ORIGINAL ARTICLE

Household disposal of pharmaceuticals: attitudes and risk perception in a UK sample

Scott Watkins[1,4] · Julie Barnett[1,4] · Martyn Standage[2,4] · Barbara Kasprzyk-Hordern[3,4] · Ruth Barden[3,4]

Abstract

Pharmaceuticals can enter the environment through disposal in toilets, sinks and general waste. In the UK, household medicines are correctly disposed of by returning them to a pharmacy. This study examined household patterns of medicine waste, storage and disposal practices via a cross-sectional survey with 663 UK adults. Multiple regression was used to explore the contribution of key variables on self-reported medicines disposal behaviour. Analysis demonstrated that age, information, awareness, probability, attitude and intention all predicted correct disposal behaviour. Results indicate that multiple factors influence different disposal destinations uniquely. Affect and age increase disposal in sink/toilet but reduce disposal in bin. Presence of children increase bin and sink/toilet disposal but decrease pharmacy returns. Awareness and received information on correct disposal reduce bin disposal and increase pharmacy returns. The results suggest people use different mental models for each destination with disposal in sink/toilets and bins considered quicker and safer in the presence of children or for those feeling anxious. It is important to understand the capability, opportunity and motivation people have to return medicines to the pharmacy in addition to raising awareness of correct medicine disposal.

Keywords Household waste · Drugs · Environment · Medicine disposal · Unused medicines · Medicines waste

✉ Scott Watkins
S.watkins@bath.ac.uk

Julie Barnett
J.C.Barnett@bath.ac.uk

Martyn Standage
M.Standage@bath.ac.uk

Barbara Kasprzyk-Hordern
B.Kasprzyk-Hordern@bath.ac.uk

Ruth Barden
R.Barden@bath.ac.uk

1   Department of Psychology, University of Bath, Claverton Down, Bath BA2 7AY, UK

2   Department of Health, University of Bath, Claverton Down, Bath BA2 7AY, UK

3   Department of Chemistry, University of Bath, Claverton Down, Bath BA2 7AY, UK

4   Wessex Water, Bath, UK

Introduction

Pharmaceuticals (also referred to as medicines, medications or drugs) prescribed in England increased from 852 million in 2008 to over 1.1 billion in 2018 [1]. Similarly, prescriptions in the USA have increased by 85% during the past 10 years despite a population increase of only 21% [2]. Worldwide, prescription sales are forecasted to grow by 7.4% from 2020 to 2026 [3]. With the rising number of prescriptions, there is heightened concern about risk of active pharmaceutical ingredients to the natural environment [see [4] for a review]. Such risks can be broadly viewed as resulting from three pathways. First, a pathway that involves medicines which are ingested, metabolised, excreted unchanged and/or metabolised. Second, a pathway whereby unused medicine is disposed in general waste, poured into a sink, or flushed down toilets. Third, a pathway attributed to waste from pharmaceutical production. These disposal practices account for approximately 88%, 10%, and 2% of medicines in the environment, respectively [5]. In this paper, we focus on the second pathway as the disposal of unused or expired medicine is malleable to change, especially by

environmental stewardship programs designed around pollution prevention [6–8].

Medicine disposed down the toilet or sink travels directly to Waste Water Treatment Plants (WWTP) whereas disposal into general waste follows a more indirect route (i.e., transported to landfill and as rainwater permeates waste, leachate is formed which is then transferred to WWTP for treatment) [9]. To reduce Active Pharmaceutical Ingredients (API) reaching WWTP, the UK and most European Union countries [10] recommend unwanted medicines be returned to a pharmacy. Therefore, within this paper we define returning medicine to a pharmacy as 'correct disposal' whereas disposal down sinks, toilets and via general waste is termed 'incorrect disposal'.

The most recent study dedicated to assessing the different mechanisms for pharmaceutical waste disposal in the UK was based on data collected in 2003 [11]. Extending the work of Bound and Voulvoulis [11], the purposes of the present work were threefold, namely to (i) provide a contemporary account of types of medicine, medicine waste storage, and disposal practices in a representative UK sample of adults; (ii) gain insight into the relationship between type of medicine preparation and choice of disposal method; and (iii) analyse the role of multiple variables in predicting self-reported medicines disposal behaviour. Our attention now turns to a review of pertinent extant literature related to these study aims alongside specific hypotheses to be tested (i.e., H1–H13).

Types of medicine, medicine waste storage and disposal practices

Bound and Voulvoulis [11] found almost all participants surveyed had pharmaceuticals in their house (98%); with most (60.2%) having a mixture of over the counter (OTC) and prescription medicines, 30.7% having only OTC medicines and 9.1% having only prescription medicines. One study in New Zealand, sought to understand why people have leftover medicines and to explore their views about possible disposal options [12]. Results showed that 62% of homes had leftover medications most commonly due to 'medical condition improved', 'change in treatment, 'excess supplied', 'passed expiry date' or 'side effects of medication'.

De Bolle et al. [13] investigated the contents of people's medical storage at home and found people had large amounts, the majority of which were OTC (65%) with 34% prescription and 1% either prescription or OTC. In the home, most medicines are stored in the kitchen (34–48%), followed by the bathroom (21–29%) and bedroom (13–24%) [12, 14, 15].

Tong et al. [16] reviewed global medication disposal practices highlighting a lack of research pertaining to medicine disposal. Here, differences in disposal behaviour and in preferences for methods of disposal related to policy, education on disposal, and culture. Kusturica et al. [23] summarised data from a range of countries concluding that disposal in general waste was most common in Ireland, India, Malaysia, Thailand, Bangladesh, Ghana, Kuwait, Lithuania, Malta, Qatar, Saudi Arabia, Serbia and the UK. Flushing medicines was common for liquid formulations in Bangladesh, New Zealand, Malta, Ireland and the U.S., whilst relative to these other countries, Sweden and Germany display a much greater extent of medicine return to pharmacies.

