



BMJ Open Disposal practices of unwanted household medications in China: a cross-sectional study

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ABSTRACT

Objectives This study aimed to understand disposal practices of unwanted medications in Chinese households and examine associations between influencing factors and these disposal practices.

Design A nationwide cross-sectional study conducted between 11 October and 26 October 2018.

Setting Municipalities directly under the central government and provincial capitals across 30 provinces and autonomous regions.

Participants A total of 6293 households participated in the study.

Primary and secondary outcome measures A self-designed questionnaire was used to survey disposing methods of unwanted medications, which were categorised into three groups: household waste disposal, recycling and use or give unwanted medications to others.

Results 2771 (44%) households reported they have unwanted medications. The majority (89%) disposed of unwanted medications in the bin, sink or toilet. Having a family member of 65 years old and above (OR: 5.45; 95% CI: 3.20 to 9.26), having a family member of medical professions (OR: 1.45; 95% CI: 1.15 to 1.83), receiving information on proper disposal (OR: 6.03; 95% CI: 4.54 to 8.00) and having a high level of perception of risk to the environment (OR: 1.56; 95% CI: 1.05 to 2.30) were associated with recycling. Additionally, a household having more than 10 medications stored (OR: 1.73; 95% CI: 1.29 to 2.34) was more likely to dispose of unwanted medications in the bin or sink/toilet. Women were less likely to use unwanted medications or give them to others (OR: 0.59; 95% CI: 0.38 to 0.90). A higher perception of health risks was associated with increased recycling, particularly among middle-aged and older adults (OR: 1.60; 95% CI: 1.04 to 2.47) and decreased likelihood of using unwanted medications or giving them to others (OR: 0.36; 95% CI: 0.20 to 0.67).

Conclusions There is an urgent need to establish a standardised management system for rational disposal of unwanted medications in China. This system should aim to promote and educate the public on rational stocking and use of medications, as well as appropriate disposal practices.

BACKGROUND

As the global economy and health industries continue to advance rapidly, drug

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study is a large-scale investigation that analyses the factors influencing the disposal of unwanted household medications across 30 provinces and autonomous regions in China.
- ⇒ However, potential recall bias may have led to an underestimation of households with unwanted medications.
- ⇒ Findings may not be generalisable to rural areas or older adults due to the sample's demographic bias.
- ⇒ We did not investigate the specific types of unwanted medications, limiting the understanding of disposal practices related to different medication categories.
- ⇒ Seasonal variations in disposal practices were not considered.

utilisation patterns have undergone significant transformations, leading to an augmentation in drug purchases. In developing countries, drug expenditure constitutes approximately 30%–40% of total health-care expenditures.¹ Approximately 78.6% of households in China report storing medicines.² However, numerous medications are not used for treating diseases due to factors such as alterations in the patient's condition (including condition improvement, deterioration or death), side effects and poor treatment outcomes. Consequently, a substantial proportion of the medications are wasted. Unused and expired medications not only are a significant waste of resources but also pose potential hazards to the environment and human health when disposed of improperly.³ Unwanted medications can infiltrate the soil, rivers and lakes, thereby contaminating the environment and increasing the risk of antibiotic resistance.⁴ Furthermore, children may be accidentally exposed to unused and expired drugs stored in the household, leading to adverse health consequences.⁵ Additionally, some addictive drugs may be shared among individuals, which increases

the risk of illicit use of psychotropic substances.⁶ There is a growing international concern regarding the potential societal, environmental and health impacts of improper disposal of unwanted household medicines.

Unwanted medications refer to those that have expired, become denatured/moldy due to improper storage, or those which remain within their expiration date but are no longer needed for use.⁷ A recent systematic review revealed that consumers used multiple methods for disposing of unwanted medicines. The most prevalent methods include discarding them in the bin and flushing them down the sink, drain or toilet.⁸ In many developing countries, the incidence of returning medications to pharmacies or healthcare facilities remains low,⁹ and much of the unwanted solid waste collected is directed to poorly managed landfills.¹⁰ Recent research on the selection of disposal destinations of unwanted medications has investigated the demographic characteristics of the public (such as gender, age and educational attainment), household factors (such as the number of medications stored in the household, type of medications and patients with chronic diseases in the house) and health education (such as proper education and clear instructions for disposal practices).¹¹ In addition to the above factors, individuals' knowledge and attitudes toward medication disposal practices are also risk factors for improper disposal of unwanted medications in households.¹² Although previous studies have found that respondents are generally concerned about improper medication disposal and have a good understanding of the environmental and health effects of unwanted medications, their actual behaviours are generally inconsistent with their awareness.¹³

The prevalence of improper disposal methods is also influenced by the availability of well-functioning disposal systems.⁸ From an international perspective, some countries have formulated policies and action guidelines for the disposal of unwanted medicines. This usually requires various government departments to jointly manage unwanted medications and encourage both enterprises and the public to participate in social governance. In the UK, the Royal Pharmaceutical Society has gradually implemented activities for proper medication disposal since the '90s. The Pharmaceutical Services Negotiating Committee published the 'Disposal of Unwanted Medicines Service Specification' in 2004 and collaborated with other organisations to specify guidelines for community pharmacies in 2013. In the USA, the Food and Drug Administration and Office of National Drug Control Policy jointly developed federal guidelines,¹⁴ while the Drug Enforcement Administration and Environmental Protection Agency manage the disposal of unwanted medications. The German Federal Ministry of Health provides guidance on household drug storage and disposal of unwanted drugs on its official website. Furthermore, France is one of the few countries to have enacted legislation regarding the collection and safe destruction of unused pharmaceutical drugs with 'Decree No. 2009-718'. Currently, China lacks

regulations and detailed operational guidelines for the disposal of unwanted household medications.¹⁵ Despite some local governments introducing regulations for recycling expired medications, these face issues such as a weak legal basis, lack of enforcement and poor operability.

