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# Knowledge, attitude, and practice of doctors and nurses about the disposal of expired and unused medicines in Dhaka city

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**ABSTRACT**

Improper medicine disposal practice has become a major concern in South Asian countries. Many healthcare professionals are not aware of safe medicine disposal practices. This survey study aimed to assess the knowledge, attitude, and practice (KAP) of unused and expired medicines among doctors and nurses in Dhaka City. A questionnaire-based, cross-sectional survey was conducted among 150 respondents. Respondents were classified into two categories: doctors = 100, and nurses = 50. Data collection was done using a pre-validated, structured questionnaire. Collected data were added to the MS Excel spreadsheet and analyzed by Statistical Package for Social Science version 23.0. Two-thirds of the nurses kept expired medicines in their houses as they did not want to waste them whereas 50% of doctors had expired medicines. Remarkably, 42.86% of nurses responded to immune system deficiencies resulting from improper medicine disposal, while it figured 28.16% among doctors. Alarmingly, 95.46% of nurses disposed of medicines via flush in the toilet/basin or dump in the dustbin, and 69.79% of doctors followed similar practices. 27.43% of doctors and 13.85% of nurses recommended reducing the number of medicines from prescription. It has been suggested that health policymakers work together with healthcare professionals and general people by launching public awareness campaigns.

## INTRODUCTION

Progressive technological advancement in the pharmaceutical field has increased medication use over the past few decades [1]. Approximately 4.5 trillion doses of pharmaceuticals were used all over the world in animal and human healthcare [2]. The emergence of numerous pharmaceutical companies and the availability of over-the-counter (OTC) or prescribed medicines at cheaper rates are the triggering factors behind the higher consumption of medications in in Bangladesh [3,4]. Development healthcare also depends on an increase in the volume of pharmaceutical waste. In many cases, prescribed medicines may go unused because of the patient's early recovery from the disease. Mismanagement of expired medicines, inappropriate disposal of medicines, and open-place waste dumping extend the risk to public health and environmental hygiene [5]. Several studies [6–9] manifested the presence of pharmaceutical effluents in groundwater, surface water, recipient water, and aquatic environments. The basic principle of medicine disposal practice involves minimum risks to public health and the environment [10]. Though people are becoming more concerned about the safe use of medicines, they need to become more aware of the safe disposal of medications. In contrast, proper medicine disposal is imperative for the safety of the household and the environment [11]. Pharmaceutical waste management and disposal practice relates to its harmful impact on human health, the environment, water, air, food chain, and the ecosystem [3,12–14]. Disposed medicines reach the environment in many ways, including inappropriate disposal of medicine in the sink, toilets/basins. When a patient disposes of medicines, it excretes in surface water, and improper disposal causes deposition in the groundwater and soil. In this way, pharmaceutical substances may reach the water bodies and drinking water which can pollute the water

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[15]. Due to that, it creates a deleterious effect on human health, and the environment, and interacts with the ecosystem (Fig. 1). If medicines like steroid hormones, antibiotics, and oral contraceptive pills are disposed of inappropriately, they have the potential to cause environmental harm [11]. Studies set the seal that the presence of improperly disposed antibiotics in the environment has significant repercussions on antibiotic resistance [16,17]. The global consumption of antibiotics increased by 65% last decade [18].

Regarding expired medicine management, there are different guidelines and policies for proper medicine disposal. The medicine take-back system is well-established in developed countries like Canada, Australia, the United States, the United Kingdom, and Sweden [19–21]. However, in comparison to Western Europe and North American countries, there is limited information on the disposal of pharmaceuticals in Asian or African countries [22]. Many developing countries have reported lacking combustion capability and, in general, have no well-known, established comprehensive medication waste management policy up to this time [23,24]. Medical waste is not a censorious issue in these countries. The World Health Organization conducted research in 22 developing countries showing the presence of healthcare facilities that did not follow proper hospital waste disposal, and the procurers ranged from 16% to 62% [25]. In Bangladesh, the PRISM Bangladesh Foundation (a nongovernmental organization) controls medical waste management systems in a few cities in Bangladesh [5]. However, the directorate general of drug administration and the Government still have not issued such proper guidelines and launched some medicine take-back programs regularly to reduce medicinal wastage. Adequate guidance on proper medicinal disposal will elevate safer disposal practices, a predominant feature of public health [26]. To ensure appropriate medicine disposal, necessary steps should align with the specific guidelines given by healthcare policymakers [3]. More importantly, public awareness about proper medicines disposal will also be advantageous. As far as improper medicine disposal practices are concerned, adequate knowledge, attitude, and practice (KAP) of doctors and nurses are fundamental in reducing so. Because doctors are involved in prescribing the medications, nurses are the last person who can closely monitor the medicine intake by patients. Checking the expiration date of medicines is another primary task for the nurses while giving them to the patient.

