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Review Paper

Environmental Sustainability Impacts of Improper Disposal of Domestic Pharmaceutical Waste in the Global South

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Abstract: Improper pharmaceutical waste disposal is a rising environmental pollutant around the world. Pharmaceutical waste disposal legislation and regulations are available to some extent but limited to industrial premises and health-care institutions. Information on the disposal of pharmaceutical waste in public hands, known as domestic pharmaceutical waste (DPW), is limited. This scoping review aims to comprehend the global practice of DPW disposal by following the PRISMA Extension for Scoping Reviews guideline. Three online databases were searched for eligible articles: peer-reviewed in English language, describing the methods that the public disposed of unwanted or expired pharmaceuticals at home (DPW Disposal) and the public's participation in their local DPW programs (DPW Program). Search terms were derived from Medical Subject Headings (MeSH) and free text when applicable. One expert report and thirty research publications were analysed. The articles originated from Asia (n=13), the Middle East (n=6), Africa (n=4), Europe (n=3), the United States (n=3) and Australia (n=1). Most pharmaceuticals are disposed of as household garbage (58.8%), returned to health facilities (17.9%) and flushed down the toilet drain (8.1%). There is a large range of diversity in public awareness (range: 14% - 82%) and participation in DPW Programs (range: 8.3% to 64%) with higher percentages reported from European countries. Existing regulations and policies have modest to moderate impact on proper DPW disposal. Our findings provide new information that may be utilised by policymakers in the process of laying the groundwork for a national plan outlining the most effective methods for disposing of DPW.

Keywords: Household pharmaceutical; domestic pharmaceutical; unused medicines; waste, disposal; sustainable cities; expired medicines

Introduction

Pharmaceuticals encompass medicinal substances and medical equipment employed for therapeutic, preventative, and diagnostic applications. The term "domestic pharmaceutical waste" (DPW) refers to pharmaceutical products that the general public holds that are either unused or expired. DPW can take many different forms, but some examples are hospital prescriptions that are unwanted or expired, supplements the user bought for their health, and medical equipment like inhalers for asthma treatment and insulin pens for

diabetes drugs. According to a report by the Organisation for Economic Co-operation and Development (OECD), the proportion of domestically consumed medication that is discarded as waste exhibits considerable variation, ranging from 3% to as high as 50%. This trend is believed to be on an upward trajectory due to the escalating consumption of medications and global investments in healthcare (OECD, 2022). Improper disposal of hazardous waste results in the generation of chemical residues that have detrimental effects on the environment and pose risks to human health (Kusturica et al., 2022). The improper disposal of DPW, such as flushing it down toilets, disposing of it as domestic garbage, and throwing it into water sources and drains, has had adverse effects on the environment (Boxall, 2004). For example, traces of DPW in wastewater has adversely affected the physiology, behaviour, reproduction, and mortality rates of aquatic species (Kusturica et al., 2022; Ortúzar et al., 2022). Additionally,the presence of antibiotics in wastewater is partly responsible for genetic changes in animals and the emergence of bacteria that exhibit resistance to multiple drugs. There is also risk of accidental or intentional misuse and poisoning if unused medicines are extracted from waste bins (Vieno et al., 2017).

According to the "2030 Agenda for Sustainable Development" Goal Targets (UNESCO, 2017; United Nations, 2015, 2023), the United Nations Educational, Scientific, and Cultural Organisation (UNESCO) has designated human pharmaceuticals as emerging contaminants in the environment. Consequently, the elimination of these contaminants is deemed a crucial measure. Efforts to mitigate pharmaceutical pollution are being implemented in numerous nations, albeit with significant variations in the level of advancement. According to documents from the European Union (2001) and Mitkidis et al. (2022), the European Union (EU) has implemented directives to address the proper disposal of pharmaceuticals that are no longer needed or have expired. The funding for the programmes was provided by either governmental entities or pharmaceutical corporations. Most European Union (EU) nations have adopted different approaches to the collection of unused or expired pharmaceuticals (DPW). These approaches include returning the medications to the pharmacy or utilising specific waste collection stations established by the local authorities (Barnett-Itzhaki et al., 2016; Rogowska & Zimmermann, 2022). In the United States, the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) play significant roles in pharmaceutical waste management, while the disposal of hazardous waste, including certain pharmaceuticals, is governed by the Resource Conservation and Recovery Act (RCRA) (Rogowska et al., 2019). The Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) have important responsibilities in the management of pharmaceutical waste in the United States. Additionally, the Resource Conservation and Recovery Act (RCRA) regulates the disposal of hazardous waste, which includes particular pharmaceuticals (Rogowska et al., 2019). The United States employs various methods to facilitate the collection of unused and expired medications. These methods encompass drug collection events orchestrated by the Drug Enforcement Administration (DEA), monthly medication collections conducted by pharmacies in specific states for non-controlled and over-the-counter medications, secure drop boxes positioned in public or secured areas, and the practise of most pharmacies collecting unused or expired drugs (Barnett-Itzhaki et al., 2016). Governmental organizations, businesses, or the industry provide funding for the disposal of unwanted and expired drugs (OECD, 2022).

