JBEP

Journal of Biosciences and Experimental Pharmacology
ISSN-2960-284X

Review Article

Unused and Expired Medicines Disposal Practices in Asian Countries

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Citation: Tabassum, S.; Samir, R. A.; Saifur, T. B.; Tarannum, N.; Bhuiyan, A. A. M.; Uddin, M. B. Unused and Expired Medicines Disposal Practices in Asian Countries. *J. Bio. Exp. Pharm. 2024,* ***2(2)***, **34-59** https://doi.org/10.62624/JBEP00.0017

Academic Editor: Dr Nusrat Subhan

Received: July 28, 2024
Accepted: December 1, 2024
Published: December 27, 2024

Publisher's Note: JBEP stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: Inappropriate disposal of medicines has an alarming impact on our environment. Unused and expired pharmaceuticals contaminate the soil and water that end up entering our food chain. Not only this, they pollute the air as well. The active ingredients diffuse in the human body and not only cause many diseases but also play a pivotal role in developing antibiotic resistance. These unused drugs are thrown into the trash, flushed down the toilet, poured into the sink, burned, or buried improperly. Proper disposal of these medications is a major challenge since many serious diseases continue to rise as medication consumption increases in Asian countries. This review writing integrates results from various research carried out between January 2010 and January 2025 across Asian countries, focusing on 23,825 samples. Household trash, followed by flushing, was the most common mode of disposal, with limited rates of returns to pharmacies. Some of the common trends include awareness, home storage, and poor disposal practices, which are primarily affected by the dosage forms of medication. Effects include pollution of the environment, increased cases of antibiotic resistance, and increased cases of diseases. Interventions mentioned as successful include learning, legal initiatives, environmentally friendly disposal solutions, and medication return campaigns. Stakeholders, including pharmacists, have a crucial role in the implementation of safe and effective disposal measures and overall proper disposal of pharmaceutical waste streams. This review study, therefore, calls for increased willingness and commitment in these regions to prevent further deterioration of health and the environment by taking adequate measures to dispose of medication properly.

Keywords: Medicines disposal, pharmaceutical waste, Asian countries, environment, pharmacist

1. Introduction

Unused medicines are those that are unwanted or discontinued by the patient but remain with them. Expired medicines are those that have lost their potency and stability**.** Non-adherence to the prescription, drug adjustment, and lack of sincerity, along with a sudden change of drug, result in the storage of expired and unwanted medicines. As the majority of the people do not know about the proper disposing system of these drugs, they simply dump them in the environment. This practice is very unsafe for both humans and the atmosphere. Some even donate them, which increases the risk of adverse or no therapeutic effects. The improper disposal of unused, unwanted, and expired medicines is a major environmental and public health threat. Contamination of water sources and the accidental swallowing of medicines by fish, children, and pets have long-term adverse effects. Again, contaminated soil and air have serious consequences. Considering the dangers associated with the above, awareness about the proper disposal measures and proper medication disposal programs is very important. Like many other South and South Asian countries, Bangladesh lacks explicit government policies and procedures for the disposal of unwanted and outdated pharmaceutical products [1]. As a result, many people choose hazardous methods to dispose of unwanted medications, such as dumping them into the trash, sink, or toilet without considering the consequences of doing so. This kind of disposal must be strictly prohibited because it endangers people's safety and the environment [2]. For example, the improper disposal of unwanted tetracyclines has been associated with renal tubular damage**,** as per a report originating from Pakistan, there has been a notable decline in the vulture population, primarily attributed to the consumption of cattle feed consisting of diclofenac. Another critical repercussion of improper medication disposal is that it increases the risk of unintentional poisoning and abuse, particularly among young children and adolescents. Additionally, a recent hypothesis suggests that the haphazard disposal of antimicrobials could potentially play a role in fostering antimicrobial resistance development effects [3]. Again, contaminated soil and air have serious consequences.

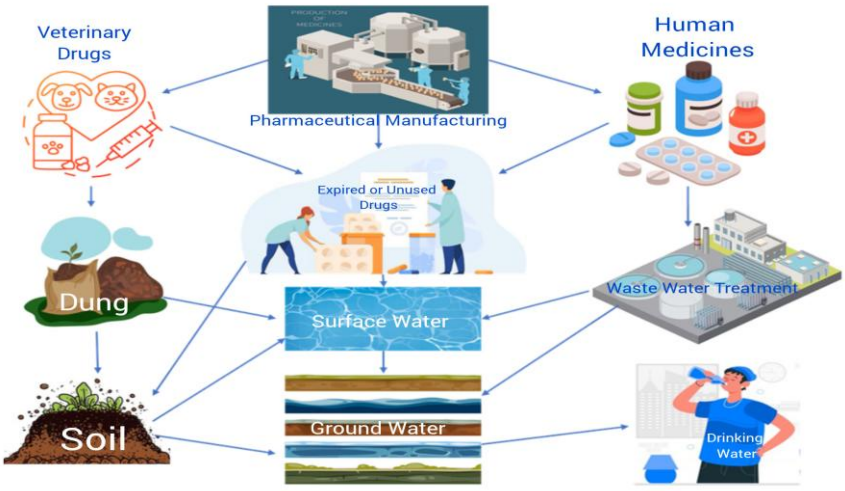

Figure 1: Consequences of Improper Medicines' Disposal Practices

In the South-Asian region, prompt actions are needed to be taken to mitigate the issues as early as possible. Addressing this problem will raise the level of living for the general population and aid in the global fight against drug desensitization, including antibiotic resistance. The pharmacists play a crucial role regarding this situation. Community pharmacists can successfully reduce the damaging consequences of medicine disposal by properly disposing of the medications they collect [4].