Numerous studies in recent years from different countries evaluated the existing knowledge and practices regarding unused and expired medicines among healthcare workers. Researchers explored the disposal practices among university students [3,26,27], healthcare professionals [28–30], and households [11,31,32]. From Bangladesh's perspective, doctors and nurses stand as major stakeholders in the healthcare sector and are involved in the process of medicines selection, prescription, patient guidance, and counseling. They could play a pivotal role in educating patients about environmentally friendly medicine disposal practices. To the best of our knowledge from the literature review, this is the first study to assess the KAPs of unused and expired medications among healthcare professionals and nurses in Bangladesh. No previous study was conducted to address this specific issue in Bangladesh's perspective. Literature shows a lack of availability of public data about the safe and effective disposal knowledge and practices towards expired medication. This study was therefore planned with the aim to report the current knowledge, practices, and attitudes of the doctors and nurses towards the disposal of unused and expired medicines in the capital Dhaka city. In the context of Bangladesh, these kinds of research [3,11,33] need to

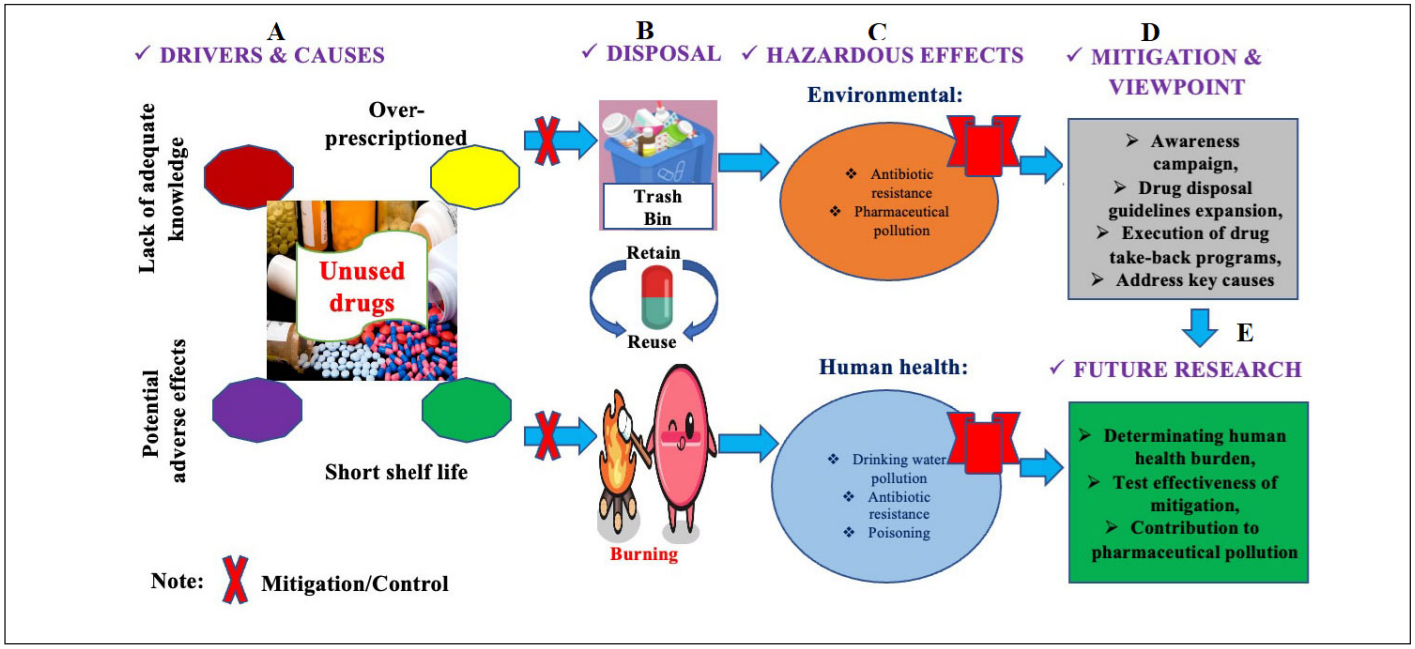


**Figure 1.** The schematic diagram illustrates: (a) Key factors contributing to the accumulation of unused and expired pharmaceuticals, (b) Common disposal practices, (c) Associated environmental and human health risks, (d) Strategies for mitigation and prevention, and (e) Future research directions.

be conducted more frequently to get more data about improper medicines disposal practices.