The regulatory framework for the management of pharmaceutical waste in Middle Eastern countries is presently undergoing development with the objective of increasing awareness and improving infrastructure. Attempts have been undertaken in Lebanon and Saudi Arabia to enact legislation pertaining to the management of pharmaceutical waste, but with a focus primarily on trash originating from healthcare facilities (Alqurshi, 2020; Hajj et al., 2022; Mobrad et al., 2020). The management of pharmaceutical waste in Asian countries varies based on factors such as economic development, infrastructure, and environmental consciousness, which in turn shape their strategy for handling and disposing of pharmaceutical waste (DPW). Certain Southeast Asian nations have the potential to harmonise their rules for the disposal of pharmaceutical waste with internationally recognised organisations such as the World Health Organisation (WHO) or the United Nations Environment Programme (UNEP). The Environmental Protection and Management Act (EPMA), which establishes a comprehensive and strictly controlled framework for its management, governs the disposal of pharmaceutical waste in Singapore. The National Environment Agency of Singapore (2023) has established a comprehensive public guideline pertaining to the appropriate disposal of medications. This

guideline specifically encompasses the identification and handling of unused and expired medications, the necessity of sorting these medications, the removal of personal information from medication labels, and the packaging requirements for medications intended for return to the pharmacy or disposal in the garbage. The management of pharmaceutical waste in Malaysia is subject to regulation under the Environmental Quality Act 1974 (EQA) and the Environmental Quality (Scheduled Wastes) Regulations 2005 (EQSWR). These regulations govern several aspects of pharmaceutical waste, including its creation, storage, treatment, transport, and disposal, particularly in the healthcare and manufacturing sectors. Currently, the regulations pertaining to scheduled waste are solely implemented within industrial companies, hospitals, and other healthcare-related organisations and facilities (Environmental Quality Act 1974 (Act 127), 2005).

The aforementioned explanations agree that various countries have implemented measures to mitigate pharmaceutical pollution. However, there has been limited progress in effectively reducing the presence of hazardous pharmaceutical pollutants, as reported by the United Nations in 2023. Consequently, the objective of this scoping assessment is to aggregate data regarding the disposal methods employed by global communities for their domestic plastic waste (DPW), as well as their corresponding reactions to local DPW initiatives. The results obtained from this study would offer significant preliminary evidence in favour of establishing a comprehensive pharmaceutical waste management system in Malaysia.

Methodology

The PRISMA Extension for Scoping Review was used to perform and report on this scoping review. Any issues that emerged during the study process were resolved through consensus among the study team members. All authors contributed to the design and final reporting of this review.

1. Eligibility Criteria

The criteria for relevant articles were: (1) research articles or expert reports; (2) written in English; (3) described the methods by which the public disposed of DPW; and (4) described the public's awareness and participation in the DPW disposal program organised by the local authority. Editorials and conference abstracts were excluded.

2. Information Resources

Relevant articles were searcher from three electronic databases i.e. PubMed, Scopus, and Web of Science, up until March 2023.

3. Search Strategy

Potential articles were searched using a combination of Medical Subject Headings (MeSH) terms and free texts derived from pharmaceutical waste, drug disposal, waste disposal, and unwanted medicines involving domestic, community, or household settings, with outcomes reported in terms of attitude, behaviour, or practise. The search method used for PubMed is illustrated in Table 1. Abstracts with inaccessible full articles were excluded.

Table 1. Search method from PubMed (dated 30 March 2023)

Search number	Query
#1	"household waste"
#2	"pharmaceutical waste"
#3	"disposal of pharmaceutical waste"
#4	"management of pharmaceutical waste"
#5	("consumer") AND ("patient") AND (" public")"
#6	"unwanted medication"
#7	"unwanted medicine"
#8	("unwanted medicine") OR ("unwanted medication")
#9	"waste disposal"
#10	"drug disposal"
#11	(regulations) OR (policies)

#12	(attitude OR (practice)
#13	((domestic) OR (community)) OR (household)
#14	#1 OR #2 OR #3 OR #4 OR #6 OR #7 #9 OR #10
#15	#5 OR #12
#16	#11 AND #14
#17	#13 AND #16
#18	#15 AND #17
#19	#15 AND #17

4. Article Selection and Data Extraction

Search results were entered into Mendeley Reference Manager software to facilitate the identification and deletion of duplicate articles. The initial screening was conducted involving relevant titles and abstracts to identify potential articles. The full-text articles were reviewed when the title and abstract were insufficient to determine the eligibility of the study. Full-text articles were retrieved for all eligible studies. Two reviewers screened the full text of all eligible articles and extracted the following data for analysis:

i. Publication details.
ii. Study method.
iii. Subject demography.
iv. Methods by which the public disposes of DPW.
v. The public's awareness and participation in the DPW disposal program.