Relationship between type of medicine preparation and choice of disposal method

The type of medicine preparation (i.e., liquid, solid, ointment) may alter disposal behaviour and Kusturica et al. [23] reported people are 2–5 times more likely to flush a liquid or dispose of it down the drain than to do so with a solid such as a tablet or capsule. Braund et al. [12] explored the relationship between medicines type and disposal destination in New Zealand. Here, 55% of respondents reported disposing of liquid medications into the water system, 24% in a system that ended in landfill, and 17% returned their liquid medication to a pharmacy. Solids were more likely to be disposed in a manner that led to landfill (51%) rather than the water system (19%) with 24% returning to a pharmacy. Further variation between medicine preparation type and disposal destination was observed for ointments with only 1% disposing of them into the water system, 80% in a disposal set for landfill, and 13% returning to a pharmacy. The current work is the first exploration of the relationship between medicine preparation type and disposal destination in a UK sample.

Role of multiple variables in predicting self-reported medicines disposal behaviour

There are a range of variables that the literature suggests can usefully be considered in predicting self-reported medicines disposal behaviour. We have summarised what we consider to be the key variables demonstrated in the extant medicine waste literature as well demographics that have been infrequently included in studies [17].

Demographics

Although numerous studies have aimed to balance samples for demographics, few have looked at the influence of socio-demographic variables on medicines disposal. Variables of interest in the present work were age, gender, presence of children and Socioeconomic Status (SES); a subjective measure of their education, job prestige and income.

Owens and Anand [18] found that percentage of respondents who reported throwing away medications in household

garbage decreased as age increased but Kotchen et al. [19] found no significant difference in trash disposal when comparing over 55 year old's to those younger than 55. Over 55s were more likely to return to a pharmacy [19] as were those in the 61- to 80 -year age range [12].

A participants' gender may also play an important role in their disposal practices. To this end, Owens and Anand [18] reported more females flushed medications down the toilet or sink, yet more males reported never disposing of their unused medicine.

To our knowledge, no study has examined SES and medicine disposal practices. We, therefore, explore this variable of general interest but propose no formal hypothesis.

Whether there are children in the household may also influence disposal behaviour. Here, the increased potential for accidental exposure and harm may lead to a preference for immediate disposal of medicines in sinks and toilets rather than via general waste [20].

Based on past research, the following four hypotheses were formulated for demographic variables:

H1 Age will be negatively associated with waste bin disposal.

H2 Age will be positively associated with return of medicines to a pharmacy.

H3 Female gender will be positively associated with sink/toilet disposal.

H4 Presence of children will be positively associated with sink/toilet disposal.

Information and awareness

Previous work suggests an awareness of correct medicine disposal options is important. For example, Vellinga et al. [21] reported 75% of participants agreed returning medicines to pharmacies and collection points was a safe and suitable means of disposal, yet only 19% had received information about this method. Similarly, in their work focussed on patient education, Seehusen and Edwards [22] reported that those who had received advice on correct medicine disposal were significantly more likely to believe it is acceptable to return medicines than those who had not. Last, and in their review, Kusturica et al. [23] highlighted the most common reason for not returning medicines to pharmacies was a lack of information.

Aligned with previous research, two following hypotheses were formulated for information and awareness:

H5 Information will be positively associated with correct disposal.

H6 Awareness will be positively associated with correct disposal.

Convenience

Perceived convenience is related to time, place and space [24]. When people are busy, live far from medicine waste collection points and do not have space to store them, correct disposal becomes inconvenient [27, 40]. Indeed Foon et al. [25] demonstrated that when collection points were further away or there was a lack of space to store medicines at home, perceived convenience was deemed to be low and attitude and perceived behavioural control were more important in determining intention to dispose. In contrast, a lack of time and space or availability can cause inconvenience, which will reduce intention to separate waste [26]. Barr et al. [27] argued that persuading people recycling was 'simple and convenient' was more crucial than persuading them of the value of recycling. In a study focusing on disposal of medicines waste, Foon et al. [25] investigated the effects of convenience (perceptions of ease of performing an action) as a moderator and found attitudes to disposal and perceived behavioural control had less impact on intention to dispose properly of unused medicines at official medicine waste collection points if convenience of doing so was high.

Based on past research, the following hypothesis was advanced:

H7 Convenience will be positively associated with correct disposal.

Risk perception: affect, probability and consequences

It is also important to consider how risk perception may affect methods of medicines disposal. Wilson et al., [28] suggest risk perception is better considered as a multidimensional measure assessing affect, probability, and consequences. Dias-Ferreira et al. [29] surveyed households in Portugal to understand perceptions of the risk of inappropriate disposal and found both disposal to waste bins or toilet/sinks was perceived as hazardous for the environment. In terms of risk behaviours, Bound et al. [30] found no definitive link between risk perception and disposal destination. They suggested the hazard was not perceived as significant enough or the individual's contribution was too small to make a difference. Lima et al., [31] used survey data from Portugal, France and Spain and found risk perception influenced responsible disposal through intention.

In the present work, the following hypothesis was tested in terms of affect, probability and consequences:

H8 Affect, Probability and Consequences will be positively associated with correct disposal.

Knowledge

Ong et al. [32] reported a significant correlation between knowledge of inappropriate disposal methods and disposal behaviour with less disposal in bins and sink/toilets amongst those that knew it was unacceptable to dispose there. Similarly, Shaaban et al. [33] found that people who received instructions about appropriate disposal were more likely to return medicines to a pharmacy.

With regards to knowledge, the following hypothesis was tested:

H9 Knowledge will be positively associated with correct disposal.