## MATERIALS AND METHODS

### Study design

This was a questionnaire-based, descriptive, and cross-sectional assessment. The study was conducted for a period of 3 months in 15 different hospitals, where 6 were government and 9 were private hospitals in Dhaka, Bangladesh. Data collection was done with the paper-based printed questionnaire using convenience sampling. Convenience sampling is a widely used sampling technique in which study populations are generally selected considering some criteria such as willingness to participate, availability at a given time, and so on. [34] The study population was chosen irrespective of gender, which included doctors and nurses. A total of 150 respondents were classified into two categories: doctors = 100, and nurses = 50. The calculation of the sample size was performed using G*Power version 3.2. Based on a statistical power of 80% and an acceptable alpha error rate of 5%, the minimum sample size required for this study was calculated to be 118 participants. Eventually, a total of 150 patients who satisfied the specified inclusion criteria and provided their informed consent were included in this study. Doctors having FCPS/FRCP/MRCP/MRCS/MD/MS postgraduate degrees were included in this study. Since there were very few B.Sc. nurses in those selected institutions, the number of nurses was less than the doctors in this study. Ethical approval was acquired from the Institutional Ethics Committee of BIRDEM General Hospital, Dhaka, Bangladesh (project code: BADAS-ERC/EC/19/00282) and this research study was carried out in conformity with the ethical principles of the Declaration of Helsinki. During the interview, individuals assigned to collect the responses first explained the purpose and importance of the study to the potential respondents, and their informed consent was obtained.

### Questionnaire design

The questionnaire was classified into two sections. The first questionnaire section was comprised of personal information like sex, age, profession, reasons for keeping expired medicines in the house, and their different classes. The second one was designed to assess unused and expired medicine disposal knowledge. It included their approach to leftover medicines—whether they knew the proper disposal method, the consequences of improper medicine discarding practices and their hazardous effects, and their recommendations to minimize leftover medications in houses. In this second section, a questionnaire to assess KAP was employed. The study tool questionnaire was prepared after extensive reviewing of questionnaires used in previous studies that assessed the KAP of expired and unused medications among different populations. The questionnaire was developed with the guidance of previous related global studies conducted in the first world countries [35,36]. Participants were given a maximum of 10 minutes to complete the questionnaire without being given any assistance to fill it. Finally, this questionnaire was reviewed for content validity by an expert in the field of study who subjected it to face and content validation. The questionnaire's reliability was evaluated through a pilot study, which involved the analysis of Cronbach's alpha [37]. The pilot study was conducted with 10 randomly selected doctors and nurses, and Cronbach's alpha coefficient was 0.70 indicating that the questionnaire could be used to conduct the study. This analysis was conducted among a small sample of doctors and nurses, who were randomly selected for the study.

### Data collection, sampling, and analysis

Individuals who were assigned to collect the responses, first, explained the purpose of the study to the respondents, and their informed consent was obtained. Respondents were also assured that their information would be considered anonymous and confidential. After obtaining appropriate informed permission, we randomly approached 180 participants who were provided with a questionnaire (in English) to fill up, of whom 158 responded. Following the receipt of 158 responses, we retained 150 responses for data analysis, those who filled out the form completely, while excluding incomplete forms. All the participants in the pilot study were also excluded from the main study. After completing the questionnaires, the responses were collected for statistical analysis.

Collected data were added to the Microsoft Excel spreadsheet dataset and transferred to Statistical Package for Social Science version 23.0 for analysis using descriptive statistics. The statistical technique was the estimation of a simple percentage used for the analysis of collected data. By carefully reviewing the questions in order to assure clarity, we fixed the number of participants to get an approximate result. Responses with multiple answers were defined in multiple response sets before descriptive statistical analysis.

## RESULTS

One hundred and fifty respondents participated in this study. Respondents were divided into two categories, 100 were doctors, and the remaining 50 were nurses. The response rate was 100% as every respondent approached successfully. Among the total respondents, 91 (60%) were male, while 59 (40%) were female. Within the group of 50 nurses, there were 16 males (32%), and a higher proportion of 34 females (68%), as in Bangladesh perspective, the nursing profession is much popular with females. Among the doctors, 75 were male, and the remaining 25 were female. Of the total respondents, the age below 27 years old was 43 (28%), and 107 (72%) were above 27 years old. (Table 1). In the questionnaire, the ages ranged from below 18 years, 18–22 years, 23–27 years, and 27 years and above 27 years.

Figure 2 illustrates the respondents' data regarding the reasons for expired medicines in houses, according to doctors and nurses. As per the study, almost two-thirds (66.67%) of nurses said they did not want to waste expired medicines. Moreover, 19.04% of nurses reported that they did not have adequate knowledge of what to do, and few nurses (14.29%) stored medications for future use. Besides, the data of doctors revealed that half of them brought more medicines, which eventually led medicines to expire. 38%

**Table 1.** Demography of study population ($n$ = 150).

| Variable and categories | | Number of responses (%) | |
|---|---|---|---|
| Classification | Doctors | 100 | (67%) |
| | Nurses | 50 | (33%) |
| Gender | Male | 91 | (60%) |
| | Female | 59 | (40%) |
| Age | Below 27 years | 43 | (28%) |
| | 27 and above 27 years | 107 | (72%) |