The extracted data were compiled using a study matrix in Microsoft Excel. All extracted data were cross-checked by the rest of the team members, and discrepancies in data extraction were resolved by consensus among the reviewers.

5. Data Analysis

The extracted data were analysed according to the outcome measures of the scoping review.

i. Methods by which the public disposes of DPW: The disposal methods were classified based on the frequency and percentages of each type of disposal method.
ii. Public's awareness and participation in the DPW disposal program: The data pertaining to awareness were provided in the form of percentages, indicating the proportion of individuals who reported remembering information regarding the DPW disposal programme or collection schedule in their respective localities. The extent of public participation in the disposal programme was measured by the percentage of respondents who actively engaged in the program.

The Findings

The final review included 29 articles (Figure 1). Of the 29 publications, one was an expert report (Amaral & Fop, 2013) and the remaining 28 were cross-sectional surveys (Akici et al., 2018; Ali et al., 2021; Al-Shareef et al., 2016; Althagafi et al., 2022; Ariffin & Zakili, 2019; Arkaravichien et al., 2014; Ayele & Mamu, 2018; Bashaar et al., 2017; Begum et al., 2021; Bettington et al., 2018; Ehrhart et al., 2020; Esseku et al., 2022; Ghemrawi et al., 2022; Hajj et al., 2022; Hassali & Shakeel, 2020; Insani et al., 2020; Kahsay et al., 2020; Kristina et al., 2018; Kumar et al., 2019; Luo et al., 2021; Magagula et al., 2022; Ong et al., 2020; Pramestutie et al., 2021; Vatovec et al., 2021; Vellinga et al., 2014; Wang et al., 2021; Watkins et al., 2022; Zorpas et al., 2018).

1. Domestic Pharmaceutical Waste Disposal Practice

The various ways that public dispose DPW were described in 27 cross-sectional surveys with a total of 18,064 respondents. Of the 27 articles, twelve described the practice in the Asian region (Ariffin & Zakili, 2019; Arkaravichien et al., 2014; Bashaar et al., 2017; Begum et al., 2021; Hassali & Shakeel, 2020; Insani et al., 2020; Kristina et al., 2018; Kumar et al., 2019; Luo et al., 2021; Ong et al., 2020; Pramestutie et al., 2021; Wang et al., 2021). The remaining articles described practices in the Middle East, n=6 (Akici et al., 2018; Ali et al., 2021; Al-Shareef et al., 2016; Althagafi et al., 2022; Ghemrawi et al., 2022; Hajj et al., 2022), Africa, n=4 (Ayele & Mamu, 2018; Esseku et al., 2022; Kahsay et al., 2020; Magagula et al., 2022), Europe, n=3 (Vellinga et al., 2014; Watkins et al., 2022; Zorpas et al., 2018) and one each from the United States (Vatovec

et al., 2021) and Australia (Bettington et al., 2018). Table 2 summarizes the characteristics of the articles. It is apparent from Figure 2 that the most common methods to dispose DPW is discard in household garbage (58.8%), followed by returning it to health facility es (17.9%) and flush down the sanitary system (8.1%).

