

## Environmental Contamination by Pharmaceutical Waste: Assessing Patterns of Disposing Unwanted Medications and Investigating the Factors Influencing Personal Disposal Choices

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### Abstract

Occurrence of pharmaceuticals in the aquatic environment is of great concern and has been the focus of an increasing number of recent studies. Trace levels of these compounds have the potential to cause harmful effects to aquatic life. The significant source of pharmaceuticals in the environment is household disposal of expired/leftover/unused pharmaceuticals. In order to minimize the amount of pharmaceuticals disposed of and discharged into the environment, the motivation behind the selection of disposal methods should be studied. This study aims to identify possible contributory factors associated with the choice of the methods of disposing pharmaceuticals and to evaluate the public perceived environmental risk of pharmaceuticals. The results are based on questionnaire responses of 767 residents in Saudi Arabia. It was found that disposal of unused pharmaceuticals through household waste and domestic water systems are the most predominant practices. Respondents possessing higher level of education and people who received instructions regarding proper disposal are more likely to return pharmaceutical waste to a pharmacy. There is no association between risk perception and the choice of disposal methods. Our findings revealed that it is more beneficial to educate people about the proper disposal rather than educating them about the risks associated with pharmaceuticals. These findings will provide insights when designing future interventions to promote specific messages to enhance knowledge, change attitude and improve practice regarding disposal of pharmaceutical waste.

**Keywords:** Pharmaceutical waste; Unwanted medications; Disposal practices; Household waste; Pharmaceutical pollution; Risk perception

### Introduction

Occurrence of pharmaceuticals in the environment is of great concern and has been the focus of an increasing number of recent studies. Pharmaceuticals are an inevitable part of our life. Large number of pharmaceuticals is used every day either for human or animal therapy and their use is on the rise. Pharmaceuticals enter the environment from human excretion and also as intact form due to improper disposal of unused/expired pharmaceuticals via sewer systems [1]. Sewage treatment plants are not designed to remove pharmaceutically active compounds from effluents and thus pharmaceuticals can potentially be discharged into waterways. Another way of disposing unused pharmaceuticals is through household waste. Incineration of the waste is considered the most effective and eco-friendly way to handle the problem, however in many countries, especially developing ones, this technique is not available and household waste may eventually end up in landfills leading to a discharge of pharmaceuticals into the environment as leachate [1]. This solution only postpones the problem and pharmaceuticals will probably show up after some years in the effluent of the landfill.

Many studies have reported the occurrence of pharmaceuticals in different matrices such as wastewater, surface water, ground water, and even drinking water at low concentrations ranging from micrograms to nanograms per liter [2]. Although these concentrations are very low, they have the potential for environmental effects. More than 600 pharmaceutical substances have been shown to be present in the environment worldwide [3]. The main groups of pharmaceuticals detected in environmental samples are human and veterinary antibiotics, hormones, non-steroidal anti-inflammatory drugs, lipid regulators, beta-blockers and anti-depressants drugs [4-6]. Continual discharge of pharmaceuticals into the environmental compartments even at trace levels might lead to long-term exposure causing a chronic threat to human and wildlife [2]. It is well documented in the literature that trace levels of estrogenic compounds (1 ng/L) may pose harmful effects on aquatic species including impairment of sexual development and feminization of

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fish [7,8]. Intersex fish (feminized males) were found for the first time in British rivers near wastewater treatment plants outfalls in 1976 [8] and then they have been reported in many other countries. It was indicated that these fish were exposed to sewage effluent containing different steroid estrogens, both natural and synthetic (ethinylestradiol) suggesting that steroid estrogens are the main cause for fish feminization [9]. Another concern is that of acute poisoning of oriental vultures by diclofenac, a non-steroidal anti-inflammatory drug used in veterinary medicine for the treatment of inflammation, pain, and fever in domestic livestock. Dramatic decline of three vulture species in South East Asia because of ingestion of diclofenac residues when feeding on carcasses of livestock that had been treated with the drug shortly before their deaths has been also reported [10]. Serious impacts of pharmaceuticals in the environment are also demonstrated by the development of antibiotic resistance in some bacterial strains due to accumulation of antibiotics in the environment [11]. Resistance to antibiotics may occur in wastewater treatment plants, receiving waters or in the environment where antibiotics are discharged directly as in case of fish farms where antibiotics are added directly to the water as medicated feed and where livestock manure is added to fish ponds as growth promoters. It has been found that resistance to ciprofloxacin among bacteria in ponds treated in this way increased from less than 5% to 80%, while resistance to oxytetracycline and sulfamethoxazole was present in 100% of the samples [12]. Additionally, the presence of antibiotics in sewage systems has the potential to seriously affect the treatment processes that driven by organic matter degradation, nitrification and denitrification [13]. Furthermore, chronic and mixture effects of pharmaceuticals are also possible. Exposure to certain combination of pharmaceuticals may pose a risk that is greater than the sum of the risk posed by each pharmaceutical individually [14]. Minimizing the amounts of pharmaceuticals that are discharged into the environment and applying precautionary principles could help preventing serious potential harm to humans and wildlife.