2. Method

A secondary data collection method was used. To meet the study's purpose, goal, and rationale, information was gathered from various search engines, including PubMed, Elsevier, Nature, and Springer Link, in addition to other suitable and relevant publications and guidelines. The relevant articles were found by searching "drug disposal", "unwanted medications", "expired medications", "disposal practice in South Asia", "waste disposal in Asia", "waste disposal", "pharmaceutical waste disposal", and many more. Various health-related websites were evaluated, research instruments such as structured interviews and questionnaires from research articles were analyzed, and articles were narrowed by focusing on specific topics. The collected data was carefully arranged and cited to provide a comprehensive picture of the Medicine disposal practices in South Asian nations as well as a few other nearby countries. The material was gathered from a majority of recent articles that contain current information. A search for appropriate references was also conducted using systematic reviews, and reference lists were examined for additional pertinent research.

2.1 Inclusion Criteria

The included studies (Jan 2010- Jan 2025) focused on questionnaire-based surveys that helped to explore how the general population of South Asia and Asia dispose of their pharmaceutical wastes. Also, it includes their attitude, knowledge, and awareness regarding improper disposal methods with percentages.

2.2 Exclusion Criteria

The articles that do not focus on discarding practices or disposal methods were excluded. Articles written in languages other than English were avoided. Writings that did not have percentages or enough data were excluded. Older data before 2010 were not included. Among 82 articles, 61 articles were found eligible to be included in this chapter. These 61 articles have answers and opinions from households, students, pharmacists, doctors, nurses, and the general public.

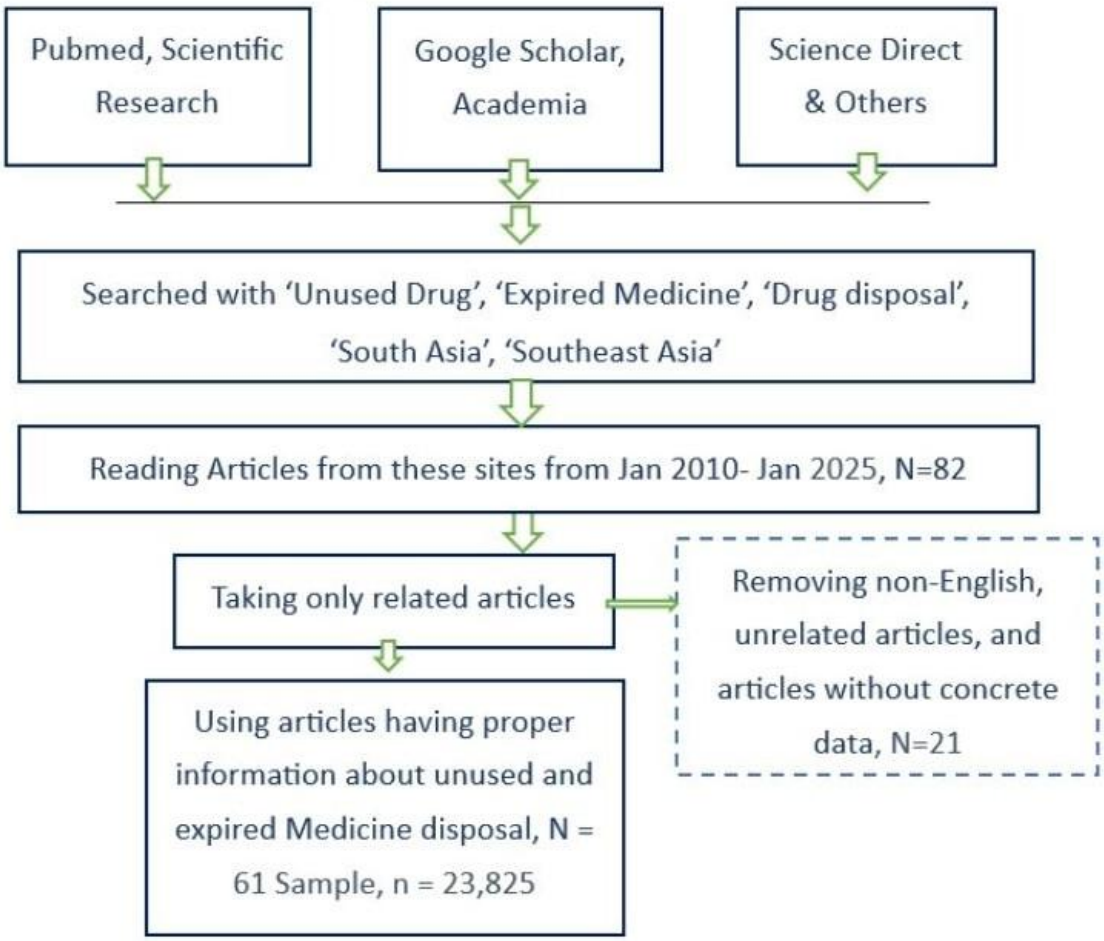

Figure 2: Flowchart of Method

3. Study outcomes

To know about the disposal practice among households and healthcare professionals, many studies have been done in several countries. In this section, the disposal practices, attitudes, methods, awareness, and knowledge of people of South Asia and Asia are discussed to decrease the detrimental effects on the environment and human health of inappropriately discarding unused and expired medications.