As the world's second-largest pharmaceutical market and the largest producer and exporter of active pharmaceutical ingredients,¹⁶ China faces the risk of long-term environmental exposure to large amounts of unwanted medications in the environment. This poses a significant challenge in reducing environmental loads and ecological risks. Therefore, understanding how Chinese households dispose of unwanted medications is crucial to minimise potential hazards to society and the environment from medication contamination sources.

METHODS

To understand the current status of household disposal of unwanted medicines in China, we conducted a 2-week cross-sectional survey. Using a convenience sampling method, we investigated households in municipalities directly under the central government and provincial capitals across 30 provinces and autonomous regions from 11 October to 26 October 2018, except Xizang and Taiwan. The surveyed population in each province was shown in [figure 1](#). The study was conducted through face to face interviews using structured questionnaires, completed with the assistance of trained investigators to ensure clarity and precision.

Questionnaire design

A self-designed four-section questionnaire was developed based on published studies.^{11 12 17} The first section gathered demographic information of household heads, including sex, age, education level and region of residence. The second section focused on basic household information and medication storage status. The third section explored respondents' perceptions of the potential risks of unwanted medications to human health and environmental health. The final section investigated actual disposal methods for unwanted household medications and knowledge of proper disposal methods. A single item measured disposal practices: 'how do you usually dispose of unwanted medicines at home?' Respondents could choose multiple disposal methods: throwing them in the trash, flushing them down the toilet or sink, recycling them, keeping or taking them, selling them or giving them to family members or friends. A pilot survey was conducted with 100 participants before the formal questionnaire was distributed, and these participants formed a separate cohort for refining the questionnaire. The reliability and validity of the questionnaire have been reported elsewhere.¹⁸

Data collection

For quality assurance purposes, we dispatched trained staff to oversee the investigators and randomly checked