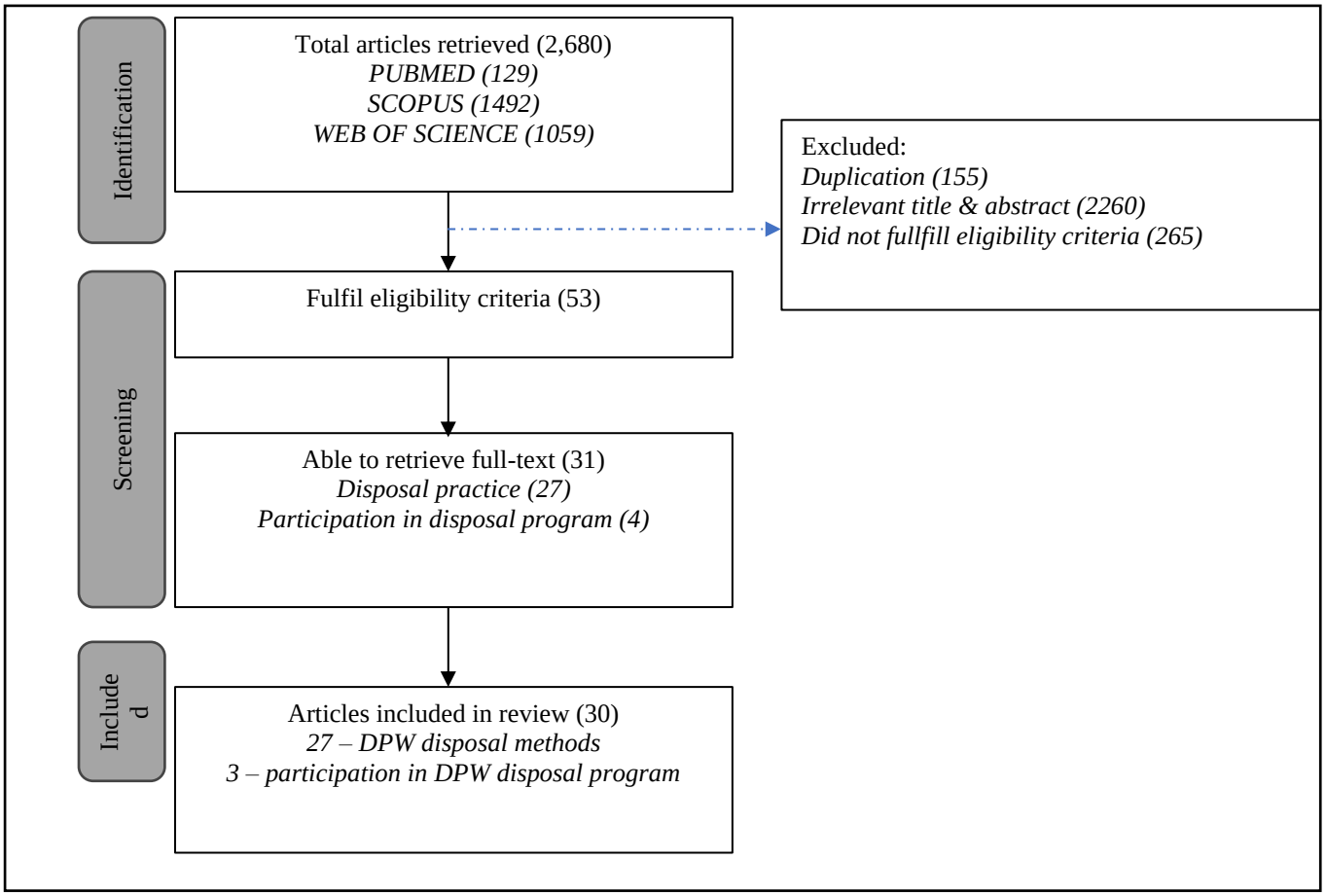

Figure 1. Flow of scoping review (DPW: Domestic pharmaceutical waste)

Table 2. Articles on domestic pharmaceutical waste disposal (arranged by country in alphabetical order)

Author (Year)	**Country**	**Study Design**	**Study Participants**	**Number Of Participants**	**Domestic Pharmaceutical Waste Disposal Methods (%)** *In All Studies, The Respondents Were Allowed To Select More Than One Method*
Bashaar et al., 2017	Afghanistan	Cross sectional survey	General public in Kabul	301	• Return to health facilities (7.3) • Household garbage (77.7) • Toilet drain (12.0) • Donate/ Give away (1.3)
Bettington et al., 2018	Australia	Cross sectional survey	Individuals aged ≥18 years	4302	• Return to health facilities (23.0) • Household garbage (65.0) • Toilet drain (23.0) • Burn (3) • Bury (6) • Municipal hazardous waste collection (8.0) • Not specified (1.0)
Begum et al., 2021	Bangladesh	Cross sectional survey	Households of Dhaka South and North City Corporation	180	• Return to health facilities (21.0) • Household garbage (47.0) • Toilet drain (4.0) • Burn (2.0) • Throw out the house (19.0) • Not specified (6.0)
Luo et al., 2021	China	Cross sectional survey	Individuals aged ≥18 years old in Southwest of China (Kunming)	558	• Household garbage (82.6) • Toilet drain (9.3) • Municipal hazardous waste collection (8.2)
Zorpas et al., 2018	Cyprus	Cross sectional survey	Individuals aged ≥18 years old in District of Nicosia (urban and rural area)	184	• Household garbage (92.4) • Toilet drain (24.5) • Burn (0.5) • Keep in the house (1.6) • Not specified (8.2)
Ayele & Mamu, 2018	Eastern Ethiopia	Cross sectional survey	General public Kebele (ward) 16 of Jinela Woreda (district), Harar City	695	• Return to health facilities (3.5) • Household garbage (53.2) • Toilet drain (30.6) • Burn (2.2) • Keep in the house (16.0) • Donate/ Give away (2.8) • Not specified (3.2)
Esseku et al., 2022	Ghana	Cross sectional survey	General public in Kabul Krowor	400	• Household garbage (98.0) • Toilet drain (4.0)