The theory of planned behaviour (TPB)

The TPB model [34] has been used to predict the behaviour of individuals in numerous environmental contexts including travel mode choice [35, 36], water conservation [37], recycling [38–40] and more recently medicine waste disposal [25]. Although studies have supported the predictive utility of the TPB in using its three dimensions: Attitude (ATT), Subjective norms (SN), and Perceived Behavioural Control (PBC) in predicting behavioural intentions and subsequent behaviours, some authors [40, 41] have argued that additional variables would enhance the TPB model. In this regard, Foon et al. [25] investigated intention of participants to properly dispose of unused medications and extended the TPB to include the following: knowledge, personal norms, perceived busyness and perceived convenience. Here, the final model showed that ATT and PBC but not SN predicted intention to correctly dispose of medicines. Personal norms and perceived busyness were significant predictors of intention to correctly dispose, and perceived convenience served to moderate effects of ATT, PBC and personal norms on intentions.

In the present work, four hypotheses were tested in regard to TPB.

H10 ATT will be positively associated with correct disposal.

H11 PBC will be positively associated with correct disposal.

H12 SN will be positively associated with correct disposal.

H13 Intention will be positively associated with correct disposal.

Aims

To recap, the aims of the present study are threefold:

1. To describe types of medicine, medicine waste storage and disposal practices in a representative UK sample.
2. To explore the relationship between type of medicine preparation and choice of disposal method.
3. To examine multiple predictors of self-reported medicines disposal behaviour.

Methods

Design

A cross-sectional study conducted online in July 2019. The survey was designed using the program Qualtrics [42] and distributed using a website that connects researchers with study participants (Prolific.ac.uk) [43]. Participants were offered £1.25 for completion of questionnaire.

Sample

Participants were 663 adults residing in the UK aged 18 to 86 years. Both age [44] and gender [45] were matched to the UK population. The age range was 18–86 years ($M = 45.3$, $SD = 15.4$) and matches the current UK population except for 60–64-year-old age group which had twice as many (14% vs 7%) as the UK population but fewer 70–79-year old's (3% vs 11%). Ethnicity was also a close match with the UK distribution and consisted of white (83.4%) followed by Asian (7.2%), Black (3.7%) Mixed (3.6%) and other/prefer not to say (2.3%).

Procedure

Participants completed consent forms and a survey online. They were instructed that they would be asked questions about their opinions and behaviour on medicines storage and disposal as well as some questions about themselves. The survey took around 10–15 min to complete.

Measures

Question wording and response options for all measures can be viewed in Table 1. The SES was adapted from Adler et al. [46]. For the convenience of disposal measure a binary variable was coded as (0) 'bedroom, handbag/bag', 'other' combined. (1) 'bathroom' and 'kitchen' combined. Bathroom and kitchen were combined because they both access water disposal via sinks and toilet. Risk perception combined questions on affect, probability and

Table 1 Question wording, response options and descriptive statistics of potential predictors, including scale reliability results

Measure	Items	Response options	Mean/*N*	SD/(%)	Reliability
Gender	Please tell us your gender	Male	321	48.4	
		Female	338	51	
		Not listed/prefer not to say	4	0.6	
Age	Please tell us your age	Years	45.3	15.4	
SES	Think of a ladder (see image of ladder) as representing where people stand in society. At the top of the ladder are the people who are best off—those who have the most money, most education and the best jobs. At the bottom are the people who are worst off—who have the least money, least education and the worst jobs or no job. The higher up you are on this ladder, the closer you are to people at the very top and the lower you are, the closer you are to the bottom. Where would you put yourself on the ladder? Choose the number whose position best represents where you would be on this ladder	(1–10)	5.3	1.7	
Children in household	How many children (under 18) live in your household?	None	461	69.5	
		1	110	16.6	
		2	69	10.4	
		3	18	2.7	
		4	5	0.8	
Received information	Have you ever received information on what to do with leftover medicine?	Yes	181	27.3	
		No	380	57.3	
		Don't know	102	15.4	
Aware could return	Were you aware that you could return any unused medicines to any pharmacy for safe disposal?	Yes	383	57.8	
		No	280	42.2	
Knowledge	How much do you think you know about the risk to the environment due to inappropriately disposed medicines? How much do you think you know about the risk to human health due to inappropriately disposed medicines?	(1) Nothing at all to (5) A great deal	2.29	0.95	0.92[b]
Medicine source	Which of the following medicines do you obtain regularly (at least every 2 months) either for yourself or someone in your household? (please tick all that apply)	Prescription only	164	24.7	
		Over the counter only	128	19.3	
		Both	230	34.7	
		None	141	21.3	
Convenience	How convenient is getting to a pharmacy?	(1) Extremely inconvenient to (7) extremely convenient	4.95	1.8	
Storage	Where in your home do you keep medicines?	Kitchen/bathroom	548	82.7	
		All other storage	115	17.3	
Risk, affect	How concerned are you (if at all) about people disposing of medicines inappropriately? When you think about people disposing of medicines inappropriately for a moment, to what extent do you feel. …fearful? …anxious? …worried?	(1) Not at all concerned to (5) extremely concerned	2.53	1.08	0.94[a]

Table 1 (continued)