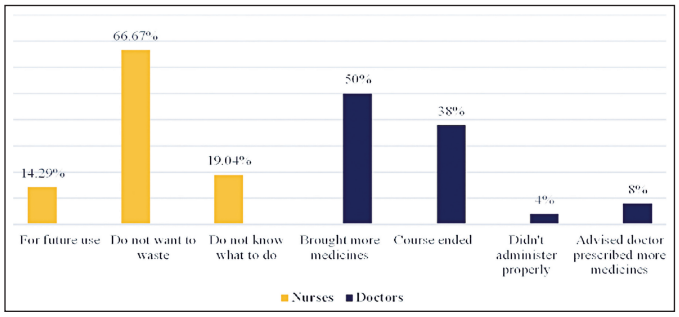


**Figure 2.** Reasons for the presence of expired medicines in houses.

of participants confirmed that because of course ended, they had expired medications. Also, 4% of total doctors did not administer medicines properly (as per required dose or missed the dose), and 8% of them were prescribed more medicines by the physician pursuant to the study. As a consequence, expired medicines were present in their houses.

This study included (Fig. 3) the different common classes of leftover medicines in houses by the respondents. Considering the facts of nurses, they were reported to have leftover antibiotics (18.84%), antihistamines (10.14%), antipyretics (11.59%), and vitamins (11.59%). In comparison, the percentage of vitamins (30.11%) represented the highest number of leftover medicines as far as doctors' points of view were concerned. This amount was 6.25%, 13.07%, and 28.98%, respectively, for antihistamines, antipyretics, and antibiotics. Not surprisingly, the highest number of leftover medicines was found in antibiotics by doctors and nurses, with an overall 47.82%, as antibiotics' prescriptions and uses are gradually increasing. If unused post-expiry date medicines are disposed of inappropriately, they may further increase the threat to the environment as such medicines may have different safety profiles. Moreover, 33.33% and 9.66% of other classes of medicines were reported to be leftovers by nurses and doctors, respectively.

Findings from this study depicted (Fig. 4) that more than 50% of both doctors (56.25%) and nurses (56.82%) disposed of their expired medicines by dumping them in the dustbin. By flash in toilet/basin, 13.54% of total doctors discarded pills, which was very high for the nurses (38.64%). Another common fate of unused/expired medicines was reported to return to the pharmacy, which was done by 20.83% of the doctors and 2.27% of nurses.

Knowledge regarding the effect of improper management and disposal of unused/expired medicines among