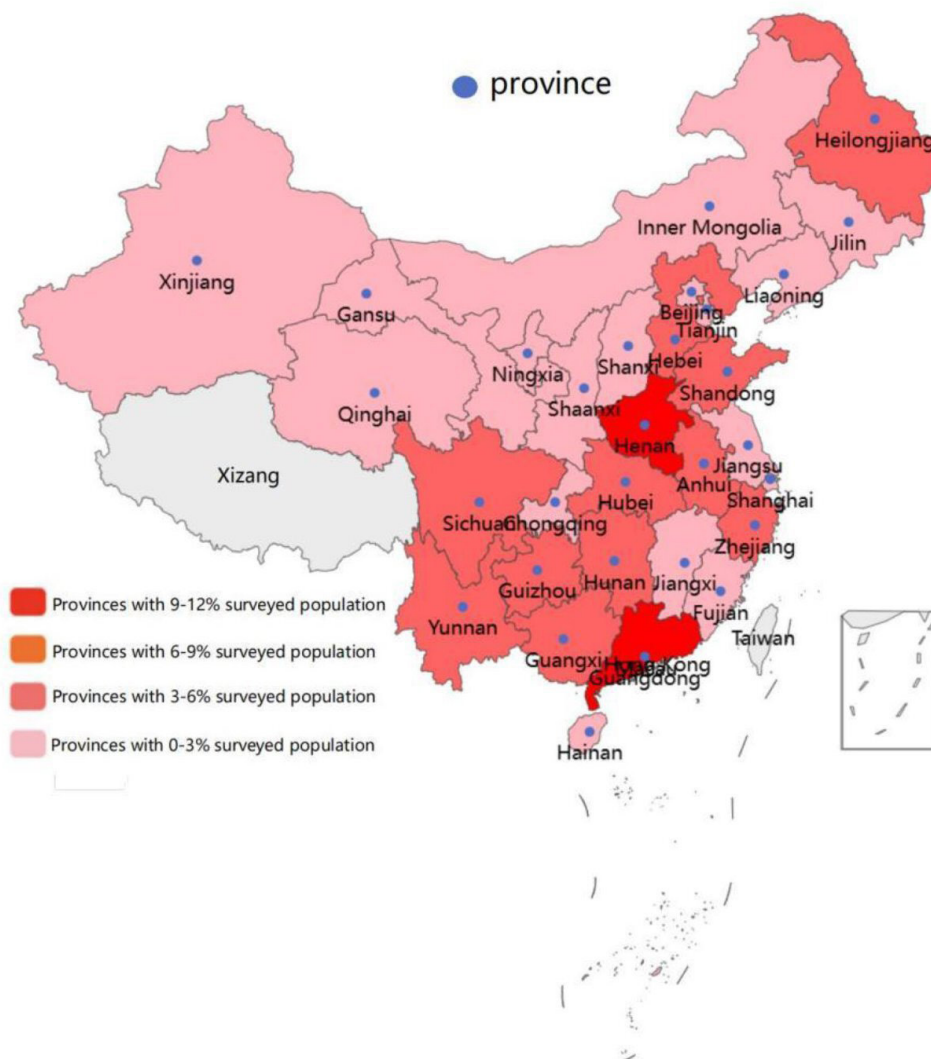


Figure 1 Distribution of participants in the unwanted medication survey across China's 30 provinces. This figure shows the proportion of the surveyed population in each province, reflecting the distribution of the survey sample in different regions.

the completion of the questionnaires. Participation in the survey was voluntary and anonymised. Trained investigators conducted the survey at the respondents' homes. After thorough screening, we collected a total of 6388 questionnaires, of which 6293 were valid and complete, resulting in a nearly 99.8% response rate. Considering our resource limitations, this sample size represents the maximum feasible within our capabilities and is sufficient to provide precise estimates for our study objectives at the designated confidence level.²

Dependent variable

In our survey, respondents were provided with six disposal options for unwanted medications. For analytical purposes, we categorised these options into three composite variables: household waste disposal, recycling and use or give unwanted medications to others. Household waste disposal refers to methods that involve discarding unwanted medications in the bin/sink/toilet.

Using unwanted medications or giving them to others included keeping or taking unwanted medications, selling to others and giving to family members/friends. These three dichotomised variables served as independent variables in subsequent analyses.

Data analysis

The categorical variables were presented as numbers and percentages. Both univariate and multivariate analyses were conducted to examine the associations between influencing factors and the disposal of unwanted medications. To verify the logistic regression model assumptions, three key tests were performed: a link test to assess the suitability of the logistic function, a Hosmer-Lemeshow test for model fit, and a multicollinearity assessment using variance inflation factors. The outcomes of these tests have validated that our model adheres to the logistic regression assumptions. In the multivariate logistic analysis, the models were adjusted for demographic

characteristics (gender, age, educational attainment and region), household factors (presence of patients with chronic diseases, medical professionals and the number of medications stored), perceptions of potential risks of unwanted medicines (health risk perception and environment risk perception) and receipt of proper disposal information. Additionally, we stratified the recycling of unwanted medications by age and information receipt (whether participants had received information about proper disposal of unwanted medications). The results were reported as ORs with 95% CIs. Statistical analyses were performed using Stata/MP V.17.0, with *p* values <0.05 considered statistically significant.

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination plans of this research.

RESULTS

Characteristics of participants

Table 1 showed the characteristics of the participants. Among the 2771 households with unwanted medications, slightly more than half (53%) of the household heads were women. The majority of respondents were under 35 years old (50.6%), had a college degree (59.4%), had family members with chronic diseases (60.1%), had less than 10 medications (67.8%) and had no medical professional in the family (67.1%). Additionally, over half of the respondents (55.1%) received information about proper disposal of unwanted medications. 1953 (70.5%) respondents believed that unwanted medications were harmful to human health, and 1777 (64.1%) stated that they were harmful to the environment. The households interviewed were from the eastern region (35.3%), central region (32.7%) and western region (32%).

Multiple disposal destinations

2771 of all respondents reported having unwanted medications in their household. Figure 2 illustrated the characteristics of these respondents' various disposal destinations. Household waste disposal was the most common destination, with 2465 (89%) respondents disposing of them in the bin/sink/toilet. Only 487 (17.6%) respondents chose to recycle and 93 (3.4%) respondents chose to use or give their unwanted medications to others. Detailed distributions of the demographic characteristics were shown in online supplemental table 1.

Factors influencing disposal behaviours of unwanted medications

Recycling

After adjusting for potential confounding factors, table 2 shows the association between participant characteristics and recycling of unwanted medications. Compared with respondents younger than 36 years, those aged 46–55 years (OR: 1.58; 95% CI: 1.08 to 2.31), 56–65 years (OR: 4.73; 95% CI: 2.79 to 8.03) and older than 65 years (OR:

5.45; 95% CI: 3.20 to 9.26) were more likely to recycle unwanted medications. High school educational attainment (OR: 1.78; 95% CI: 1.18 to 2.70), households without patients with chronic disease (OR: 0.62; 95% CI: 0.49 to 0.78), having more than 10 medications stored at home (OR: 0.79; 95% CI: 0.62 to 1.00), household with medical professionals (OR: 1.45; 95% CI: 1.15 to 1.83), information about proper disposal (OR: 6.03; 95% CI: 4.54 to 8.00), health risk perception (OR: 1.56; 95% CI: 1.05 to 2.30) and environment risk perception (OR: 3.72; 95% CI: 2.55 to 5.41) were factors significantly associated with recycling of unwanted medication. In age subgroup analyses, receiving information about proper disposal of unwanted medications was significantly associated with medication recycling for both respondents over (OR: 4.70; 95% CI: 2.82 to 7.83) or under 45 years of age (OR: 7.11; 95% CI: 4.96 to 10.19). However, respondents aged under 45 years who perceived health risks (OR: 1.60; 95% CI: 1.04 to 2.47) were more likely to recycle unwanted medications, whereas this association was not observed for older respondents (*p* >0.05). Perception of environmental risk was significantly associated with recycling behaviour among those respondents younger than 45 years (OR: 3.45; 95% CI: 2.28 to 5.24) and older than 45 years (OR: 4.71; 95% CI: 1.94 to 11.43). Perceptions of environmental risk remained significantly associated with recycling behaviour regardless of whether or not they received information about proper disposal of unwanted medications ((OR: 3.42; 95% CI: 2.29 to 5.12); (OR: 5.52; 95% CI: 1.96 to 15.53)). Sample size and unadjusted models are shown in online supplemental table 2.