Many studies have been conducted in various countries to investigate the methods used for disposing medication waste [15-18]. In contrast to the considerable and rapidly increasing amount of information about occurrence of pharmaceuticals and disposal practices of unused medications in the developed Western countries, relatively little is known in the Middle East and there is a very important data gap. For a more comprehensive picture of the global situation, further studies should be undertaken in the Middle East countries, especially for those which have large human population where medication disposal practices may have a significant impact on the global environment. Taking Saudi Arabia as an example, it houses a resident population of 31 million people of multi-ethnicity and the governmental healthcare facilities offer free medications for all citizens which increased the risk of accumulation of unused medications. In addition, many of drugs are available without a prescription and obviously

having excess of medications in homes poses some risks such as the potential implications for accidental childhood drug poisoning and increased the risk of sharing drugs between people leading to improper self-medication. It is worth to note that the total pharmaceutical expenditure in Saudi Arabia has been estimated at 3.5 billion USD in 2010, while the cost of medication wastage was 150 million USD annually [19]. Therefore, there is a pressing need for investigating the disposal practices of pharmaceutical waste in the Middle East countries and addressing the issues related to improper disposal practices, if the likely environmental impact of pharmaceuticals is to be reduced.

The main objective of this study was to evaluate the perception of environmental and health risk associated with pharmaceuticals and to investigate the factors influencing the choice of disposal methods. This information will provide insights for regulators and decision makers when designing future interventions aiming at enhancing knowledge, changing attitude and improving practice regarding disposal of pharmaceutical waste in the Middle East.

## Methods

A self-administered structured questionnaire was designed and used as a tool for data collection. The questionnaire was carried out across Saudi Arabia and was randomly distributed over a period of three months from February 2017 to April 2017. The survey was conducted in both English and Arabic versions. The inclusion criteria for eligible participants were: 1) people aged 18 or over, 2) able to speak Arabic or English, and 3) willing to take part. In total, 1,000 surveys were distributed and 767 were completed, yielding a cooperation rate of 76.7 percent.

The questionnaire consisted of three parts. The first part is mainly focused on participants' characteristics including age, gender, nationality, and education level. The second section was designed to investigate the perception of pharmaceuticals including occurrence of pharmaceuticals in the aquatic environment, sources of environmental contamination by pharmaceutical waste, health risk and environmental risk associated with the most significant classes of pharmaceuticals namely antibiotics, hormones and pain killers. These groups were selected because 1) their toxicity to the environment was proven and documented [3,20], 2) they are prescribed in large volumes and 3) the evidence of their occurrence in different environmental matrices is well documented [2]. For example, antibiotics are widely prescribed and sold in the Gulf countries without a need for a prescription as 77.6% of pharmacies in Saudi Arabia dispensed antibiotics without a prescription mainly to treat cases with viral infections [21] suggesting lack of antibiotics knowledge. Pain killers were also included because they are widely prescribed and sold over-the-counter in very high volumes and have been widely detected in the environment [11]. Hormones including oral contraceptives were also selected because of their toxicological properties [7]. The

third section investigates the disposal pattern of unused pharmaceuticals.

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 22. Descriptive data were expressed as percentage and frequency. Chi square test (p-value of 0.05 was considered to be significant) was used to identify possible contributory factors associated with risk perception, attitude and practices regarding disposal of pharmaceutical waste.