Table 1: Medicines' Disposal Practice in Different South Asian Countries

Region	Study Design & Sample Size (n)	Findings	References
Bangladesh	Cross-sectional study, structured questionnaires n=250	Here, the majority of students had very little knowledge and awareness about the disposal system of unused drugs.	[2]
Afghanistan	In-person interviews with pre-validated structured questionnaire n=301	Numerous respondents felt that government officials were responsible for educating people regarding how to properly dispose pharmaceuticals. 77.7% of those surveyed dispose of all their leftover medications in the household garbage bin.	[3]
India	Cross-sectional, questionnaires n=385	Some were aware, but mostly unaware. Dumping in the garbage was the most prevalent form of disposal. 82.1% of participants dispose of the unused medicines in trash cans, and only 2.6% return these medicines to pharmacies.	[5]
India	Cross-sectional, interviewer-administered questionnaire n=555	87% of the participants have unused medication in their houses and less than 46% of the respondents know about the denotation of expiry date.	[6]
India	Cross-sectional study, questionnaires n=118	A large proportion (63.5%) of the drugs stocked were topical formulations. 73% of the participants stated that they planned to get rid of excess medications in their home's dustbin.	[7]

India	Cross-sectional, interviewer-administered questionnaire n=200	39% of the respondents know proper disposal methods. 76% of the participants believe that there is a need for some facilities to collect waste medications.	[8]
India	Cross-sectional questionnaire-based study n=400	According to roughly 17% of participants, smash the pills before throwing them in the garbage. Only 5% return them to the pharmacy.	[9]
India	Questionnaires based on a cross-sectional study n=120	The two most popular approaches are flushing and throwing medications in the garbage. 66% of thought returning to the pharmacy was best.	[10]
India	Questionnaire-based cross-sectional study n=956	The maximum consumers kept their medications at home (87%). After keeping the expired medications for a few days, 92.6% of the customers dumped them elsewhere.	[11]
India (Kerala)	Cross-sectional survey, Interview n=30	66.66% were unaware of the proper elimination of out-of-date and unusable medicines. The participants who said they knew, actually know of the packaging disposal.	[12]
India	Cross-sectional Study n=372	The participants mostly throw their out-of-date and unusable medicines into the dustbin. They do not have adequate knowledge about proper disposal.	[13]
South-India	The questionnaires, in-person, semi-structured interview n=480	The majority of participants (45.97%) threw away unwanted medications in the garbage, and 83.3% were unaware of the harmful	[14]

		consequences drug abandonment has on the environment.	
North-India	The questions that are both open-ended and closed-ended n=236	94% of the population threw the unused drugs into trash cans, and most of the participants claimed that they were unaware of the environmental issues.	[15]
India	Cross-sectional study, interview n=56	The impact of unused drugs was unknown to 55% of individuals. 57.1% of the participants throw them into the garbage.	[16]
India	Cross-sectional study, interview n=150	Not-used medicines are thrown into the dustbin by 62% of those interviewed, and into the sink or toilet by 18%.	[17]
India (West Bengal)	Cross-sectional study n=143	67.1% of the responders had unused drugs in their homes. Discontinuation after feeling better and the potential for future use were the primary reasons for keeping leftover medicines in storage.	[18]
North India	Cross-sectional, structured questionnaires based n=84	Approximately 90% of the individuals surveyed kept some medicines at their homes, and the most typical way to get rid of them is by throwing them in the garbage.	[19]
India	Pre-cross-sectional survey n=150	84.62% of respondents store medicines in their rooms. 23.33% of students were ignorant about the expiry date of the medications.	[20]
South India	Face-to-face semi-structured interview n=127	63.9% were unaware of the environmental hazard	[21]
India (BG Nagar)	Descriptive cross-sectional questionnaire	91.41%, and 73.44% of respondents throw solid and liquid dosage forms	[22]

	n=128	in the garbage, respectively. Also, 1.56% of participants throw solid dosages in the sink and 3.91% in the toilet.	
India	Cross-sectional observational questionnaire-based study n=220	55.9% of those surveyed were unaware of the detrimental impacts of inappropriate medication elimination. The most popular way is to throw them in the trash.	[23]
Pakistan	Cross-sectional, questionnaire-based study n=676	Mostly unaware of safe disposal. 60.56% of female participants throw them in the dustbin, and 48.72% of male responders bury these medications on the ground.	[24]
Pakistan	Closed-end Question n=1022	Approximately 80% of those surveyed kept unneeded medicines where they live, whereas 20% utilized all the medicine they bought.	[25]
Pakistan	Cross-sectional survey n=830	27% of respondents kept medicine after expiration, and 88% of participants did not have knowledge about proper disposal methods. 58.1% throw these in the dustbin, and 14.5 % give them to relatives and friends.	[26]
Bangladesh	Cross-sectional study, questionnaires n=200	Mostly unaware of safe disposal. But more than 15% know and practice proper methods.	[27]
Bangladesh	Cross-sectional study, structured questionnaires, n=400	21% of those questioned returned expired prescribed drugs to the pharmacy requesting repayment, 19% put them through the window, and 47% threw them in the garbage without any additional action.	[28]