Bin or sink/toilet

Table 3 showed the association between various factors and disposal of unwanted medications in bins and sink/toilet. For the total population, people aged 56–65 years (OR: 0.22; 95% CI: 0.12 to 0.38), people older than 65 years (OR: 0.15; 95% CI: 0.08 to 0.26), households without patients with chronic disease (OR: 1.56; 95% CI: 1.19 to 2.05), having more than 10 medications storage (OR: 1.73; 95% CI: 1.29 to 2.34), households with medical professionals (OR: 0.63; 95% CI: 0.48 to 0.83), receiving proper disposal information (OR: 0.26; 95% CI: 0.17 to 0.44) and environment risk perception (OR: 0.27; 95% CI: 0.17 to 0.44) were factors significantly associated with the disposal of unwanted medications into bins and sink/toilet. Moreover, older individuals (over 45) with more than 10 medications were more likely to dispose of them in a bin, sink or toilet (OR: 3.71; 95% CI: 2.03 to 6.80). Receiving proper information about medication disposal was associated with lower household medication disposal behaviours in both young (OR: 0.23; 95% CI: 0.15 to 0.34), middle-aged and older adults (OR: 0.33; 95% CI: 0.19 to 0.57). Perception of risk to the environment reduced bin and sink/toilet disposal among young (OR: 0.29; 95% CI: 0.17 to 0.49), middle-aged and older adults (OR: 0.22; 95% CI: 0.08 to 0.65). Sample size and unadjusted models are shown in online supplemental table 3.

Table 1 Sociodemographic characteristics of respondents

Characteristic	Total		Households with unwanted medicines		Households without unwanted medicines	
	N	%	N	%	N	%
Gender						
Male	2963	47.1	1301	47.0	1662	47.2
Female	3330	52.9	1470	53.0	1860	52.8
Age (years)						
≤35	3428	54.5	1401	50.6	2027	57.6
36–45	1792	28.5	841	30.4	951	27.0
46–55	634	10.1	287	10.4	347	9.9
56–65	259	4.1	119	4.29	140	4.0
>65	180	2.9	123	4.4	57	1.6
Education attainment						
Middle school or below	724	11.5	279	10.1	445	12.6
High school	1954	31.1	845	30.5	1109	31.5
Bachelor's degree or above	3615	57.4	1647	59.4	1968	55.9
Patients with chronic diseases at home						
No	3241	51.5	1106	39.9	2135	60.6
Yes	3052	48.5	1665	60.1	1387	39.4
The number of medications stored at home						
≤10	5051	80.3	1880	67.8	3171	90.0
>10	1242	19.7	891	32.2	351	10.0
Households with medical professionals						
No	4488	71.3	1860	67.1	2628	74.6
Yes	1805	28.7	911	32.9	894	25.4
Having received information about proper disposal of unwanted medicines						
No	3131	49.8	1244	44.9	1887	53.6
Yes	3162	50.2	1527	55.1	1635	46.4
Health risk perception						
Low	1647	26.2	818	29.5	829	23.5
High	4646	73.8	1953	70.5	2693	76.5
Perception of risk to the environment						
Low	1961	31.2	994	35.9	967	27.5
High	4332	68.8	1777	64.1	2555	72.5
Region of residence						
Eastern province	2348	37.3	977	35.3	1371	38.9
Middle province	2138	34.0	907	32.7	1231	35.0
Western province	1806	28.7	887	32.0	919	26.1

Using unwanted medications or giving them to others

Table 4 showed the association between various factors and giving unwanted medications to others. Women (OR: 0.59; 95% CI: 0.38 to 0.90) were independently associated with using unwanted medications or giving them to others. Those who had medical professionals in the family (OR: 1.61; 95% CI: 1.01 to 2.55), low levels of health risk perception (OR: 0.34; 95% CI: 0.19 to 0.61) and high levels of environmental risk perception (OR: 2.69; 95%

CI: 1.44 to 5.03) were more likely to use unwanted medications or give them to others. Sample size and unadjusted models were shown in online supplemental table 4.