Measure	Items	Response options	Mean/N	SD/(%)	Reliability
Risk, probability	(1) How likely is it that people will dispose of medicines inappropriately this year where you live? (2) I am confident that people will not dispose of medicine inappropriately this year where I live (3) How often do people dispose of medicine inappropriately where you live?	(1) Extremely unlikely to (5) extremely likely (1) Strongly disagree, to (5) strongly agree (1) Almost never to (5) frequently	3.48	0.98	0.78[a]
Risk, consequences	(1) If people did dispose of medicines inappropriately, it is likely that it would negatively impact me (2) If people did dispose of medicines inappropriately, it would have a severe effect on me personally	(1) Strongly disagree to (5) strongly agree	2.58	0.96	0.80[b]
TPB, PBC	In the next six months I have complete personal control over returning medicine to the pharmacy if I really wanted to do so	(1) Strongly disagree to (5) strongly agree	6.3	1	0.86[b]
TPB, subjective norm	Most people who are important to me would want me to return medicines to the pharmacy over the next six months Most people whose opinions I value would approve of me returning medicine to the pharmacy over the next six months	(1) Strongly disagree to (5) strongly agree	4.8	1.3	0.83[b]
TPB, attitude	For me returning medicines to the pharmacy over the next six months would be…	(1) Extremely useless to (7) extremely useful (1) Extremely unwise to (7) extremely wise (1) Extremely unenjoyable to (7) extremely enjoyable (1) Extremely unpleasant to (7) extremely pleasant	4.8	1.1	0.80[b]
Intention	I intend to return unused medicines to the pharmacy over the next 6 months I intend to put unused medicines in the general waste bin over the next 6 months I intend to put unused medicines down the toilet/sink over the next 6 months	(1) Strongly disagree to (5) strongly agree	5.2	1.2	
Dependent variable	How do you dispose of … Liquid medicines when they are no longer needed? (please tick all that apply) …Solid medicines… … Ointments/creams…	(1) They are thrown in the rubbish bin, (2) They are emptied into the sink/toilet, (3) They are returned to a pharmacy, (4) They are returned to another healthcare setting, (5) They are given to friends or family, (6) They are disposed of in some other way			
Dependent Variable (Regression Analysis)	When you have had medicine to dispose of in the past, how often have you… …returned it to the pharmacy? …put it down the sink/toilet? …put it in the general waste? …disposed of it in any other way? …given it to friends or family?	(1) Never to (7) Every time			

Note. Internal consistency was reported as [a]Cronbach's alpha coefficient for variables of three items or more and [b]Spearman–Brown correlation coefficient for variables of two items

consequences [28]. Exploratory factor analysis was conducted to examine factor structure of the measure and reliability, mean and standard deviations are given for each dimension. Knowledge questions were adapted from past work [47]. Perceived Behavioural Control (PBC), Subjective Norm and Attitude were used to assess dimensions of the TPB [34].

The dependent variable for regression analysis was frequency of disposal in different destinations. Scores for the inappropriate destinations (toilet/sink and general waste)

Table 2 Source of medicines at home, number of medicines not required, and reasons for storing medicines past their intended usage

	Have at home	
	%	n
None	3	22
Prescription only	9	57
OTC only	22	144
Prescription and OTC	66	440
Total	100	663
	Have at home and not needed	
None	51	339
1–5	44	292
6–10	4	24
11+	1	8
Total	100	663
	Reason for meds at home[a]	
Recovery	39	211
Meds expired	22	120
Too much prescribed	13	73
Meds changed	12	67
Side effects	10	56
Other	3	18
Total	100	545

[a]Multiple choices allowed

were reversed and combined with pharmacy to give a mean composite variable with higher scores equating to more correct disposal. Individual disposal destinations were also explored to allow the composite disposal variable to be investigated further.

Analytical plan

Analyses were performed using IBM SPSS Statistics (Version 27). Descriptive statistics were used to summarise study data and provide insight into how and where people obtain and dispose of their medicines. Using oblimin rotation a principal axis factor analysis was used to examine the factor structure underlying Risk (Affect, Probability, Consequences) and Knowledge-related items. Multiple hierarchical regression using a bias-corrected bootstrapping approach ($n = 5000$ replicated samples) was employed to examine predictive utility of a set of key variables as identified in the extant literature in explaining self-reported medicines disposal behaviour. Given the exploratory nature of our analyses and a lack of a clear theoretical rationale for eliminating predictor variables, we took a two-step approach to analyses. Here, Step 1 one comprised demographic variables

with Step 2 containing predictor variables. Squared semi-partial correlations were used to determine the proportion of variance uniquely explained by each independent variable when all other predictors within the model are controlled for.

Results

Types of medicine, medicine waste storage and disposal practices

The participants' socio-demographic characteristics are shown in Table 1. As shown, 663 adults provided data with gender being balanced ($n = 338$, 51% female). Mean age of the study participants was 45.3 years and most participants were of white ethnicity and lived in households without children ($n = 461$, 69.5%).

Table 2 shows the number of medicines stored at home, the number of medicines at home that are not required, and reasons for having these medicines at home. Most participants ($n = 522$, 79%) reported obtaining medicines regularly (i.e., at least every 2 months) and almost all participants ($n = 641$, 97%) had some type of medicine at home. Three quarters of the sample ($n = 497$, 75%) had prescription medicines at home with 584 participants 88% reporting that they had OTC medications, and 440 (66%) indicating that they had both. Just under half of the sample ($n = 324$, 49%) had medications that were no longer needed. The most common reason provided for this was recovery from illness before finishing medication.

Awareness of pharmacy disposal

More than half of respondents ($n = 383$, 58%) were aware that medicines could be returned to a pharmacy, yet only 181 (27%) could recall receiving information that this was the correct method of disposal. Information was sourced from a variety of places with pharmacy being most common (Fig. 1). Most participants who indicated that they had received information also reported that they were aware that they could dispose of medicines at a pharmacy ($n = 173$, 96%). Of those that had said they had not received information, and only 149 (39%) were aware that they could dispose of medicines at a pharmacy.

Disposing of medicines

Eighty-four per cent of the sample ($n = 559$) reported they had previously disposed of medicines. Overall, 94% of medicine disposal fitted into three disposal categories: bin, sink/toilet, and pharmacy with the remaining 6% returned to other healthcare destinations (e.g., GP's, hospitals), given to friends/family or were unspecified. The bin was

most common disposal destination with 48% of the sample endorsing this response followed by take back to pharmacy (27%) and sink/toilet (25%).