					• Burn (5.0) • Bury (8.0)
Kumar et al., 2019	India	Cross sectional survey	Consumers of medicines from the outpatient pharmacy of a tertiary care hospital	145	• Return to health facilities (14.4) • Household garbage (65.5) • Toilet drain (11.6) • Donate/ Give away (1.3) • Not specified (5.5)
Insani et al., 2020	Indonesia	Cross sectional survey	Individuals aged ≥18 years old.	497	• Return to health facilities (0.2) • Household garbage (82.1) • Toilet drain (5.3) • Burn (4.0) • Donate/ Give away (0.4)
Kristina et al., 2018	Indonesia	Cross sectional survey	Households in Yogyakarta Province	324	• Return to health facilities (3.1) • Household garbage (71.6) • Toilet drain (17.3) • Keep in the house (85.8) • Donate/ Give away (23.2)
Pramestutie et al., 2021	Indonesia	Cross sectional survey	General public in the City of Malang, Malang Regency, and the City of Batu	322	• Household garbage (49.4) • Toilet drain (8.2) • Burn (3.7) • Bury (2.2) • Keep in the house (7.5)
Vellinga et al., 2014	Ireland	Cross sectional survey	General public in the streets of Galway and Cork	398	• Household garbage (51.0) • Toilet drain (43.0) • Not specified (6.0)
Hajj et al., 2022	Lebanon	Cross sectional survey	Lebanese adult	735	• Return to health facilities (25.7) • Household garbage (29.1) • Toilet drain (8.7) • Keep in the house (60.3) • Donate/ Give away (49.7)
Ariffin & Zakili, 2019	Malaysia	Cross sectional survey	Households in a residential area in Hulu Langat.	103	• Return to health facilities (25.2) • Household garbage (63.1) • Toilet drain (8.8) • Burn (3.8) • Bury (3.8) • Keep in the house (26.2) • Not specified (2.0)
Ong et al., 2020	Malaysia	Cross sectional survey	Individuals aged ≥18 years old	483	• Return to health facilities (19.4) • Household garbage (64.0) • Toilet drain (10.6)

					• Burn (6.6) • Municipal hazardous waste collection (37.4) • Donate/ Give away (23.3)
Hassali & Shakeel, 2020	Malaysia	Cross sectional survey	General public in Cheras area	426	• Return to health facilities (1.1) • Household garbage (84.9) • Toilet drain (12.4) • Not specified (1.4)
Wang et al., 2021	Malaysia	Cross sectional survey	General public from Kuala Lumpur and Selangor	1184	• Return to health facilities (14.2) • Household garbage (21.0) • Toilet drain (1.6) • Keep in the house (23.2) • Donate/ Give away (1.6) • Not specified (0.5)
Kahsay et al., 2020	Northern Ethiopia	Cross sectional survey	General public of Adigrat city	359	• Return to health facilities (4.8) • Household garbage (69.1) • Toilet drain (9.2) • Burn (1.9) • Keep in the house (4.2) • Donate/ Give away (6.9) • Not specified (3.2)
Al-Shareef et al., 2016	Saudi Arabia	Cross sectional survey	Attendees of pharmacy and primary clinic in King Khalid University Hospital (KKUH), and King Saud University (KSU)	1057	• Return to health facilities (3.4) • Household garbage (79.2) • Toilet drain (7.0) • Municipal hazardous waste collection (3.7) • Keep in the house (0.7) • Donate/ Give away (1.6) • Not specified (1.7)
Althagafi et al., 2022	Saudi Arabia	Cross sectional survey	Individuals aged $\geq$ 18 years old	1105	• Return to health facilities (19.6) • Household garbage (41.5) • Toilet drain (3.9) • Not specified (15.4)
Ali et al., 2021	Saudi Arabia	Cross sectional survey	General public of Eastern province, Saudi Arabia	916	• Return to health facilities (33.3) • Household garbage (67.0)
Magagula et al., 2022	South Africa	Cross sectional survey	Students aged $\geq$ 18 years old at the University of Johannesburg	371	• Return to health facilities (10.8) • Household garbage (63.3) • Toilet drain (22.4) • Burn (10.8) • Keep in the house (22.6) • Donate/ Give away (7.8) • Throw out the house (20.2)