Bangladesh	Cross-sectional survey, questionnaires n=310	73% of the participants throw solid waste medications in the dustbin. 58% of the participants pour the liquid dosages into the sink or toilet.	[29]
Nepal	Cross-sectional, face-to-face interview n=210	65.2% of respondents did not know about proper unused medicine disposal. However, 59.5% of the participants check expiry dates of medicines.	[30]
Nepal	A web-based cross-sectional descriptive study n=294	Healthcare professionals tended to keep medicines at home. Their way of disposal was not appropriate.	[31]
Western Nepal (Pokhara city)	Cross-sectional, semi-structured questionnaires n=54	They lack awareness about the impact of improper disposal practices. 52.36% disposed of in municipal dump.	[32]
Myanmar	Cross-sectional questionnaire-based study n=183 healthcare institutions	They are knowledgeable, and most of the facilities maintain proper disposal. Only 0.55% of the participants throw these medicines into the dustbins. The use of incineration and burial pits is commonly practiced.	[33]
Sri Lanka	Face-to-face interview n=200	78% of participants had unused medicines in their homes. 57.5% said they had unused medicine at home because of self-discontinuation.	[34]
Sri Lanka	Cross-sectional study, n=40 pharmacies	25% of participants burn, and 22% throw the solid dosages in the landfill. For liquid dosages, 17% of participants burn them, and 28% throw the liquid dosages in the landfill.	[35]

Bangladesh	Questionnaire-based cross-sectional study n=150	Not more than 84 respondents threw expired medicines into the dustbin, and 13 of them returned them to the pharmacy.	[36]

Table 2: Medicines' Disposal Practice in Other Asian Countries

Region	Study Design Sample Size (n)	Findings	References
Malaysia	Cross-sectional study n=426	Over 80% of those who took the survey said they had knowledge about the mounting problems that affect both our surroundings and human well-being.	[37]
Malaysia	Cross-sectional study n=244	47.8% of the respondents throw their unused medication in the garbage. 26% user return their unused medicines to the pharmacies.	[38]
Malaysia (Rawang)	Cross-sectional, questionnaires (close ended questions) n=384	About 69.5% of the people surveyed had no idea what medication waste was, and most of them (74.3%) dumped them into trash cans.	[39]
Malaysia	Cross-sectional, structured questionnaires n=885	Merely 2% of the population utilized the drug take-back program, despite 87% of them being knowledgeable of drug waste. Furthermore, 83% of those interviewed fill landfills with unnecessary medications.	[40]
Malaysia	Cross-sectional study n=481	Among the 481 participants, 93.1% of participants store medication at home. Mostly educated female students practice this.	[41]
Malaysia	Cross-sectional study n=319	54% of the respondents throw the solid dosage forms in the dustbin. 46.4% of the respondent pour their unused liquid dosages into the sink.	[42]
Malaysia	Cross-sectional survey n=1184	84% of the respondents own unused medication. 21% of participants throw them in the household trash can.	[43]

Region	Study Design Sample Size (n)	Findings	References
Malaysia	Cross-sectional survey n=483	37% of participants throw the waste in the municipal hazardous waste collection.	[44]
Malaysia	Cross-sectional survey n=103	Of the people who took part, 25.2% returned the drugs to the pharmacies.	[45]
Malaysia	Cross-sectional survey n=1067	62% of those who were surveyed said unwanted liquid dosages are thrown in the sink and toilet. Only 6% of respondents return these medications to the pharmacy. 65% of participants' unused solid dosage forms end up in landfills.	[46]
Malaysia	Cross-sectional Survey n=200	For them, dumping drugs that are expired in the garbage is the most popular method of elimination. 60.6% of participants throw them in rubbish bins.	[47]
Indonesia	Cross-sectional study n=324	85% reported they store any unneeded medicines at home, and only 3% of participants return to pharmacies. 17.3% drain them into the toilet.	[48]
Indonesia	Cross-sectional study n=497	About 82% of the participating population discarded their unwanted drugs by throwing them in the trash cans. The percentage of respondents who returned the medicines to the drug store was just 0.2%.	[49]
Indonesia	Cross-sectional studies n=322	49.4% of the participants throw unused medicine in household garbage. 8.2% of the respondents drain them in the toilet, and 3.7% burn the medications.	[50]
Indonesia	Cross-sectional questionnaires-based survey n=497	82% of the respondents usually throw unused drugs in the trash. 5% of participants used the toilet, and 4% used other methods. Only 0.2% of the medications are returned to pharmacies.	[51]

Region	Study Design Sample Size (n)	Findings	References
Thailand	Cross-sectional, Structured interview n=331	A large number of them (89%) stated that they received no instruction on how to discard drugs properly. 73% were in favor of the "Take-back" initiative. Liquid doses were thrown into the drainage system by 7.4% of individuals.	[52]
Vietnam	Cross-sectional questionnaire-based Study n=525	83% of the respondents throw unused medicines in dustbins, and 24% use other methods of disposal. Only 5% of participants return these drugs to the pharmacy.	[53]
China	Cross-sectional Study n=613	71.6% of the respondents disposed of them in trash cans and sinks. 8.3% of the people return them to the collection point.	[54]
Saudi Arabia	Questionnaire-based Study n= 1105	79.5% of the respondents dispose of their unused medicine in the trash bin. Only 4% of the responders return them to the pharmacy.	[55]
Japan (Kobe)	Cross-sectional Study n=75	82.7% of participants throw the containers in the trash.	[56]
Lebanon	Cross-sectional Study n=450	78.9% of the participants discard the expired drugs into household garbage.	[57]
Iraq	Cross-sectional Study n=591	Approximately 70% of the respondents threw medicines in household garbage.	[58]
Qatar	Cross-sectional Study n=410	76% of the respondents threw medicines into their trash cans, and 79% of them kept medicines at home for future use.	[59]
Saudi Arab	Questionnaire-based cross-sectional study n=503	Almost half of the people (58%) kept expired medication in their homes. 86% of the respondents threw the expired drugs in the garbage.	[60]
UAE	Questionnaire-based cross-sectional study n=219	41% of people throw expired drugs in the trash, and very few flush them down the toilet. 101 people returned them to the pharmacy	[61]