Multiple disposal destinations

More than half ($n = 297$, 53%) of those who had previously disposed of medicines used a combination of disposal destinations compared to the 260, 47% disposing in only one. Of the 436 (66%) people who disposed in the bin, 208 (48%) of those also reported they disposed down the sink/toilet and 125 (29%) reported that they returned medicines to the pharmacy. Of the 242 (37%) people that returned medicines to a pharmacy, a little over half 125 (52%) also disposed medicines in the bin and 72 (30%) down the sink/toilet. Of the 230 (35%) people who disposed down the sink/toilet, most of them ($n = 208$, 90%) also disposed in the bin and 72 (31%) returned to the pharmacy.

Relationship between medicine preparation and choice of disposal method

Participants were asked about disposal practices in relation to medicine preparation: liquids, solids, and creams/ointments. Disposal strategies related to the type of medicine being disposed. Liquids tended to be disposed of in the sink or toilet followed by the bin, then by return to a pharmacy. In contrast, solids were more associated with disposal in the bin or return to the pharmacy. The bin was also the most popular destination for unused cream/ointments which were rarely disposed of in the sink/toilet (Fig. 2).
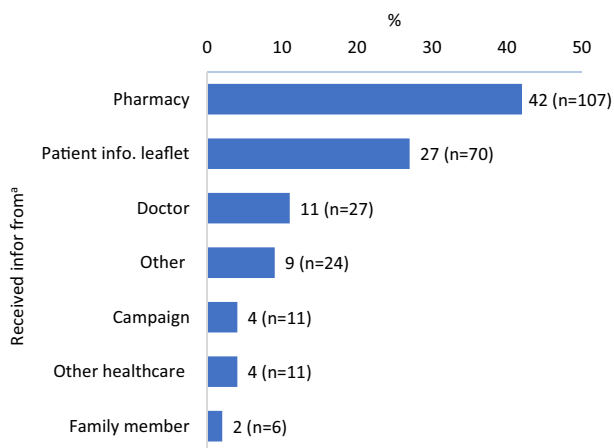
Fig. 1 Source of information on correct disposal at pharmacies

Role of multiple variables in predicting self-reported medicines disposal behaviour

Factor analysis on risk measure

A factor analysis was conducted to identify the inter-relationships between the risk and knowledge related items. Factors of *affect* and *probability* had eigenvalues over Kaiser's criterion of 1 and collectively explained 66.9% of the variance. The consequence and knowledge factors explained a further 12.6% of the variance. As all four constructs have been theoretically established as risk measures, all items were retained for further analysis [28, 30, 48]. Mean statistics, standard deviations and Cronbach alpha values are shown in Table 1.
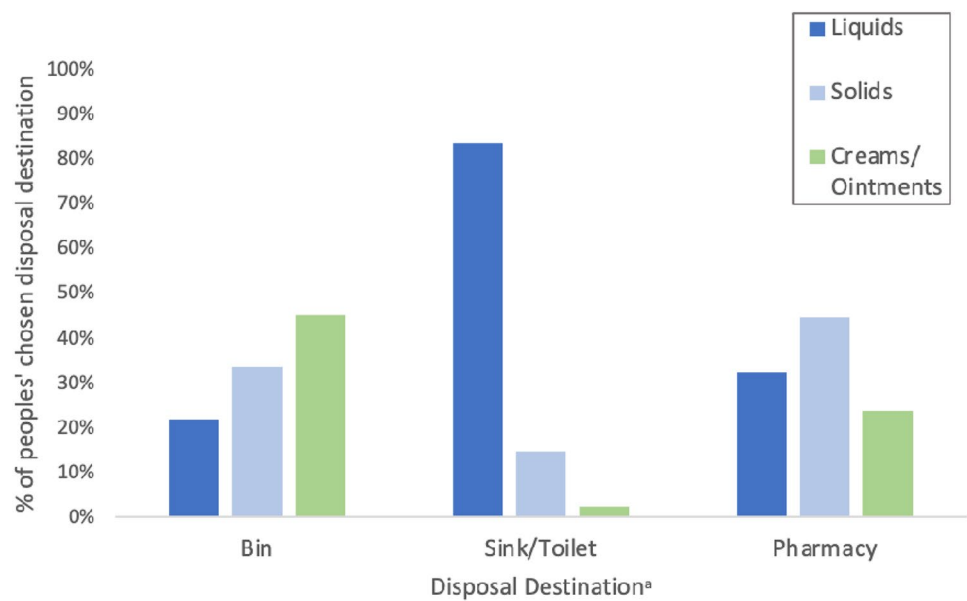
Predictors of correct medicine disposal behaviour

Four separate regression model analyses were conducted using the 2-Step approach outlined in the Analytical Plan section. In these analyses, Correct Disposal (i.e., composite of all three locations Pharmacy, Bin, and Sink/Toilet) and each location individually (i.e., Pharmacy, Bin and Sink/Toilet) served as the four dependent variables. As shown in Table 3, the R^2 value showed the demographic predictors (i.e., age, gender, SES and number of children) to account for 17.8 of the variance in correct disposal. In terms of individual disposal locations, the R^2 values showed that 16.1%, 22.6%, and 2.2% of the variance in returning to the pharmacy, placing in bin, and disposing down the sink/toilet, was accounted for by these variables, respectively. Here, age positively predicted the correct disposal composite score as well as returning to pharmacy and disposing in bin. Female gender was a positive predictor of the correct disposal composite score and returning medicines to a pharmacy. Presence of children also positively predicted disposal down sinks and toilets.