Akici et al., 2018	Turkiye	Cross sectional survey	Employees from across eight provinces of Turkey	1121	• Return to health facilities (66.1) • Household garbage (33.9)
Arkaravichien et al., 2014	Thailand	Cross sectional survey	General public in Ban Ped sub-district, Khon Kaen City, Thailand.	311	• Return to health facilities (1.0) • Household garbage (70.8) • Toilet drain (7.4) • Bury (2.3) • Keep in the house (25.6)
Ghemrawi et al., 2022	United Arab Emirates	Cross sectional survey	General public of the seven emirates in the UAE	503	• Return to health facilities (4.0) • Household garbage (86.0) • Toilet drain (5.0) • Keep in the house (3.0) • Not specified (2.0)
Watkins et al., 2022	United Kingdom	Cross sectional survey	General public $\geq$ 18 years old	663	• Return to health facilities (27.0) • Household garbage (48.0) • Toilet drain (25.0)
Vatovec et al., 2021	United States	Cross sectional survey	Individuals aged $\geq$ 18 years old in Vermont	421	• Return to health facilities (22.0) • Household garbage (19.0) • Toilet drain (9.0) • Keep in the house (26.0)

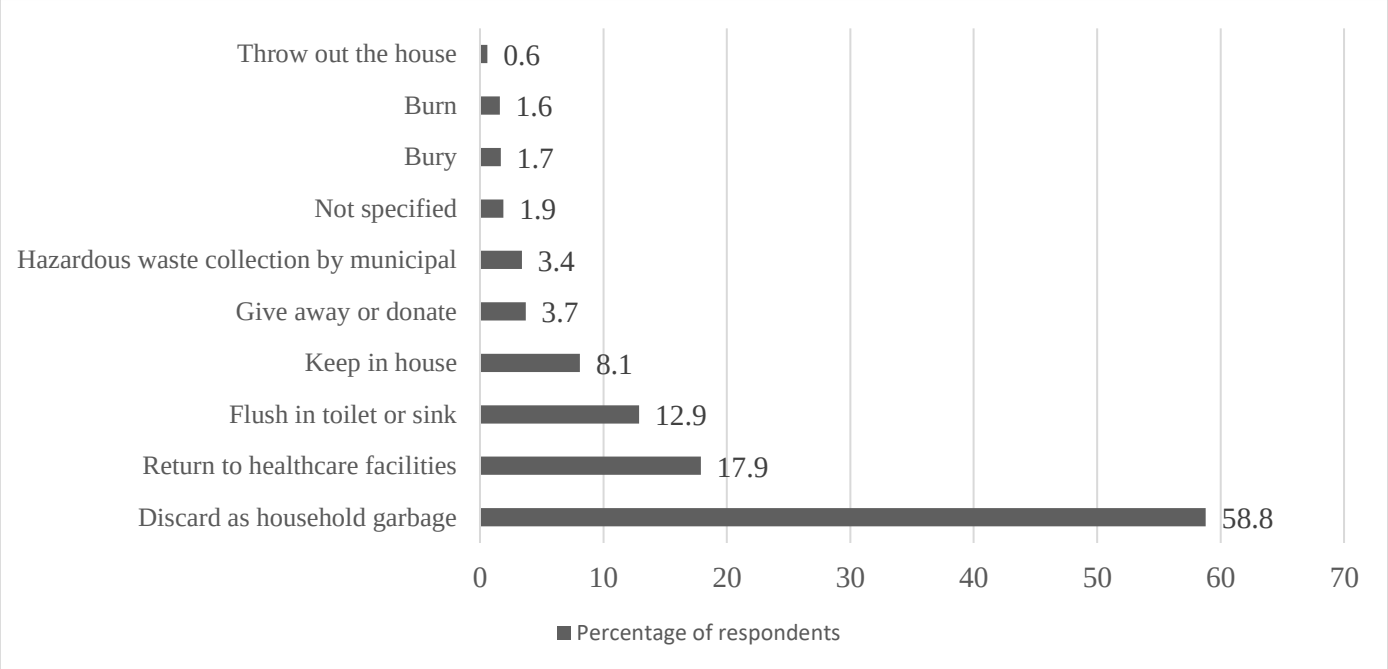

Figure 2. Domestic pharmaceutical waste disposal methods by the general public from reviewed articles

2. Participation in Domestic Pharmaceutical Waste Disposal Programs

Information about the public's uptake of DPW disposal programmes initiated by their local authority was gathered from three articles (Amaral & Fop, 2013; Ehrhart et al., 2020; Yang et al., 2018). The expert report by Amaral and colleagues described DPW participation in the European countries of Belgium, Hungary, Italy and the United Kingdom (Amaral & Fop, 2013). Whereas the other two articles described participation in the United States (Ehrhart et al., 2020) and Malaysia (Yang et al., 2018). Countries in the European region have more established DPW programmes in place due to the legal framework provided by directives issued by the European Union. Public awareness of DPW ranged from 14% to 82%. The public's participation in the DPW programmes ranged from 8.3% to 64%, with a higher rate in the European regions (Table 3).