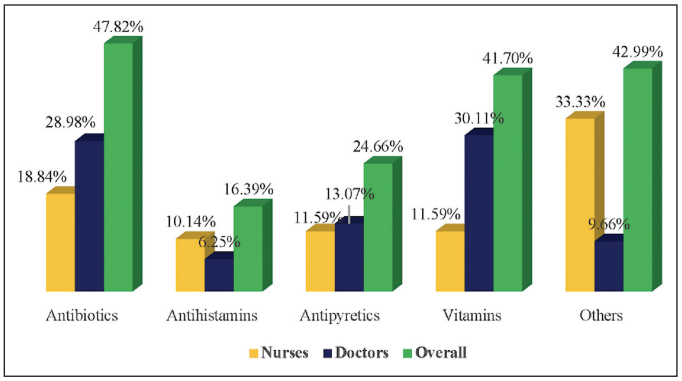


**Figure 3.** Different classes of leftover medicines in houses.

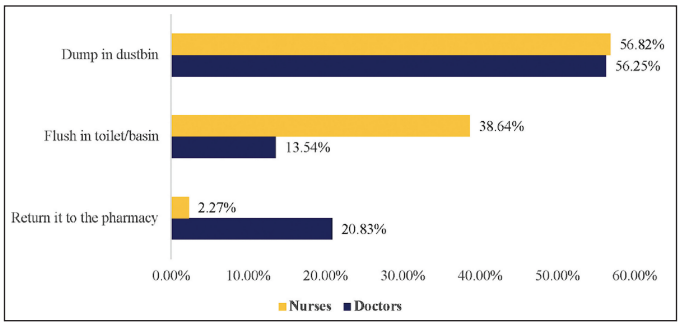


**Figure 4.** Fate of expired medicines.

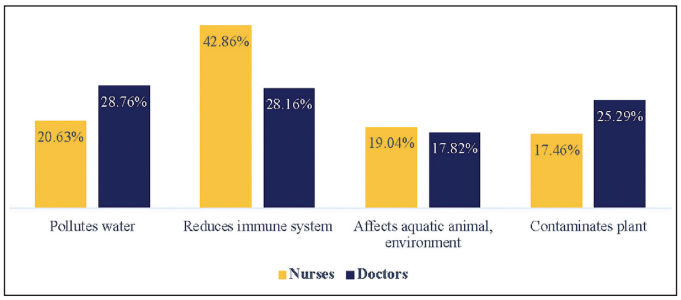


**Figure 5.** Knowledge about harmful effects of medicine disposal.

doctors and nurses was also reflected in this research (Fig. 5). Where 20.63% of total nurses have knowledge about the effects of expired medications contributing to water pollution. It reduced the immune system (42.86%), was harmful to aquatic animals and the environment (19.04%), and contaminated plants (17.46%), according to nurses. Besides, nearly a similar percentage of doctors reported about knowing the effects of this on water pollution (28.76%) and immune deficiency (28.16%). Also, effects on the aquatic animals, environment (17.82%), and plant contamination (25.29%) were known to the doctors. The figure mentioned above revealed that nurses might have more information about immune deficiency because of unused/expired medicines.

Unearthing Figure 6 suggested some recommendations on how to minimize the leftover medicines and their hazardous effects. The highest percentage of total nurses (41.54%)

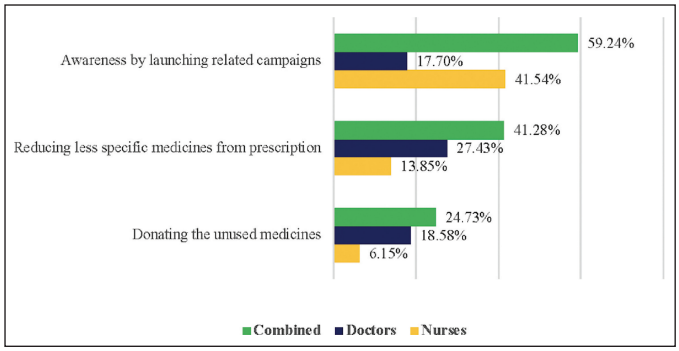


**Figure 6.** Recommendations on minimizing leftover medicines and their hazardous effect.

recommended creating awareness by initiating medicines disposal-related campaigns, whereas this percentage seems to be much less in terms of doctors (17.70%). 27.43% of doctors suggested diminishing less selective, less specific medicines from the prescription, and 13.85% of nurses were found to recommend so. Findings from this also showed that the lowest percentage of total nurses (6.15%) and 18.58% of doctors proposed donating unused medicines to reduce leftover medications and their hazardous effects. When some common questions were asked to the doctors, and nurses about their knowledge concerning unused/ expired medicine disposal practices (Table 2), encouragingly, there was a good percentage of nurses (84%) regarding awareness of expired medicines disposal, whereas, only 4% of nurses were informed about the 'Medicines Take Back' program as compared to doctors (37%).

## DISCUSSION

Although the study was conducted in Dhaka city, Bangladesh, the implications of this study apply to the entire Bangladesh, South Asian regions, and also the whole world. The rapid growth of the pharmaceutical industry, and during the COVID period and post-COVID period, the increased consumption of pharmaceutical products has led to their increasing presence in the environment with diverse biological effects. This is a challenge and is receiving increasing attention [38–40].

This study explored the KAP among doctors and nurses about expired medicines and their disposal in Dhaka city. In this research, from the total respondents, the age below 27 years old was 43 (28%), and 107 (72%) were above 27 years old (Table 1). Several studies included information about the ethnicity (28) and locality (12,29) of the corresponding participants in South Asian regions, contrasting our findings. It is worth mentioning that our research included data from both doctors and nurses regarding their KAPs toward unused and expired medicines. More importantly, our sampling was carried out in 15 different hospitals including government and private hospitals, which has represented a better real scenario regarding the issue. In the Bangladesh context, though research focused on the medicine disposal habits of students [3] and the general population [10], there still exists notable gaps as no comprehensive study has been conducted on the practices of doctors and nurses in this regard.

**Table 2.** General knowledge of respondents concerning unused/ expired drug disposal ($n$ = 150).

| Variable, categories and responses | | | Number of responses (%) |
|---|---|---|---|
| Knowing about the disposal of expired medicines | Doctors | Yes | 44% |
| | Nurses | Yes | 84% |
| Knowledge about the 'Drug Take Back' program | Doctors | Yes | 37% |
| | Nurses | Yes | 4% |

Storing expired medications at house can lead to intentional or accidental consumption, which may lead to a severe health crisis [41]. The most common reason for having unused medications is 'in case they are needed later' [42]. According to the data given in Figure 2, common reasons for having expired medicines in houses as affirmed by nurses; the highest % of nurses (66.67%) did not want to waste medicines. What is more, they deposited medicines for future use. Besides, doctors either brought more medicines or the course ended, so they reported having expired medication in their house. A recent study conducted in India [28] found that nearly half of healthcare professionals store leftover medicines at home as their medical conditions improve. This survey incorporated medical officers, medical and dental students, paramedical students, and staff. Another recent research study in Malaysia [43] confirmed that the dominant reason for unused medications was nonadherence in terms of chronic illness. Participants who did not take or forgot to take their medicines as prescribed were considered nonadherent. Considering acute illness, the leading cause of having unused medications was because consumers' medical conditions got eased, and they did not need all the prescribed medicines. Another research indicated that the main reasons why the respondents keep unused medications at home were that their treatment was changed by their doctor (28.6%) and they felt better (25.1%) [44]. The research proved that unused medicine for acute illness was higher in % than that for chronic disease [43]. There can also be other reasons for having leftover medications, including changed treatment, unclear instructions, inconvenience, and an excess supply of medicines [45]. This excess of remedies in houses has potential implications for accidental childhood ingestions [46].