As shown in Table 3, and after controlling for demographic characteristics in Step 1, 59.2% of the variance in correct disposal was explained in Step 2 (R^2 change $= 0.414$, Fchange (16,444) $= 37.52$, $p < 0.001$). In terms of individual disposal locations, the final model predicted 52.8% (R^2 change $= 0.37$, Fchange (16,444) $= 28.78$, $p < 0.001$)), 51.5% (R^2 change $= 0.29$, Fchange (16,444) $= 22.13$, $p < 0.001$), and 17.1% (R^2 change $= 0.15$, Fchange (16,444) $= 6.65$ of the variance in returning to the pharmacy, placing in the bin, and disposing down the sink/toilet, respectively. The results from Step 2 showed age to negatively predict disposal in bin and positively predict disposal down the sink/toilet. Presence of children negatively predicted correct disposal and positively predicted disposal via the bin and sink/toilet. Both Receiving information and Awareness of being able to return medicines were positive predictors of correct disposal, returning

Discussion

With increasing volumes of pharmaceuticals being prescribed, it is important we limit the number of medicines disposed incorrectly by ensuring people dispose of their medicines in appropriate, environmentally safe methods, preventing future environmental harm [49]. Using a nationally representative UK sample, in this paper we have (i) described patterns of medicines waste usage, storage and disposal practices; explored the relationship between type of medicine preparation and choice of disposal method; and (iii) examined a set of predictors of self-reported medicines disposal behaviour.

to a pharmacy and negative predictors of placing in the bin. Affect was a negative predictor of disposal in the bin and a positive predictor of disposing medicines via sink/toilet. Probability was a negative predictor of correct disposal and a negative predictor of disposal in the bin. Attitude was a negative predictor of correct disposal and a positive predictor of disposal down the sink/toilet. Intention to correctly dispose in the future was a positive predictor of reported correct disposal behaviour as well as returning medicines to the pharmacy. Intention was also a negative predictor of disposing of medicines via the bin and down the sink/toilet.

The squared semi partial correlation (sr^2) values presented in Table 3 show the proportion of variance uniquely explained for each dependent variable by each independent variable. As shown, these values ranged from 0 through to 0.191 (or 19.1% of the unique explained variance).

Patterns of medicine waste disposal practices

Consistent with UK data collected in 2003 [11] almost all participants ($n = 641$, 97%) in this work reported having medicines in their house with two-thirds having a mix of prescription and OTC medications. In the present work and that of Bound and Voulvoulis, 9% of the respective sample sizes reported obtaining only prescription medicines and it is important this should not mask the fact that more pharmaceuticals are being prescribed per person (polypharmacy) to a greater absolute number of people [50].

In the present study, the bin was the most common disposal route for unused pharmaceuticals. The percentage of bin disposal was lower in this work ($n = 426$, 48%) than reported in earlier UK research (i.e. 65%) [11]. Yet, whilst a reduction in general waste disposal suggests a positive trend, disposal via toilets and sinks increased (i.e. $n = 230$, 25%) when compared with data from 2003 (12%) [11]. It is unclear why liquid disposal appears to have increased relative to bin disposal but one reason may be the increase in recycling.

In the present work, return rates to pharmacies were 27% ($n = 242$) compared to 22% in 2003. General waste and sink/toilet disposal are also much lower than reported in research conducted in other countries such as Sweden, where increasing numbers of the population are worried about the impact of pharmaceuticals [51]. This has been linked to increased awareness of the issue stemming from information campaigns [51]. Thus, a plausible explanation may be that the UK has not yet had any high profile, national campaigns relating to medicine waste disposal and over half of the study sample reported not seeing any information on how to dispose of unused medicines.

Table 3 Multiple hierarchical regression results for correct disposal and individual disposal locations

	Correct disposal		Pharmacy		Bin		Sink/toilet	
	β	sr^2	β	sr^2	B	sr^2	B	sr^2
Step 1	R^2 0.178, $F(4,456)=240.73$, $p<0.001$		R^2 0.161, $F(4,456)=21.84$, $p<0.001$		R^2 0.226, $F(4,456)=33.20$, $p<0.001$		R^2 0.022, $F(4,456)=2.53$, $p<0.05$	
Age	0.39***	0.136	0.37***	0.124	−0.46***	0.191	0.04	0.001
Gender	0.13**	0.017	0.17***	0.03	−0.06	0.003	−0.05	0.003
SES	−0.05	0.003	−0.04	0.002	0.01	0	0.08	0.006
Children	−0.04	0.001	0.05	0.002	0.05	0.002	0.11**	0.01
Step 2	R^2 0.592, $F(16,444)=40.26$, $p<0.001$		R^2 0.528, $F(16,444)=31.04$, $p<0.001$		R^2 0.515, $F(16,444)=29.51$, $p<0.001$		R^2 0.171, $F(16,444)=5.72$, $p<0.001$	
Age	0.04	0.001	0.03	0.001	−0.17***	0.018	0.15***	0.016
Gender	0	0	0.05	0.002	0.05	0.002	0	0
SES	−0.02	0	−0.01	0	−0.02	0	0.07	0.005
Children	−0.07*	0.004	0.02	0	0.07*	0.005	0.12**	0.014
Received info	0.09***	0.006	0.11***	0.009	−0.09*	0.006	0.03	0
Aware could return	0.42***	0.103	0.40***	0.092	−0.40***	0.093	−00.1	0.005
Knowledge	−0.03	0	0	0	0.03	0	0.03	0.001
Convenience	0	0	0.04	0.001	−0.01	0	0.06	0.003
Storage	−0.01	0	0.03	0.001	−0.01	0	0.01	0
Affect	0.02	0	0.05	0.001	−0.12**	0.007	0.17***	0.013
Probability	0.08***	0.007	0.04	0.003	−0.09**	0.008	−0.04	0.002
Consequences	0.07	0.003	0.05	0.002	−0.03	0	−0.09	0.005
TPB, PBC	−0.04	0.001	0.−01	0	0.03	0.001	0.03	0.001
TPB, subjective norm	0.02	0	0.07	0.002	−0.01	0	0.05	0.002
TPB, attitude	−0.11**	0.006	−0.08	0.004	0.06	0.002	0.12**	0.007
Intention	0.41***	0.082	0.30***	0.043	−0.21***	0.021	−0.48***	0.109

Note. β = standardized regression coefficients. sr^2 = squared semi-partial correlation. Bootstrapped confidence intervals and standard errors are available on request from the lead author

* $p<0.05$. ** $p<0.01$. *** $p<0.001$

Most of the sample disposed of medicines in multiple locations. It is important to understand the reasons guiding these behaviours as the aim of any intervention will be to decrease the frequency of disposing medicine into the bin, toilet and sink. It is also important to consider ways in which shifting to increased pharmacy disposal requires different strategies than to switch from inappropriate disposal to a completely—and certainly more effortful – disposal location.