Table 3. Summary of articles on uptake of domestic pharmaceutical waste disposal programs by the public

Author (Year)	Country	Domestic pharmaceutical waste (DPW) disposal initiatives by local authority	Year started	Program uptake by the general population
Amaral & Fop, 2013	Belgium	DPW collection bins exclusively from the pharmacies.	2005	• From 2000 to 2011, the volume of recovered residues increased by 33%, an average of 2.5% per year. • 62% of respondents were aware that they could return unused medicines to a pharmacy. • 35% of respondents returned solid medications and 28% liquid medications to the collection point respectively. • Only 29% reported that they remembered receiving information on the collection scheme.
	Hungary	DPW collection bins from pharmacies, distributors and other selling point.	2005	• The amount of household pharmaceutical waste collected in Hungary from 2007 increased from 176.7 tonnes to 222.7 tonnes in 2012 but still lower than initial goal (300-500 tonnes per year). • 63% of respondents were aware of the unused or expired medications collection scheme. • 40% of respondents returned solid medications and 43% liquid medications to the collection point respectively. • Majority (78%) respondents remembered that they had received information on the collection scheme.
	Italy	DPW collection bins in pharmacies, healthcare centres or on the streets.	2005	• 82% of respondents were aware of the existence of a collection system for unused pharmaceuticals in the municipality of Rome. • 64% of respondents returned solid medications and 60% liquid medications to the collection point respectively. • 65% remembered that they had received information on the collection scheme.

	United Kingdom	DPW collection bins at pharmacies returned to the National Health Service.	2005	• Only 38% of the survey respondents in London were aware of the availability of a program to return unused medicines to a pharmacy. • 17% of respondents returned solid medications and 11% liquid medications to the collection point respectively. • 31% remembered that they had received information on the collection scheme.
Ehrhart et al., 2020	United States	DPW collection at dedicated centres.	2010	• 8.3% of respondents choose to discard unused or expired drugs to Dropbox. • Only 14% of consumers were aware of the location of the nearest Dropbox and 8% received recommendations to dispose of leftover drugs using the Dropbox. • 56% of respondents did not know about Drop boxes at the time of the survey.
Yang et al., 2018	Malaysia	DPW collection bins at public hospitals and clinics.	2010	• Based on survey conducted in government hospitals and health clinics in Sabah, out of 244 respondents, only 26% have utilised the MRP and returned their medication biannually on average.

Discussion

This scoping review examines the existing practises employed by global communities in disposing of unused or expired pharmaceuticals and medical devices. The evaluation also assessed the extent to which the general people embraced the DPW initiatives in their own communities. Our research acknowledges that the global pattern of pharmaceutical waste (DPW) disposal has remained unchanged following UNESCO's declaration in 2017 to address the issue of pharmaceutical waste contamination. The efficacy of current legislation, regulations, and national initiatives aimed at addressing the disposal of pharmaceutical waste in domestic settings, both within individual countries and on a global scale, has been found to be minimal or only somewhat effective. The findings of this present study indicate that around 60% of the global population engages in the practise of disposing of domestic plastic waste (DPW) by means of household garbage disposal. One potential rationale for this phenomenon could be that there is a predominant emphasis on addressing the disposal of pharmaceutical waste generated by industrial and healthcare settings, while the approach to managing such waste from community sources remains ambiguous.

Indeed, it is worth noting that in Africa and Asia, the disposal of pharmaceuticals through household waste or their disposal via the washbasin or toilet represents the sole viable alternative (Rogowska & Zimmermann, 2022). The presence of restricted infrastructure and rules may impede the adoption of progressive behaviour change, notwithstanding the potential for heightened public awareness. One potential consequence of disposing of hazardous waste, such as DPW, as regular household garbage is the inadvertent consumption and subsequent poisoning of children, pets, or individuals with cognitive impairments. This is particularly worrisome in the case of pharmaceuticals that possess a significant propensity for misuse, such as psychotropic chemicals, analgesics, cough syrups containing opioids, or other substances with the potential for abuse. It is crucial to emphasise that our current understanding of the impact of chemical interactions on human beings remains limited. The aquatic system in Malaysia exhibits a diverse range of pharmaceutically active compounds, such as caffeine, metformin, paracetamol, diclofenac, amoxicillin, and others (Al-Odaini et al., 2013; Al-Qaim et al., 2015; Praveena et al., 2018). According to a study conducted by Wilkinson et al. (2022), it was shown that Sungai Kajang, located in Malaysia, ranked in the top 20 rivers worldwide in terms of the highest cumulative concentrations of active pharmaceutical ingredients. Regrettably, the current restrictions governing the release of pharmaceutical waste remain insufficiently stringent.