DISCUSSION

To our knowledge, this is the first study to analyse the factors that influence disposal practices of unwanted medications using survey data from 30 provinces in

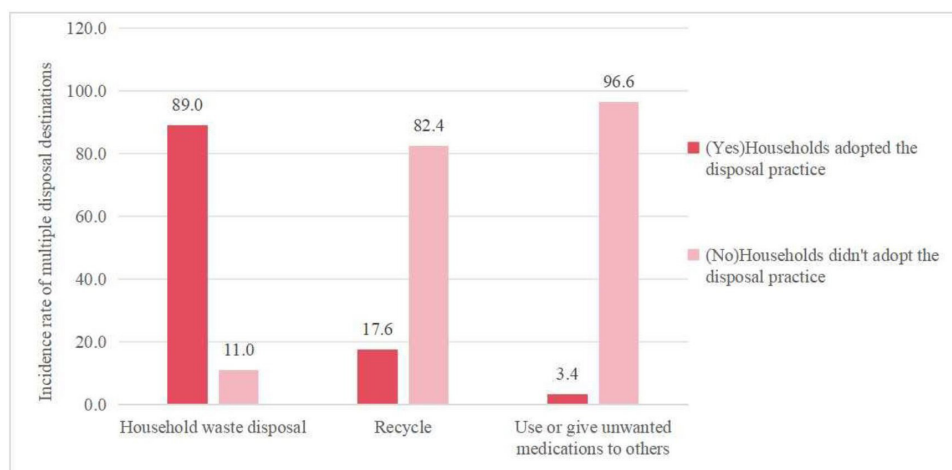


Figure 2 Rates of 2771 respondents reporting multiple disposal destinations. It presents the proportions of different disposal methods for unwanted medications, such as household waste disposal, recycling and using or giving them to others, visually demonstrating the differences in the proportions of various disposal methods.

China. Our study showed that 44% of households had unwanted medications. This proportion is consistent with the results of a survey conducted on household medication management (50%) in Kunming, Yunnan Province, China.¹⁹ The presence of expired or unused medication in households is a global phenomenon, with previous studies reporting proportions of households with unwanted medications being 88% in Ireland,²⁰ 72% in Portugal,²¹ 60% in Australia,²² 42% in the²³ USA and 31% in Sweden.²⁴ The relatively low proportion of unwanted medications in China may be related to moral frugality, a trait of Chinese national identity.²⁵ Unused medications are often assigned high values. People tend to store and use them until the expiration date before disposing of them.

This study found that the primary disposal practice for unwanted medication in China was disposal with household waste, with less than 20% of households preferring recycling. In developing countries lacking policy measures for the disposal of unwanted medications, the proportion of disposal via household waste was higher, such as Kuwait (87.7%),²⁶ Saudi Arabia (86.2%),¹⁴ Lebanon (84.3%–92.4%),²⁷ India (81.9%)⁹ and Ethiopia (77.1%).¹³ In most of these countries, less than 10% of unwanted medications are returned to the pharmacies. However, in some developed countries with better disposal systems, the proportion of recycling of unwanted medications is higher, such as Sweden (43%),²⁴ the UK (27%)³ and Australia (22.5%).²² Additionally, some developing countries that have medicine return programmes exhibit similarly high recycling rates, such as Malaysia (25.2%).²⁸ Therefore, at the national level, the government should formulate measures to guide the proper disposal of unwanted medications.

Gender and disposal of unwanted medications

This study found that men were more likely to use or give away unwanted medications. This behaviour may stem from a reduced concern or interest in proper medication

storage and disposal, potentially leading to disregard for expiration dates and associated risks, as well as a greater propensity to use or share medications without considering the consequences.²⁹ This reduced concern for proper medication practices aligns with findings from previous studies.³⁰ Furthermore, men may unintentionally use unwanted medications due to a lower likelihood of reading medication labels. These findings highlight the need for targeted educational interventions to increase awareness of proper medication disposal and the potential risks associated with the misuse of unwanted medications.

Age and disposal of unwanted medications

Age was positively associated with recycling of unwanted medications and negatively associated with disposal in bins and sinks/toilets. Patients frequently visiting pharmacies or receiving healthcare services, often elderly in China, are more familiar with returning medications. Perceived inconvenience (time and space) and inflexible work schedules hinder younger adults from proper disposal, leading them to dispose in bins, sinks or toilets due to laziness and busyness. However, young adults are more concerned about environmental contamination and believe that pharmacy interventions could effectively control environmental contamination from unwanted medications.³¹ Therefore, younger adults may be more likely to keep or take or give to others if they perceive high environmental risks. Middle-aged and older adults, a high medication storage group, are more vulnerable to adverse drug reactions and may be more impacted by health risk perception in medication disposal.³²

The number of medications at home and disposal of unwanted medications

Overstocking of medications implies poor home medication management,³³ often due to a lack of awareness about proper waste disposal.³⁴ Our study found that middle-aged and older adults (over 45) with over 10 medications