One of the significant findings from our research was the illustration of some of the different common classes of medicines that were frequently leftover in the houses of doctors and nurses in Dhaka city (Fig. 3). Antibiotics (47.82%) were predominant in that list, followed by vitamins (41.70%), which combined the overall data of doctors and nurses. The list of other leftover medicines included antihistamines, antipyretics, and some other classes of medicines. Our finding shows similarity to another study conducted in Yogyakarta [47], where unused or expired antibiotics (59.51%) followed by vitamins (11.88%) were leftover in households. Compared to these studies, research done in Gujarat, India [48] recorded that analgesics (26.5%) were the most common classes of unused medicines stored. The findings of our study also showed how often the interviewee doctors and nurses were using antibiotics, even though they were supposed to be more aware. It is noteworthy

that exposure to degraded or expired tetracycline has been found to cause renal tubular damage [49]. Antibiotic use and resistance research conducted in 30 EU/EEA countries in 2019 highlighted the importance of healthcare workers playing a critical role in the use of antibiotics and educating patients to minimize the spread of infection in a healthcare setting, particularly when they are inextricably linked in prescribing, dispensing and administration of medicines [50]. The fate of expired medicines is a critical issue that affects both healthcare providers and patients [51]. Our findings revealed that 56.25% of doctors and 56.82% of nurses disposed of expired medications by dumping them in the dustbin. Also, 20.83% of doctors returned these medicines to the pharmacy, whereas 2.27% of nurses did so (Fig. 4). Medicine disposal practices in the households of Dhaka Metropolis [11] exposed that some of the most common fates of unused and leftover medicines were dumping in dustbins (47%), followed by returning to the pharmacy for a refund (21%) and throwing through the window (19%). However, a 2022 study (26) found that 42.5% of pharmacy students at Centro Escolar University—Manila discarded unused and expired medicines by placing them in a zip-lock bag or resealable plastic container. Another way of discarding unused and expired medicines, according to our findings, was flushing in the toilet/basin (nurses-38.64%, doctors-13.54%), which is indistinguishable from medication disposal through sink or toilet (31.6%) in households in South Africa [31] by the patients. However, a study in Johannesburg [52] announced "disposal in the garbage can" as the most common method. Contemporary research in 2022 in Quetta, Pakistan [12] reported the same medicine disposal methods as our study and they showed that 27.3% of the general population did not take any action (kept expired medicines at home). Some studies in Asian countries showed other medicine disposal practices. Studies conducted in Saudi Arabia [53] (nursing students-74.2%) and Malaysia [44] (health care professionals-84.9%) showed that the highest % of medicine consumers disposed of expired medicines by discarding them in household garbage. Locating containers inside pharmacies within Saudi government hospitals and polyclinics can efficiently collect unwanted medications [54].

Our findings showed that doctors might have been more informed about water pollution (28.76%) than nurses (20.63%), whereas 19.04% of nurses and 17.82% of doctors responded to environmental pollution due to improper medicine disposal (Fig. 5). It is essential to properly educate doctors and nurses about the proper disposal practices of unused and expired medications. Because study reported a significant fact that of people who received information concerning the appropriate disposal of medicines, 85% did not dispose of unused or expired medications in household garbage [55].

Along with our findings, a study in Karachi [56] reported that 82.7% of participants were well-informed about these matters. Another research work in 2021 in the Dhaka Metropolitan area [11] resulted in 26% of respondents having an idea about medicine pollution because of irrational disposal practices. It also mentioned that 91% of participants checked medicines' expiry dates, unlike our study. Findings from Ain Shams University Hospitals, Cairo [29] mentioned that the overall percentage of physicians with a satisfactory knowledge score in terms of medicine waste disposal (68.3%) was higher than nurses (60.9%). Besides, our research outcome identified a surprising fact that 42.86% of nurses were aware of immune system deficiency due to inappropriate medicine disposal; on the other hand, 28.16% of doctors were aware. It is known that medicines have afterlives as environmental pollutants and that most water treatment plants and septic systems are not equipped to remove pharmaceuticals from wastewater [57]. A study on undergraduate pharmacy and other discipline students in Bangladesh [3] ensured that 157 respondents out of 250 knew about the environmental hazards due to improper medicine disposal. Research at a tertiary care hospital in Ahmedabad, India [48] displayed similarity to our study, and it confirmed that 16% of respondents showed awareness considering the necessity of safe medicine disposal to prevent environmental pollution. Additionally, plant contamination due to unconditional and irrational medicine disposal was known by 25.29% of doctors and 17.46% of nurses. Improper medicine disposal practices affect the health system as well as the environment. Poisoning cases are reported worldwide because of accidental exposure to leftover medicines and their inappropriate disposal in houses [58]. So, proper medicine disposal knowledge is necessary to encounter these circumstances.

