packaging, is a significant contributor to environmental pollution in India.[20] There is a need for better recycling programs and public-private collaboration to handle the pharmaceutical packaging waste effectively.

CONCLUSION

Overall, this study affirms that comprehensive, community-based initiatives supported by education, infrastructure, and ongoing engagement can significantly enhance the safe disposal of pharmaceuticals. However, addressing issues such as the non-recyclability of packaging and OTC medicine misuse remains crucial. Future efforts can be focused on expanding bin networks, improving recycling logistics, and advocating for environmentally friendly packaging at the manufacturing level. Additionally, regular data monitoring and feedback loops can help refine strategies and ensure the long-term effectiveness of pharmaceutical waste management systems.

Study played a vital role in combating antimicrobial resistance (AMR). Inadequate disposal of unused or expired pharmaceuticals especially antibiotics can result in environmental contamination, which fosters the emergence and dissemination of resistant microorganisms. The project contributes significantly for reducing pharmaceutical pollutants and supports broader efforts to control the spread of AMR.

In conclusion, the Green Pharmacy initiative demonstrates that a comprehensive strategy combining education, infrastructure, and community engagement can significantly improve pharmaceutical waste disposal practices. Future efforts should focus on expanding disposal infrastructure, promoting sustainable packaging solutions, and fostering continuous public education to sustain and enhance these positive outcomes.

Recommendations

The Extended Producer Responsibility (EPR) framework plays a pivotal role in ensuring the long-term sustainability of the project, particularly through active participation from the pharmaceutical industry. By mandating that producers are accountable for the post-consumer phase of their products, EPR incentivizes proper waste management practices, financial support mechanisms, and infrastructural development, thereby reinforcing the project's operational continuity and environmental impact.

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