Region	Study Design Sample Size (n)	Findings	References
Philippines	Questionnaire-based cross-sectional study n=709	11% of the respondents returned expired drugs to the Pharmacy, and 42.5% placed them in a resealable plastic bag.	[62]
Saudi Arab	Questionnaire-based cross-sectional study n=820	Seven hundred ninety-eight threw expired drugs in the garbage, and 595 threw unused but not expired medications into the trash.	[63]

In a cross-sectional questionnaire-based study conducted in India, where 385 participants took part. Among them, a vast number of respondents had leftover medicines at their houses. The leading cause is that they stop using medication after feeling better from the illness. Just 2.6% of the people surveyed brought their medicines back to pharmacy stores, while 82.1% discarded them in the trash [5]. A study was also conducted in India, where 956 respondents were included. 73% of the people surveyed threw the leftover medications in the trash can, and 20% of those individuals disposed of the drugs in sinks or toilets [11].

A questionnaire-based study was conducted in Pakistan, where 1022 respondents mentioned that they had leftover medications at home. They stock the medicines after they stop using medication after feeling better or the doctor changes the medicines. 83% of the answerers threw drugs in the dustbin, and only 2% returned them to pharmacies; 12% of them poured them down the toilet [25]. Another study in Pakistan included 676 participants. Here, 60.52% of the female participants threw the leftover medicines in the trash can, and 48.72% of the male participants disposed of the drugs by burying them [24].

A study was conducted in Bangladesh, where 200 participants took part. Among them, the majority had leftover drugs at home. 47% of the respondents threw drugs in the dustbin, 8% disposed of these drugs into a sink or toilet, 29% used other methods, and 16% returned them to pharmacies [26]. In another study in Bangladesh, including 400 samples, it was observed that 47% threw them in the garbage, 2% of the respondents burned them, and 21% of respondents returned their leftover and outdated prescription drugs to pharmacies [28].

In a cross-sectional study in Myanmar consisting of 183 samples, the study mentioned about throwing out-of-use and out-of-date medicines in dustbins, 49.18% of them practiced the burial of expired medication, and 55.9% used open pit burning [33].

An in-person interview-based study was conducted in Nepal, and 210 participants took part. Of these participants, 65.2 % did not know about proper medicine disposal. [30]. Another web-based cross-sectional descriptive survey was done in the same country, including 294 respondents. There 72% of the respondents threw

the medicines, 21% flushed them down the toilet, and just 2% brought these outdated and leftover drugs back to the pharmacy [31].

In Sri Lanka, a study was conducted including only 40 samples. Here, 25% of the participants burnt and 22% of the participants threw away the solid unused and expired medications. 17% of them burned, and 28% threw the liquid dosage forms in landfills [35].

In Bangladesh, a questionnaire-based cross-sectional study was performed among 150 people, of which 100 were doctors and 50 were nurses. Among the nurses, 56.82% threw medicines in dustbins, 38% flushed them in basins, and only 2.2% returned them to the pharmacy. On the other hand, 56.25%, 36.64%, and 20.83% of the doctors threw the medicines in the dustbins, flushed them down the basin, and returned to the pharmacy, respectively [36].

An in-person interview using a pre-validated structured questionnaire, including 301 participants, was conducted in Afghanistan. Here, 77.7% of people throw expired medicines in dustbins, 12% drain them in toilets, 3% use other methods, and 7.3% return them to pharmacies. 14.3% of the respondents threw unused medications in the trash, 1.3% drained them in sinks or toilets, and 63.1% used other methods. Only 21.3% of the medicines are returned to pharmacies [3].

In a structured questionnaire-based study in Malaysia containing 885 participants, just 2% of people used the drug take-back program, despite 87% of people being conscious of drug waste. Furthermore, 83% of the people surveyed discarded unneeded medicines in landfills [40]. Another study showed that among the 481 participants, 93.1% of participants store medication at home. Mostly, they were educated female students who performed self-medication [41]. Again, there was a study that had 483 participants among them 64% threw the medication in the dustbin, 10.6% flushed those in the toilet, 6% used other methods, and only 19.4% of them returned the expired and unused medicines to the pharmacy [44].

In a cross-sectional study in Indonesia consisting of 322 participants where 49.4% of the people who took part threw out-of-use and out-of-date medicines in dustbins, 8.2% poured these in a sink or toilet and 39.3% used other methods. Returning to the pharmacies was seen by only 3.1% of the respondents [50]. In another cross-sectional study in Indonesia consisting of 497 participants where 82% of the responding people threw left-out and outdated medicines in dustbins, 5% poured these in a sink or toilet and 4% used other methods. Returning to the pharmacies was seen by only 0.2% of the respondents [51].