To reduce the possible number of expired medicine stocks, practicing First-Expiry-First-Out can be done while arranging and selling the stocks in community pharmacies [14]. A prodigious finding of our study revealed some considerable recommendations to minimize leftover medications and how their hazardous effects can be controlled according to doctors' and nurses' points of view (Fig. 6). Here, 17.70% of doctors and 41.54% of nurses suggested launching awareness-related campaigns. Reducing fewer specific medicines from prescription can also be effective, according to 27.43% of doctors and 13.85% of nurses. Furthermore, donating unused medication (24.73% of doctors and 18.58% of nurses showed in Figure 6) can be a choice to minimize leftover medicines. It may include medicine take-back, returning unused medicines to the pharmacy, or donating to friends and relatives. A study in Tamil Nadu [30] also proved similar results, where 13.6% of doctors and 22.2% of nurses suggested lowering the number of prescribed medicines, and 7.2% of doctors and 14.1% of nurses agreed to donate the medication. As a result, it may reduce hazardous effects because of leftover medicines. Also, short-term dispensing, educating people, and redistribution of medicines can minimize medicinal wastage and its dangerous effects [57]. Exploration from a study conducted in South India [59] displayed a shocking result that only 18.3% of doctors and 13.4% of nurses were aware of the environmental hazards due to improper medicine disposal. Several studies mentioned that creating awareness to minimize leftover or expired medicines can be done through newspapers, TV, and social media, as well as with the help of the health ministry and the pharmaceutical industry [3,33,52].

The study visualized that the responses about expired medicine disposal were higher in % for nurses than doctors. Besides, the medicine take-back program was more familiar to doctors (37%) compared to nurses (4%) (Table 2). This is a noticeable information for both professionals as they are the

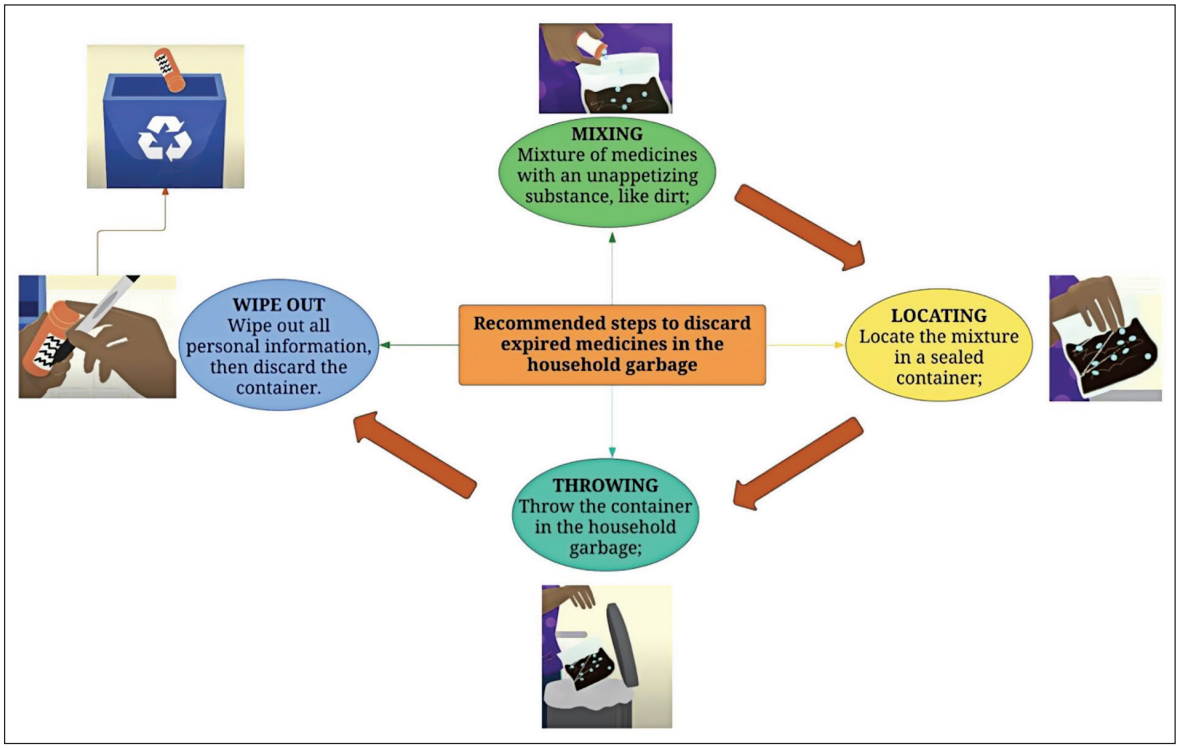


**Figure 7.** Recommended steps to discard the "Non-Flush List" medicines in the household garbage. Derived from Food and Drug Administration (FDA).