Table 2 Factors influencing recycling of unwanted medications

		Age		Information group	
Characteristic	Model 1b	≤45 years (n=2242)	>45 years (n=529)	Yes	No
Gender					
Male	1.00	1.00	1.00	1.00	1.00
Female	1.00 (0.80,1.24)	0.98 (0.77,1.26)	1.01 (0.64,1.61)	0.99 (0.78,1.27)	0.95 (0.57,1.58)
Age (years)					
≤35	1.00	–	–	1.00	1.00
36–45	1.18 (0.92,1.53)	–	–	1.19 (0.91,1.56)	1.18 (0.57,2.41)
46–55	1.58 (1.08,2.31)*	–	–	1.49 (0.98,2.26)	1.87 (0.76,4.58)
56–65	4.73 (2.79,8.03)***	–	–	2.99 (1.55,5.76)**	9.91 (3.75,26.19)***
>65	5.45 (3.20,9.26)***	–	–	4.29 (1.98,9.25)***	8.00 (3.10,20.65)***
Education attainment					
Middle school or below	1.00	1.00	1.00	1.00	1.00
High school	1.78 (1.18,2.70)**	1.53 (0.79,2.99)	1.70 (0.99,2.92)	1.3 (0.79,2.12)	3.77 (1.60,8.88)**
Bachelor's degree or above	1.24 (0.80,1.92)	1.11 (0.58,2.11)	0.66 (0.32,1.36)	1.03 (0.63,1.70)	1.38 (0.51,3.72)
Patients with chronic diseases at home					
No	1.00	1.00	1.00	1.00	1.00
Yes	0.62 (0.49,0.78)***	0.67 (0.52,0.86)**	0.50 (0.29,0.85)*	0.66 (0.51,0.85)**	0.52 (0.29,0.92)
The number of medications stored at home					
≤10	1.00	1.00	1.00	1.00	1.00
>10	0.79 (0.62,1.00)	0.98 (0.74,1.28)	0.40 (0.24,0.67)***	0.95 (0.73,1.24)	0.27 (0.14,0.52)***
Households with medical professionals					
No	1.00	1.00	1.00	1.00	1.00
Yes	1.45 (1.15,1.83)**	1.72 (1.34,2.21)***	0.57 (0.30,1.09)	1.46 (1.14,1.86)**	1.65 (0.89,3.08)
Receiving information about proper disposal of unwanted medications					
No	1.00	1.00	1.00	–	–
Yes	6.03 (4.54,8.00)***	7.11 (4.96,10.19)***	4.70 (2.82,7.83)***	–	–
Health risk perception					
Low	1.00	1.00	1.00	1.00	1.00
High	1.56 (1.05,2.30)*	1.60 (1.04,2.47)*	1.56 (0.61,4.04)	1.47 (0.96,2.24)	2.12 (0.75,5.95)
Perception of risk to the environment					
Low	1.00	1.00	1.00	1.00	1.00
High	3.72 (2.55,5.41)***	3.45 (2.28,5.24)***	4.71 (1.94,11.43)**	3.42 (2.29,5.12)	5.52 (1.96,15.53)**
Region of residence					
Eastern province	1.00	1.00	1.00	1.00	1.00
Middle province	0.92 (0.70,1.21)	0.95 (0.71,1.28)	0.99 (0.49,1.99)	0.95 (0.71,1.28)	0.79 (0.36,1.74)
Western province	1.34 (1.03,1.75)*	1.11 (0.82,1.50)	3.11 (1.59,6.09)**	1.19 (0.89,1.60)	1.95 (0.98,3.89)

Model 1b: in the multivariate logistic regression, age, gender, education attainment, region, having patients with chronic diseases, presence of medical professionals and the number of medications stored, health risk perception and environment risk perception were adjusted, and the dependent variable was whether someone recycled unwanted medications.

–, The item is not applicable.

*p<0.05, **p<0.01, ***p<0.001.

at home were more likely to dispose of unwanted medications in bin/sink/toilet. This may stem from handling numerous medications due to multiple health issues and

perceiving these methods as clean and convenient. High medication storage levels could contribute to a lack of awareness about proper disposal,³⁵ leading to disposal in

Table 3 Factors influencing disposal of unwanted medications into bin and sink/toilet