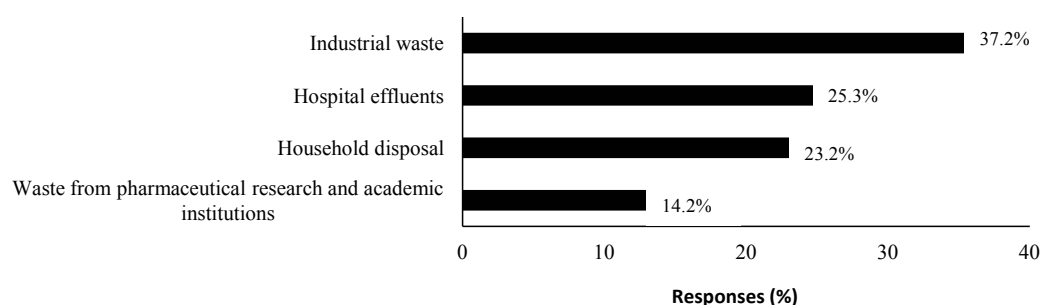
### Analysis

Over the three month collection period, 767 respondents were completed the survey. Overall, 73.8% were female and 26.2% were male. The most common age group was 20-39 years (68.8%). The respondents were mainly of Saudi nationality (88.7%). College degree is the highest level of education completed for 54.9% of the respondents.

The majority of the respondents (70.7%) indicated that pharmaceuticals could be found in the aquatic environment. Three quarters of the respondents (75.1%) perceived that pharmaceuticals could be harmful to human health if

misused. When asked about the sources of environmental contamination by pharmaceutical waste, participants perceived that industrial waste is the main source of contamination (37.2%), followed by hospitals effluents (25.3%); while household disposal came in the third place (23.2%) (Figure 1). When asked about the hazards of the selected classes of pharmaceuticals, it was found that 51.2% of the respondents perceived that antibiotics are hazardous to the environment, while 66.9% and 62.7% perceived pain killers and hormones non-hazardous to the environments, respectively.

The influence of demographic characteristics on respondent's perception of risks to the environment was studied and the results are shown in Table 1. It was found that there is no significant association between age, gender and educational level on the respondents' awareness of occurrence of pharmaceuticals in the aquatic environment and their harmfulness to health when misused. However, there is an association between the educational level and the risk perception of antibiotics, hormones and pain killers. The perception of the potential risk is highest in those



**Figure 1:** Responses regarding the sources of environmental contamination by pharmaceutical waste.

Response	Frequency	Gender	Age	Educational level
Pharmaceuticals could be found in the aquatic environment				
Yes	542 (70.7%)	No significant difference	Awareness increased with age	No significant difference (p=0.279)
No	225 (29.3%)	(p=0.723)	(p<0.001)	
Occurrence of antibiotics in the environment is hazardous				
Yes	393 (51.2%)	No significant difference	No significant difference	Awareness highest in those with higher education (p=0.007)
No	374 (48.8%)	(p=0.741)	(p=0.082)	
Occurrence of hormones in the environment is hazardous				
Yes	254 (33.1%)	No significant difference	No significant difference	Awareness highest in those with higher education (p=0.019)
No	513 (66.9%)	(p=0.095)	(p=0.670)	
Occurrence of pain killers (NSAIDs) in the environment is hazardous				
Yes	286 (37.3%)	Female > male (p<0.001)	No significant difference	Awareness highest in those with higher education (p=0.009)
No	481 (62.7%)		(p=0.138)	
Pharmaceuticals could be harmful to human health if misused				
Yes	576 (75.1%)	No significant difference	No significant difference	No significant difference
No	191 (24.9%)	(p=0.086)	(p=0.089)	(p=0.468)

**Table 1:** Influence of demographic characteristics on risk perception.

with higher educational level ( $p=0.007$ ,  $0.019$ ,  $0.009$  for antibiotics, hormones and pain killers, respectively) (Table 1). Interestingly, females' perception of pain killers risk is higher relative to that of males.

Majority of respondents (62.9%) discarded unwanted medications in household waste, with the remainder emptying them into the sink or toilet (16.6%), returning them to a pharmacy (6.5%) or a physician (1.4%). The reminder (3.5%) indicated that they never disposed of pharmaceuticals, while 9.1% gave them to someone else. The influence of demographic characteristics on choice of disposal methods was examined. It was found that there is an association between the educational level and the selection of returning unwanted medications to a pharmacy ( $p=0.033$  & Pearson  $\chi^2=12.17$ ). Highly educated respondents (58.4%) are more likely to return medications to a pharmacy than others of lower educational levels. It was also found that, gender exerts influence on the practice of giving unwanted medications to someone else ( $p=0.042$  & Pearson  $\chi^2=4.13$ ). Females are more likely to give unwanted medications to others as a disposal method (84.1% vs. 15.9%).