In a study in Thailand, among 331 participants, 89.4% of the participants had leftover medicines at their residences. For them, throwing in the garbage was the most popular form of disposal. 7.4% of the unused liquid dosages were disposed of into the drain. 89% of the participants said they received no instruction on appropriate discarding methods [52].

In another study in Vietnam involving 525 participants, 84% of those questioned discarded their unwanted and outdated medicines in dustbins, and 23% used other methods. Only 5% of the respondents reported returning

to the pharmacies. Among the individuals, 70% had abandoned prescription drugs at their houses, 20% disposed of their medicines, and 15% gave those to others [53].

In a cross-sectional study in the UAE, 11% of the participants, among 709 respondents, returned expired medicines to the Pharmacy, 42.5% kept them in a resealable plastic bag, and 12% of them didn't know what to do with their medicines [61]. In another study conducted in Saudi Arabia, among 820 participants, 565 respondents threw unused medication into the garbage, and 331 kept it for future use. On the other hand, in the case of disposing of the expired medications, 798 people threw them in the garbage, and 28 returned to the pharmacy. The rest threw their medication in the toilet, burned it, and buried it in the soil. [62]

4. Discussion

In these regions, to prevent infections, medication abuse or misuse, health issues for the public, and environmental damage, it can be challenging to get rid of outdated and out-of-use pharmaceutical products properly. This study will examine how many South Asian and Southeast Asian countries, including India, Nepal, Bangladesh, Malaysia, Afghanistan, Indonesia, Pakistan, Malaysia, Indonesia, Vietnam, Myanmar, and Sri Lanka, discard abundant and outdated medicinal products. Data was collected through cross-sectional studies and questionnaire-based surveys conducted between 2010 and 2024. The research instruments were predominantly comprised of questionnaires, structured interviews, and closed-end questions, and they were administered to medical students, healthcare professionals, pharmacy and general students, doctors, staff nurses, pharmacists, and the general population. According to a survey done in India, topical medicines made up 63.5% of the prescriptions that were kept in storage, and 73% of participants preferred to throw all of them in residential garbage cans. Just 5% of healthcare workers took their medications back to the pharmacy, while 17% smashed them before discarding them, which is frightening. Furthermore, many medical personnel stored medications inside their homes using incorrect handling techniques. In one study in India, 385 participants took part. Among them, a large proportion of individuals have leftover prescription drugs at their residences. The main reason is that they stop using medication after feeling better from the illness. 82.1% of those questioned threw pharmaceuticals in the waste bin, and only 2.6% returned them to pharmacies [5]. Again, in another study in India, 956 respondents were included. 73% of the participants threw the unused medications in the trash can, and 20% of those people disposed of the drugs in sinks or toilets [11]. On the other hand, in a Pakistani study, 1022 participants took part. Among them, most individuals had unused and outdated medicines at their homes. They stock the medicines after they stop using medication after feeling better or the doctor changes the medicines. 83% of the respondents threw drugs in the dustbin, and only 2% returned them to pharmacies, which is almost similar to India. 12% of them poured into the toilet [25]. Again, another study in Pakistan includes 676 participants. Here, 60.52% of the female responders threw the out-of-use medicines in the trashcan, and 48.72% of the male participants disposed of the drugs by burying them [24]. Students of pharmaceutical sciences and others in Bangladesh showed a lack of understanding and awareness regarding appropriate drug management procedures. Again, lots of participants kept different kinds of medicines in their homes, which had the potential to cause health and environmental damage.

A cross-sectional questionnaire-based study was conducted in Bangladesh, where 200 participants took part. Among them, a lot of people kept medicines inside their houses. 47% of the respondents threw drugs in the dustbin, 8% disposed of these drugs into a sink or toilet, 29% used other methods, and 16% returned them to pharmacies [27]. Again, in another study in Bangladesh, including 400 samples, 47% threw them in the garbage, 2% of the respondents burned them, and 21% of the people involved gave the pharmacy their abandoned and outdated prescription drugs back [28]. On the contrary, in Sri Lanka, 25% of the participants burned, which is less than in Bangladesh, and 22% of participants threw solid unused and expired medications, which is almost similar. 17% of them burn, and 28% throw the liquid dosage forms in landfills [35]. In another cross-sectional study conducted on doctors and nurses in Dhaka, Bangladesh, it was found that neither doctors nor nurses are aware of these safe medicine exposures. The most shocking news is that being healthcare professionals, only 2.2% of doctors return their medicines to the pharmacy, and the rest of them throw them away as garbage in dustbins and basins [36]. More than 80% of people in Malaysia were conscious of the increasing problem of medicine waste, its consequences for consumers, and the present scenario. The fact is unpleasant that drugs are gotten rid of in India by pouring them into the sink as well as the toilets or by putting them in the dustbin. However, 66% preferred returning unused medicines to pharmacists. In Thailand, sadly, 89% of respondents stated that individuals received no instructions on how to discard unused medications properly. [52] According to a different survey, 92.6% of those surveyed in India and 77.7% within Afghanistan disposed of unwanted and out-of-date prescriptions in their residence's garbage cans, while 87% of buyers preserved pharmaceuticals at their houses [3]. Surprisingly, all the individuals agreed that inappropriate disposal methods could have negative effects on the ecosystem and human health. Then there are 82.1% of the participants from Indonesia who were students admitted that they dump undesired medication in the garbage, and about 80% of Pakistanis kept outdated and unwanted medications in their residences. In a cross-sectional study in Indonesia consisting of 497 participants, where 82% of the answerers threw outdated and out-of-use drugs in dustbins, 5% poured these in a sink or toilet, and 4% used other methods. Only 0.2% of the respondents reported returning to the pharmacies [51]. In Indonesia, 85% reported they saved any unneeded medications at their house, and only 3% of participants returned to pharmacies, 17.3% drain them into the toilet [48]. In another cross-sectional study in Indonesia consisting of 322 participants, where 49.4% of the participating personnel threw their unneeded medications in dustbins, 8.2% poured these in a sink or toilet, and 39.3% used other methods. Only 3.1% of the respondents reported returning to the pharmacies [50]. This throwing of medication into the garbage turned into a massive number in Saudi Arabia where among 820 respondents, 798 respondents threw their expired medications to the garbage and only 28, i.e. 3.4% return them to the pharmacy. It is quite shocking that 72.6% even threw their unused medicines into the garbage, where they could have easily kept them in their home for future use or given them back to the pharmacy [62]. To sum up, the most common disposal method among all the countries is throwing on the dustbin. Sadly, 83% of the respondents threw unused medicines in dustbins and 24% used other