An intriguing observation is that the prevalent practise within the community is the act of distributing or contributing unused or expired pharmaceuticals to others. The aforementioned observation indicates a concern regarding pharmaceutical safety that arises when medications are shared without knowledge of their intended use. This practise can have negative consequences for those with chronic illnesses, as well as vulnerable populations such as children and older adults. The potential adverse outcomes associated with medicine sharing encompass the administration of an incorrect dosage, the manifestation of side effects, and the onset of an allergic response, which may be exacerbated in individuals with pre-existing organ dysfunction. Individuals who have experienced an allergic response to a particular medication typically possess familiarity solely with its proprietary name, but its generic name and other brand names are likely to be unfamiliar to them. According to a study conducted in Croatian pain clinics, the act of sharing analgesic prescriptions among patients was found to provide a potential risk of unpleasant responses, including vomiting and bleeding, due to potential drug interactions (Beyene et al., 2014). There are multiple causes that can account for this result. One such aspect is the inclination to assist others, particularly within familial contingencies. Additionally, the unavailability of necessary medication or restricted access to healthcare facilities may contribute to this phenomenon. Furthermore, individuals may possess surplus or unneeded prescription medications, leading to uncertainty regarding appropriate disposal methods (K. Beyene et al., 2016). Furthermore, there are additional rationales for the act of sharing medications. These include individuals having comparable medical illnesses or symptoms, experiencing a depletion of their prescribed medication supply, perceiving easier accessibility in comparison to seeking medical consultation, encountering emergency situations, and seeking to economise (Alhomoud, 2019; Renny et al., 2019; Song et al., 2022).

When considering the extent to which the public engages with the DPW programme implemented by their local authority, it is crucial to acknowledge that community initiatives for pharmaceutical waste disposal differ across countries due to variations in socioeconomic conditions, as well as the existing regulations,

policies, and guidelines in place. Europe possesses a comparatively more well-developed system for managing pharmaceutical waste in comparison to other regions. This is a result of the legislative framework that the European Union has established for its member states. The disparity in public awareness and engagement in DPW programmes, particularly in European regions, can be attributed to various factors. The inadequate adherence of the general population to proper disposal methods for expired medications suggests that there is potential for increasing engagement in Drug Take-Back (DTB) programmes, even in countries that already have established rules, policies, or national initiatives for drug collecting. This is evident in nations like the United Kingdom, Ireland, Australia, and the United States. The results of our study align with previous research on the adoption of medication-collecting schemes, namely in the United Kingdom. For instance, a study conducted by Ehrhart et al. (2020) found that less than 50% of participants surveyed in London were aware of the existence of initiatives that allow for the return of unneeded medications to a pharmacy. The primary factor contributing to low awareness among the general public regarding safe medication disposal methods, as indicated by studies conducted in Indonesia, Malaysia, Belgium, and the United Kingdom, involving 69% to 79% of respondents, is the absence of exposure to educational programmes and awareness campaigns (Alfian et al., 2021; Amaral & Fop, 2013; Hassali & Shakeel, 2020). The limited utilisation of medicine disposal programmes administered by the governing body was also discovered to be linked with the geographical placement of the collecting facility, the time constraints imposed, and the inconvenience of travelling great distances to reach the facility (Lim, 2016; Stoddard et al., 2017). The findings of a qualitative investigation conducted by Chong et al. (2022) revealed that pharmacy premises in Malaysia encountered obstacles in managing DPW that were returned to them. These barriers were attributed to the absence of clear instructions for establishing the service and the imposition of a substantial incineration cost. In the aforementioned study, the chemists proposed enhancements to the collection centre with the aim of enhancing consumer convenience. These improvements included garnering support from health professionals, implementing incentives for service providers, and fostering strategic collaboration among all relevant parties.

Conclusion

This study and others published elsewhere have highlighted the concern related to the emergence of increasing pharmaceutical pollutants. Several studies have shown its ecological impact. However, evidence pertaining to its impact on humans remains loosely documented. Many drugs are designed to be biologically active and to stay stable in the environment for extended periods of time. Because most metabolised drugs are polar in nature, they can contaminate the water system as biological waste, resulting in chronic pollutant exposure for aquatic organisms as well as humans (Al-Odaini et al., 2013). This situation will have a negative impact on water security. In accordance with the current laws and policies, Malaysia's foundation for safe medication disposal in the community is still uncertain. Recommendations for future initiatives should include strengthening the legislative framework, educating the public, and improving infrastructure and the DPW collection system.

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