Relationship between the preparation type of medicine and choice of disposal

Our work represents the first UK investigation of the relationship between preparation type of pharmaceutical waste and disposal destination. Here, there were clear regularities: liquids tend to be disposed in sink or toilet and solids, creams and ointments in general waste. The broad relationship between medicine type was similar to results from a New Zealand study [12] in respect of disposal to general waste for solids (UK: $n = 317$, 54% vs NZ: $n = 229$, 51%) and ointments (UK: $n = 426$, 76% vs NZ: $n = 361$, 80%). However, our results showed a lower percentage of liquids disposal in sinks/toilets (UK: $n = 226$, 38% vs NZ: $n = 249$, 55%). Globally, the pattern of disposing liquids into waste water is similar with a review of international surveys concluding respondents were 2–5 times more likely to flush a liquid than solid [23]. These practices are in line with general disposal practices where solid household waste is disposed of via bin and where the toilet or sink is the most obvious receptacle for liquid waste. Rates of liquid disposal have more than doubled since Bound and Voulvoulis [11] and although not examined in the present work, one reason could be increased recycling whereby people are more likely to pour away liquid medication in order to recycle bottles/containers. When recycling was less common, more unused medicine bottles may have been discarded in the bin. The route to natural waterways and environment is more direct through flushing than via general waste and landfill. Boehringer [52] deemed it to be more harmful suggesting a prudent approach would be to focus strategies on reducing exposure at this destination by raising awareness of the environmental dangers of this route and including take back advice on liquid containers and bottles. In Sweden, pharmacies supply transparent bags with informational text on where unused medicines should be placed which enables households to correct handling [51].

The rates for pharmacy disposal are higher in the UK than in New Zealand both for liquids (UK: $n = 170$, 28% vs NZ: $n = 79$, 17%) and solids (UK: $n = 236$, 40% vs NZ: $n = 110$, 24%). Our data suggest a higher likelihood of returning a medicine to a pharmacy if it is solid rather than liquid or creams/ointments. Global surveys which have collected data on medicine preparation and disposal have focused on general waste or toilet/sink disposal rather than pharmacy disposal limiting international comparison. Many countries have no standard medicine disposal protocols or procedures for pharmacies to accept unused medicines [16, 23] which may be one reason for why comparison of pharmacy takeback by country is limited. Current European legislation obligates member states to implement appropriate collection schemes for unused medicines [53, 54] but in some member states there is little information to demonstrate any collections systems exist [55]. It is important that a policy for medicine collection is financed properly and clearly outlines the responsibilities of each organisation. The legislation in Lithuania, for example, states the government are responsible for financing but the roles are unclear which means in practice, pharmacies pay for disposal of collected medicines and are, therefore, less likely to accept them [23].

The role of multiple variables in predicting self-reported medicines disposal behaviour

Several variables had a unique role in predicting previous disposal behaviour. The results of the regression analyses supported our hypothesis (H1) and past work (e.g., [12, 18]) that age would negatively predict a person's waste bin disposal. In contrast to previous work [19, 21, 56] and our hypothesis (H2), age was not a positive predictor of returning unused medicines to a pharmacy. Yet, age was a positive predictor of sink/toilet disposal [19]. It may be older people express a guardian role around family and are more inclined to flush medicines for safety reasons.

Contrary to Hypothesis 3, Owens and Anand [18] findings that demonstrated females have greater sink/toilet disposal were not supported in the final model. SES was not a significant predictor of correct disposal. The hypothesis of presence of children predicting more frequent sink/toilet disposal (H4) was supported. Presence of children was also a positive predictor of bin disposal and a negative predictor of correct disposal, suggesting households with children disposed less appropriately than households without. Here, it may be that people with children are more likely to flush and dispose in bins for reasons of child safety. It may also be that those with children perceive themselves to have less time available to them. In this regard, Foon [25] reported that perceived busyness had a negative effect on intention to properly dispose medicines.

In support of Hypotheses 5 and 6 both *received Information* on correct disposal and *awareness* that medicines can be safely disposed at a pharmacy were positive predictors of correct disposal. Similarly, both variables were positive predictors of returning medicines to a pharmacy and not disposing in the bin, although interestingly they were not associated with lower disposal in sinks/toilets. Such findings

may suggest awareness of incorrect disposal is limited to disposal in the bin and sink/toilets may not be seen as incorrect or harmful. Campaigns that carry a particular emphasis on avoiding water pollutions via the sink/toilet in addition to encouraging safe pharmacy returns would help to address this and we discuss the role of information campaigns below.

Convenience (H7) was included as a positive predictor of correct disposal but was not significant in the final model. Convenience of getting to a pharmacy was rated highly ($M = 4.95$ from 7) which is likely due to widespread availability of pharmacies. However, it may be that other convenience factors such as ease of medicine storage (before disposal), remembering to dispose and having time to dispose may be more important to disposal destination than convenience of getting to a pharmacy.