methods of disposal in Vietnam whereas only 0.55% of participants in Myanmar threw the medication in dustbins [33,53].

4.1 Effects of improper medicine disposal on human health

Human health is seriously threatened by inappropriate medicine disposal, since recent studies have shown the intricate biological effects of pharmaceutical contamination. Active pharmaceutical ingredients (APIs) are introduced into water supplies by practices like flushing pharmaceuticals down the toilet or throwing them in the trash, which may interfere with endocrine function and cause developmental problems [64]. Pharmaceutical pollution also contributes to antibiotic resistance, which reduces the efficacy of necessary therapies and raises global health issues [65].

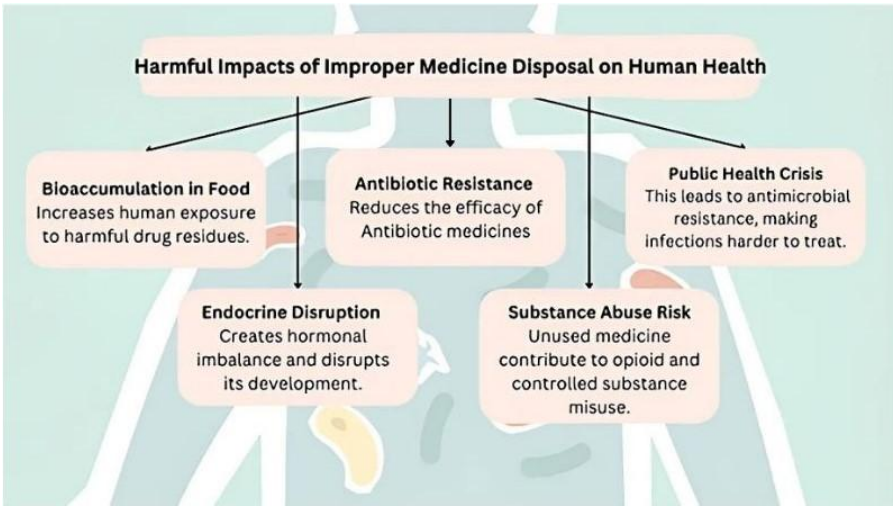

Figure 3: The harmful impact of medicine disposal on human health

In addition to contaminating water, inappropriate disposal can cause pharmaceutical residues to bioaccumulate in the food chain, raising human exposure and health hazards [66]. Concerns over long-term impacts are raised by persistent drug chemicals in the environment, highlighting the need for immediate public awareness campaigns and regulatory actions.

Moreover, inappropriate medicine disposal has an effect on society that goes beyond substance abuse. Prescription medications that are unused or expired in homes encourage the use of illegal drugs, especially opioids and other controlled substances [67]. This public health risk is linked to more general issues like antimicrobial resistance, reproductive abnormalities, and hormone disruption [64,65]. To address these issues and lessen the extensive health and societal repercussions, focused initiatives, education, and stricter disposal laws are needed.