		Age		Information group	
Characteristic	Model 2b	≤45 years (n=2242)	> 45 years (n=529)	Yes (n=1527)	No (n=1244)
Gender					
Male	1	1		1.00	1.00
Female	1.23 (0.95,1.60)	1.37 (1.01,1.85)*	0.93 (0.55,1.57)	1.37 (1.02,1.83)*	0.93 (0.53,1.65)
Age (years)					
≤35	1	–	–	1.00	1.00
36–45	1.01 (0.74,1.38)	–	–	0.91 (0.65,1.27)	1.95 (0.78,4.87)
46–55	0.70 (0.45,1.11)	–	–	0.75 (0.45,1.25)	0.68 (0.26,1.80)
56–65	0.22 (0.12,0.38)***	–	–	0.36 (0.17,0.75)**	0.11 (0.04,0.32)***
>65	0.15 (0.08,0.26)***	–	–	0.15 (0.07,0.34)***	0.16 (0.06,0.46)**
Education attainment					
Middle school or below	1	1	1	1.00	1.00
High school	0.68 (0.42,1.09)	0.97 (0.45,2.11)	0.67 (0.37,1.23)	1.25 (0.71,2.18)	0.13 (0.04,0.42)
Bachelor's degree or above	0.78 (0.47,1.30)	1.01 (0.48,2.11)	1.68 (0.72,3.94)	1.2 (0.68,2.12)	0.3 (0.08,1.11)
Patients with chronic diseases at home					
No	1	1	1	1.00	1.00
Yes	1.56 (1.19,2.05)**	1.43 (1.06,1.93)	2.04 (1.10,3.78)*	1.48 (1.09,2.00)*	1.78 (0.92,3.44)
The number of medications stored at home					
≤10	1	1	1	1.00	1.00
>10	1.73 (1.29,2.34)***	1.28 (0.91,1.79)	3.71 (2.03,6.80)***	1.48 (1.06,2.07)*	3.46 (1.71,7.00)**
Households with medical professionals					
No	1	1	1	1.00	1.00
Yes	0.63 (0.48,0.83)**	0.52 (0.38,0.70)***	1.72 (0.80,3.70)	0.56 (0.42,0.76)***	0.86 (0.41,1.81)
Receiving information about proper disposal of unwanted medications					
No	1	1	1	–	–
Yes	0.26 (0.19,0.36)***	0.23 (0.15,0.34)***	0.33 (0.19,0.57)***	–	–
Health risk perception					
Low	1	1	1	1.00	1.00
High	0.67 (0.41,1.09)	0.71 (0.42,1.22)	0.50 (0.16,1.60)	0.75 (0.44,1.29)	0.41 (0.13,1.24)
Perception of risk to the environment					
Low	1	1	1	1.00	1.00
High	0.27 (0.17,0.44)***	0.29 (0.17,0.49)***	0.22 (0.08,0.65)**	0.27 (0.16,0.47)***	0.28 (0.10,0.80)*
Region of residence					
Eastern province	1	1	1	1.00	1.00
Middle province	1.22 (0.87,1.73)	1.16 (0.80,1.68)	1.19 (0.48,2.93)	1.01 (0.70,1.46)	3.49 (1.21,10.09)*
Western province	0.57 (0.42,0.78)***	0.74 (0.52,1.05)	0.19 (0.09,0.43)***	0.59 (0.42,0.85)**	0.63 (0.31,1.29)

Model 2b: in the multivariate logistic regression, age, gender, education attainment, region, having patients with chronic diseases, presence of medical professionals and the number of medications stored, health risk perception and environment risk perception were adjusted, and the dependent variable was whether someone disposed unwanted medications into bin and sink/toilet.

–, The item is not applicable.

*p<0.05, **p<0.01, ***p<0.001.

Table 4 Factors influencing giving unwanted medications to others

		Age		Information group	
Characteristic	Model 3b	≤45 years (n=2242)	>45 years (n=529)	Yes (n=1488)	No (n=1244)
Gender					
Male	1	1	1	1.00	1.00
Female	0.59 (0.38,0.90)*	0.53 (0.34,0.85)**	1.16 (0.35,3.89)	0.57 (0.32,0.99)*	0.61 (0.31,1.21)
Age (years)					
≤35	1	–	–	1.00	1.00
36–45	0.98 (0.61,1.57)	–	–	0.99 (0.55,1.79)	0.95 (0.41,2.16)
46–55	0.75 (0.32,1.73)	–	–	0.81 (0.30,2.23)	0.63 (0.13,2.98)
56–65	0.89 (0.25,3.13)	–	–	0.54 (0.07,4.35)	1.5 (0.28,7.90)
>65	0.51 (0.11,2.34)	–	–	1 (1.00,1.00)	1.2 (0.22,6.61)
Education attainment					
Middle school or below	1	1	1	1.00	1.00
High school	1.04 (0.40,2.68)	1.02 (0.29,3.58)	1.32 (0.30,5.76)	1.47 (0.32,6.71)	0.69 (0.19,2.52)
Bachelor's degree or above	1.29 (0.51,3.28)	1.22 (0.37,4.03)	2.29 (0.46,11.47)	1.41 (0.32,6.29)	1.26 (0.35,4.52)
Patients with chronic diseases at home					
No	1	1	1	1.00	1.00
Yes	1.61 (1.01,2.55)*	1.57 (0.98,2.55)	2.09 (0.42,1.41)	1.72 (0.94,3.15)	1.44 (0.69,2.98)
The number of medications stored at home					
≤10	1	1	1	1.00	1.00
>10	1.32 (0.85,2.04)	1.34 (0.84,2.13)	1.28 (0.37,4.40)	1.75 (1.01,3.03)*	0.80 (0.37,1.70)
Households with medical professionals					
No	1	1	1	1.00	1.00
Yes	0.98 (0.62,1.53)	0.99 (0.62,1.59)	0.71 (0.14,3.64)	0.86 (0.49,1.51)	1.21 (0.56,2.61)
Having received information about proper disposal of unwanted medications					
No	1	1	1	–	–
Yes	1.26 (0.81,1.97)	1.28 (0.79,2.06)	0.97 (0.28,3.33)	–	–
Health risk perception					
Low	1	1	1	1.00	1.00
High	0.34 (0.19,0.61)***	0.34 (0.18,0.63)**	0.36 (0.05,2.63)	0.24 (0.11,0.50)***	0.59 (0.23,1.50)
Perception of risk to the environment					
Low	1	1	1	1.00	1.00
High	2.69 (1.44,5.03)	2.91 (1.49,5.66)**	1.79 (0.26,12.47)	4.16 (1.78,9.76)**	1.51 (0.59,3.87)
Region of residence					
Eastern province	1	1	1	1.00	1.00
Middle province	0.41 (0.24,0.71)**	0.39 (0.22,0.71)**	0.52 (0.13,2.05)	0.44 (0.22,0.87)*	0.37 (0.15,0.89)*
Western province	0.54 (0.32,0.89)*	0.60 (0.35,1.02)	0.27 (0.06,1.28)	0.56 (0.29,1.08)	0.45 (0.19,1.06)

Model 3b: in the multivariate logistic regression, age, gender, education attainment, region, having patients with chronic diseases, presence of medical professionals and the number of medications stored, health risk perception and environment risk perception were adjusted, and the dependent variable was whether someone used or gave unwanted medications to others.