most crucial person in the healthcare system. 84% of nurses were recorded to be conscious about expired medicines disposal in our research, and a similar study [30] confirmed that almost all nurses (98%) checked the expiry date of the medicines before using them, as they are the one who dispenses medicines to the patients. Also, this study demonstrated closeness to our findings in terms of medicine take-back programs' awareness with 23%, whereas, our data [Table 2.] figured 37%. According to many studies [13], the medicine take-back program is an excellent way to remove expired or unused medicines from houses. Our study findings emphasized the need to develop programs and policies to ensure unused and expired medicine collection from doctors and nurses. Also, disposal methods were a significant issue in our studies. According to the Food and Drug Administration (FDA), the best option for managing unused and expired medicines is to find a medicine take-back location [60]. Usually, the medicine take-back location is a local pharmacy or a hospital. Another important and concerning issue is antibiotic resistance because of the inappropriate disposal of antibiotics, manifested in research [61]. Antibiotics have been detected in the surface water and wastewater of many countries like China [62], Vietnam [63], Croatia [64], Pakistan [65], and other countries [66], which is a huge concern.

### Recommendations to minimize unused and expired medicines in household garbage

From our study findings, the participant doctors and nurses supported some recommendations like launching awareness-related campaigns, reducing less specific medicines from prescription, donating unused medication, medicine take-back (returning unused medicines to the pharmacy), or donating OTC medicines to friends and relatives.

The disposal of pharmaceuticals collected from medicine take-back programs have mostly relied on incineration [67]. The U.S. Environment Protection Agency recommended incineration as the preferred method of disposing of household pharmaceuticals collected through medicine take-back programs [68]. If the unused or unwanted medication is not on the flash list, consumers would through them in the trash following the recommended steps for household disposal of medicines. (Fig. 7) [63]. Together with this, minimization and recycling efforts usually offer the most sustainable approaches to pharmaceutical waste management [67]. Though pharmacy reuse is a complex issue especially concerning safety and liability, controlled reuse of medicines can be a way to reduce their negative environmental impact [69]. Recovery of active pharmaceutical ingredients (APIs) is another important feature in the management of proper medicine disposal. A contemporary finding reported that most of the active ingredients in commonly discarded medicines continue to be in stable form for many years after their expiration dates printed on product labels [70]. The solvent extraction method for recovery of APIs from expired or unused medications is the most studied technique [59]. As a whole, recovering active ingredients is economically more profitable than synthesizing those ingredients from scratch owing to the simplicity of medicine ingredients in many products [71,72].

## LIMITATIONS

This study has some limitations. Though two prominent healthcare professionals were involved in this study, it could not include other healthcare professionals'

pharmacists and did not reach the general public regarding their approaches towards medicine disposal practices. Different medicine formulations like solid, liquid, and semi-solid were not taken into consideration in this particular study. Additionally, this research was Dhaka city-oriented. It could not go further to include other metropolitan cities in the country.

Further participation of respondents on a large scale is recommended in order to obtain more information about unused and expired medicines disposal practices.

## CONCLUSION

The majority of the study respondents' doctors, and nurses dispose of unused and expired medications by dumping them in a dustbin, toilet/basin. This practice contradicts the recommended guidelines established by the FDA and national policies. Such practices pose potential risks to public health and the environment [73]. This study tried to generate preliminary evidence on leftover and household medicine disposal patterns and knowledge of the consequences of it. Findings from this study can help to assist in creating awareness about appropriate medicine disposal practices in households and trigger interest and attention among policymakers about formulating relevant regulations. Implementing public awareness-related campaigns in public–private partnership programs in Bangladesh will be beneficial in reducing inappropriate disposal methods of medications. Last, but not least, it is our responsibility to make sure proper medicine disposal practices to protect people and the ecosystem.

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## AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

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## CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

## ETHICAL APPROVALS

The study protocol was approved by the Institutional Ethics Committee of BIRDEM General Hospital, Dhaka, Bangladesh (Approval Number: BADAS-ERC/EC/19/00282) and this research study was carried out in conformity with the ethical principles of the Declaration of Helsinki.

## DATA AVAILABILITY

All data generated and analyzed are included in this research article.

## PUBLISHER'S NOTE

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## USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declares that they have not used artificial intelligence (AI)-tools for writing and editing of the manuscript, and no images were manipulated using AI.

## INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

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