4.2 Hazardous impact of improper medicine disposal on the environment

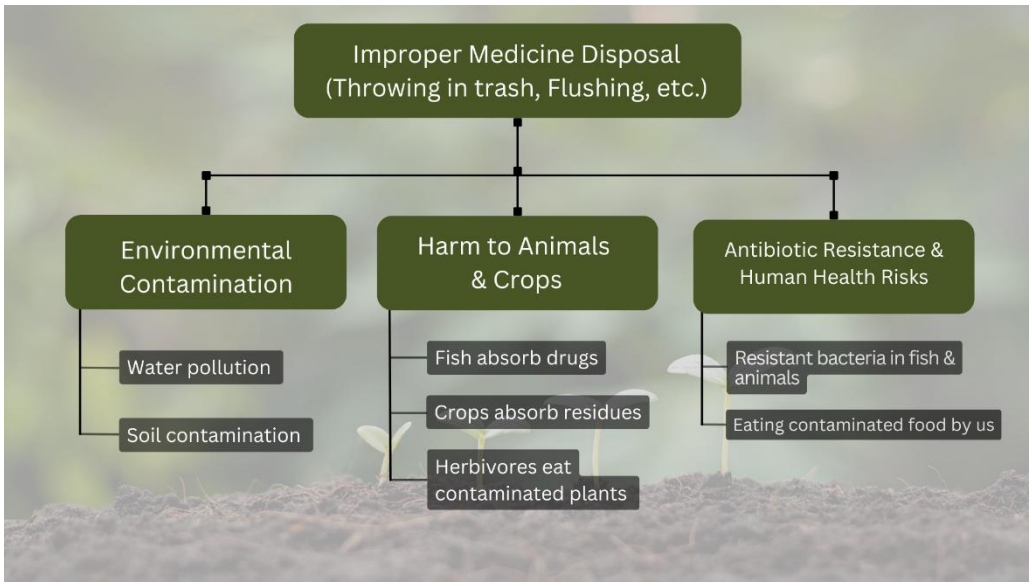

Figure 4: The impact of improper medicines disposal on the environment

Due to improper medicine disposal, our environment is facing an extreme risk, and day by day, it is increasing. The API (Active pharmaceutical ingredients) or the excipients that have been used by drugs will significantly contaminate water, soil, rivers, and our ecosystem as well [68]. It exerts its harmful effects mostly in the aquatic world and in agriculture [69]. The presence of drug residues in the ponds or river water can contaminate the entire ecosystem living within it. Thus, the fish living there will face its harmful impacts. Similarly, the contaminated soil will grow crops and grasses, which will be eaten by the herbivorous animals. So, they will face the side effects of those disposed of drugs. Most importantly, we can feel the danger when it comes to drugs having high potency and a narrow therapeutic index [70]. Its harmful side can also be understood very clearly when the animals or fish develop antibiotic resistance, and that will be eaten by us, so that we will develop the same harmful effects. Similarly, the irrigated crops will raise the harmful effects inside them, and we will face the same effects when we eat them as our food [64].

5. Recommendations

The following recommendations are made to address the significant issue of inappropriate disposal of unused and expired pharmaceuticals:

a. Educate and increase awareness regarding the drawbacks of hazardous disposal techniques. Seminars, workshops, and campaigns should be organized to raise people's social awareness. They must be informed of the physical well-being and the risks of the atmosphere linked to inappropriate pharmaceutical elimination.

b. Governments and healthcare institutions should establish easily accessible drug take-back programs [71]. It is vital to educate the public on the places of operation and benefits of these programs. Offering monetary incentives for returning unused or expired medications can encourage wider use.

c. Punitive measures can be used to discourage and promote responsible behavior by imposing fines on those who flush or dispose of medications in garbage cans.

d. Initiatives at the Pharmacy Level:

i. Inventory management: To minimize medication expiration, pharmacists must adhere to the First-In-First-Out principle [71].

ii. Prescription Practices: OTC drug distribution should be limited, and the sale of medications without a legitimate prescription should be prohibited.

iii. Buyback Programs: To encourage consumers to return leftover medications, the pharmacist may accept them in exchange for the price they paid.

e. Technological Solutions: One of the most important technical solutions for regulating medication disposal is the creation of online platforms that track disposal sites and enable returns. These services can guarantee that unused or expired prescriptions are disposed of appropriately by giving users up-to-date information on the closest drug take-back sites. They can also provide advice on how to effectively and safely return drugs. By making this information easily accessible, these platforms can significantly lower the risks to human health and the environment associated with improper medication disposal. They can also assist in tracking and analysing disposal patterns, which can improve waste management strategies [71].

By implementing these actions, we may reduce the adverse impacts of inappropriate medicine discarding and encourage ecologically beneficial and public health-protecting sustainable practices.

6. Limitations

Most of the studies used a limited number of populations from each country. These small groups are not proper representatives of a country. The articles used in this review article didn't have enough information regarding other types of disposal practices other than throwing in trash cans. In some Asian countries, not a single survey study has been conducted about inappropriate medicine disposal practices.

7. Conclusion

The issue of medication misuse that results from the improper disposal of unused and expired medicines is a serious threat to public health and the environment. It results in prescription drug abuse, poisonings, antibiotic-resistant bacteria, and contamination of the environment. Medical personnel, policymakers, pharmaceutical companies, and the general public should cooperate to popularize proper ways of medicine disposal and educate people on the importance of safe medication disposal practices. Responsible disposal practices need to be applied best until the risks have been completely resolved, thus protecting human health, as

well as the environment. In South and Southeast Asian nations, this problem is a major obstacle. There are no strong guidelines for many health hazards issues like medicine disposal practice, proper labelling of ingredients used in widely used energy drinks in a country like Bangladesh [72]. These unhealthy practices cause environmental pollution and public health issues. Importance should be given to addressing these issues and encouraging pharmacists working in policy-making sectors to come forward to implementing a medicine take-back program and other pragmatic initiatives. The suggested appropriate pharmaceutical waste elimination guidelines and preventative actions highlight how important it is for stakeholders to work together. This study highlights the ecological and public health hazards that concern the decision-making personnel. This would help to make prompt decisions regarding this and convey the implementation. It would open room for pharmacists and other healthcare practitioners to contribute to the environment's well-being and the people.

Statement and Declarations

Author Contribution: ST wrote the primary manuscript. RAS, TBS, AAMB, and NT revised the manuscript. MBU conceptualized, supervised the work, and edited the final draft.

Conflict of Interest: The authors declare no competing conflict of interest.

Funding: This work received no external funding/financial aid from any organization.

Ethical approval: Not applicable

Informed Consent: Not applicable

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