–, The item is not applicable.

*p<0.05, **p<0.01, ***p<0.001.

trash or flushing them down the sink/toilet.⁵ In China, unwanted medications are classified as hazardous household waste. Households with large medication stocks,

unaware of classification standards, may dispose of them as general waste. Therefore, advocating for rational medication preparation and use, with particular attention to

households with overstocked medications and patients with chronic conditions, is crucial.

Proper disposal information and disposal of unwanted medications

Appropriate health education effectively transforms public attitudes and behaviours towards medication disposal.³⁶ Our study revealed that respondents informed about proper disposal methods increased recycling and decreased household waste disposal, aligning with previous research.^{11 37} Kusturica *et al* noted that a lack of information was the primary reason for not returning medications.¹⁰ A significant correlation was observed between knowledge of disposal methods and behaviour. A Malaysian survey found that knowledge reduced the proportion of medications discarded in trash or flushed down sinks/toilets.¹² Furthermore, healthcare professionals exhibited greater awareness than the general public. Households with medical professionals had higher access to disposal information, thereby increasing the likelihood of recycling unwanted medications. Subgroup analysis revealed that among those unaware of proper disposal methods, a stronger perception of environmental risk was associated with a higher likelihood of recycling unwanted medications compared with those who were informed. This suggests that self-perceived risk can be a stronger driver of disposal behaviour than externally provided information. This may be because inadequate information can heighten anxiety³⁸; individuals with a strong sense of environmental risk may then default to the generally accepted correct methods, such as recycling, when specific disposal options are unknown.

Perception of risk to the environment and disposal of unwanted medications

The perception of risk to the environment is associated with proper disposal of unwanted medications. When individuals recognise the environmental problems caused by waste medications, they are more inclined to return them to pharmacies. Previous studies have shown that environmental identity moderates the relationship between risk perception and proper disposal behaviours.³⁹ For those with high levels of pro-environmental behaviour, the perception of risk to the environment increases their willingness to dispose of pharmaceutical residues in a proper disposal behaviour. The public believes that discarding unwanted medications in bins or toilets/sinks is harmful to the environment.²¹ Therefore, people with a high perception of environmental risk are more likely to recycle unwanted medications and less likely to dispose of them improperly, thereby preventing them from contaminating water and soil. It is crucial to educate the public on proper disposal methods and to highlight the environmental and health hazards associated with improper disposal.

It is important to note that our study did not distinguish between expired/deteriorated medications and unused but non-expired medications in the analysis. While this

approach allowed us to explore general patterns of medication disposal behaviour, it may have obscured potential differences in disposal practices between these two categories. Future studies should consider separating these categories during data collection and analysis to provide more targeted recommendations. Furthermore, our study precedes the COVID-19 pandemic, which has profoundly affected public health, including medication usage and disposal practices. Future research should explore changes in public awareness, policies and drug disposal behaviours before and after the pandemic to further standardise drug policy. Our survey results provide a valuable baseline for understanding medication disposal behaviours in China during the pandemic and postpandemic periods.

Limitations

This study had several limitations. First, the number of households with unwanted medications may be underestimated due to inevitable recall errors. Second, the sample size of our study was substantial, but we cannot generalise this finding to the entire Chinese population as most respondents were from urban areas and under 35 years old. Older adults often have multiple chronic conditions, which can present greater challenges in medication storage and disposal. While we conducted a subgroup analysis to explore differences in the disposal of unwanted medications between older and younger adults, the limited sample size restricts the generalisability of these findings. Future research should prioritise a large-scale survey specifically targeting older adults in China to validate these preliminary observations. Third, we did not investigate the types of unwanted medications used in Chinese households. Throwing unwanted medications in the bin or flushing them down the sink/toilet is not the best disposal method. However, this outcome depends on the type of medication used. Disposing of certain types of medication with household waste can also be reasonable. Finally, our survey was conducted in the winter, yet the extent to which this seasonal factor influenced our results remains uncertain. Future studies need a more comprehensive assessment and consideration of the timing factors of the survey.

CONCLUSIONS

This cross-sectional study assessed the disposal practices of unwanted medications in 6293 households in China and found that nearly half of the households had unneeded medications. Most participants chose household waste disposal, potentially due to a lack of professional knowledge, health risk perception and environmental risk perception. There is an urgent need to establish a standardised management system for the rational disposal of unwanted medications and to promote education on proper storage, use and disposal practices among patients.

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