The probability variable in the present work captures assessments of the likelihood of good disposal practices by others in the neighbourhood. Probability of good disposal by others positively predicted overall good disposal behaviour (H8) and was also a negative predictor of bin disposal. It is interesting to reflect on this alongside the profile of results for the subjective norm variable which refers to the idea that important people would approve of and support good medicines disposal behaviours. This was not a significant independent predictor of disposal behavior—this was also the case in the study by Foon et al., [25] where intention was the outcome variable. The difference may reside in the question wording with probability questioning a person's likelihood of inappropriate disposal and SN questioning people's belief about approval of returning medicines to a pharmacy in the next 6 months; disposing inappropriately is likely seen as more disapproving than not returning medicines to a pharmacy. Additionally, disposing of medicines is often an infrequent behaviour and may not be necessary in the next 6 months. For instance, when asked in Sweden, a country known for its high rates of pharmacy return, what people did with unused drugs, more than half the respondents replied they were stored in the cupboard [51]. Future studies may want to adapt this question by removing reference to a timeline for the behaviour to occur.

Contrary to H8, affect did not predict the overall disposal measure or disposal to the pharmacy but was a negative predictor for the bin and a positive predictor for disposal in sink/toilet indicating those more fearful and anxious of inappropriate disposal were also those reporting less frequent disposal in bin and more frequent disposal in sink/toilet. One possibility here relates to the explanation proposed in relation to the children variable. It may be that for some the notion of inappropriate disposal relates to safety—and anxiety and concern about this necessitates immediate and self-evident removal of that potentially dangerous substance. This is achieved through disposal in the sink or toilet more easily than in the bin or via the pharmacy both of which

likely require the substance to be present in the house for a more extended period.

A positive association between Knowledge and correct disposal (H9) was not found. The disjoint between environmental risk-knowledge and behaviour is apparent in other studies [19, 57] which have found those with good knowledge of harmful effect of medications on the environment still practice incorrect disposal. It may be that individuals who consider themselves knowledgeable on the environmental risk do not believe it is sufficiently risky enough for them to change behaviour.

Although attitude was a significant predictor of *intention* to dispose in the study by Foon et al. [25], it was not positively associated with correct behaviour (H10). Those that were more negative about returning medicines to the pharmacy over the following 6 months were those that were more likely to have had higher frequency correct disposal in the previous 6 months. This may be due to disposal frequency with those who have already returned medicines considering a repeat disposal over the next 6 months as useless and unwise.

The potential disjuncture between attitude and performance of the behaviour was also evident in relation to the PBC variable which was not positively associated with correct behaviour (H11). Indeed, there is little evidence for the direct effect of PBC on *behaviour* [58]; having control over the performance of a behaviour may be unrelated to its occurrence [59]. This was evidently the case here, and notably so given the mean of PBC was high.

Intention to return in the next 6 months was positively associated with past behaviour. This fits with previous theories that experience increases the accessibility of intention [60]. Sheeran et al. [61] found greater experience enhances predictive validity up to a point; thereafter increased experience was associated with weaker prediction of intention. The relative infrequency of medicine waste recycling makes it more likely to follow the intention stability perspective rather than become habitual thereby reducing intention–behaviour consistency.

Study limitations

The cross-sectional nature of the study limits determination of causality between variables in the model, for example, it is not possible to establish whether higher awareness to dispose at pharmacies resulted from previous disposal or was the cause of that disposal. The sole use of a questionnaire introduces possible common-method variance and further exploration of the determinants of medicines waste would benefit from triangulation with other data sources. Additionally, remembering infrequent yet possibly unremarkable events poses particular challenges to self-reports

of recall of disposal frequency, type, and destination [62]. Finally, we have sought to set this research in the context of other studies in the area and particularly in relation to previous UK research [30]. Overall, however, the literature is relatively sparce and available comparisons are in different cultural settings sometimes with different disposal options and policies.

Future research

To address limitations inherent in cross-sectional study designs, future work may want to consider a longitudinal approach. Moving beyond self-report data is essential if we are to evaluate a campaign on medicines returns. Here, having a clear baseline understanding of what medicine is returned to a pharmacy, taking account of population and seasonality is required. In establishing these baseline parameters and informing the design of a campaign, it would also be useful to understand why specific medicines are being returned with medicine data at the point of return also ensuring greater accuracy of measurement type and count.

This study is the first to allow characterisation of the way in which people's disposal strategies can vary—most people in this study had disposed of medicines waste in at least two different locations. We suggest that future research continues to recognise this and seeks to further understand the circumstances that lead to disposal to the different destinations. We have suggested one determinant of this is *type* of medicine but given variability in the disposal destinations of a single medication preparation type (e.g., liquids), a clearer understanding of this is required.

It may also be important to consider how people's mental models of disposing of medicines waste relates to more general—much more established—models of recycling behaviour. This might usefully explore, for example, whether unused liquid medicine is disposed of in the sink or toilet to recycle the plastic or glass bottle.

Research in this area should ultimately inform strategies to change medicines disposal behaviours. We have noted the value of increasing awareness of the options for safe disposal of medicines waste but a more tailored analysis of the capability, opportunity and motivation people have to return medicines to the pharmacy is required in order to design and target appropriate interventions [63] that will be effective in reducing the amount of medicines waste in the environment. This might, for example, involve reminders about disposal at point of dispensing, and on packaging, developing ways of ensuring pharmacy disposal processes are frictionless. Official disposal options in some countries are not via the pharmacy—situating official disposal options in other places may assist in increasing visibility and legitimacy of correct medicines waste practices.

Of course, addressing the issue of medicines waste disposal is only one side of the equation. It is also vital to develop and prioritise pharmaceuticals that have less impact on the environment as well as to avoid unnecessary prescriptions. Social prescribing is an initiative increasingly embedded in primary care in the UK that may have a role in contributing to this [64].

Conclusion

In conclusion, this research has provided a comprehensive snapshot of medicines waste disposal practices in the UK. This has updated previous work conducted in 2005. There is a clear synergy between the health of people and the environment: prescribing practices and the treatment of medicines waste have substantial unwanted impacts on the environment. Consideration must be given to both prevention of the problem as well as to its cure.

Declarations

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