Of the respondents, 73% declared that they had never received any instructions about proper ways of disposing medications. It is worthy to mention that there is an association between participants' awareness about proper disposal of pharmaceuticals and the selection of disposal methods. Respondents who received instructions about proper disposal are more likely to return pharmaceuticals to a pharmacy ( $p=0.003$  & Pearson  $\chi^2=11.45$ ).

We found that respondents are willing to participate in a pharmacy take-back program if applied in their communities. When asked whether they agree to return unwanted or expired medicines to a pharmacy, 90.9% indicated their willingness. A full overview of the participants' responses is provided in Figure 2.

The relationship between their willingness and

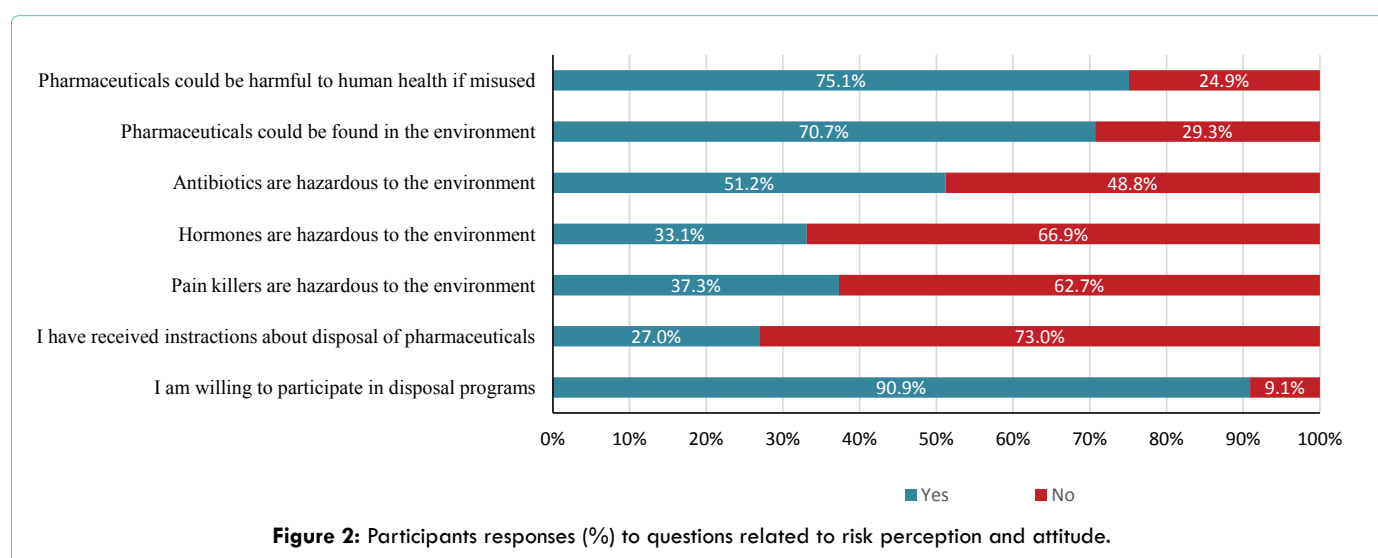
demographic characteristics was examined and we found that female respondents are more likely to state a willingness to participate (75% females vs. 25% males) ( $p=0.014$  & Perarson  $\chi^2=6.09$ ) and there is no correlation with age or educational levels.

## Discussion

Risk perception is the way that people evaluate a hazard. Many factors can affect the risk perception including a compromise between benefits and risk, feeling of control, cultural background, past experience, exposure to media and demographic characteristics such as age, gender and educational level [22]. Generally, the perception of risk increases when the risk is imposed (pharmaceutical residues in the environment) rather than being voluntary (e.g. smoking). The people's background knowledge and their familiarity with the risk help them to form their perception of that risk. In order to minimize the amount of pharmaceuticals disposed of and discharged into the environment, the motivation behind the selection of disposal methods should be studied. Information provided from investigation of risk perception is beneficial for instructing and improving risk assessment and management.

It was demonstrated that more than half of people perceived that antibiotics is hazardous to the environment, while about two thirds of people perceived hormones and pain killers as not hazardous to the environment (Table 2).

The perception of the risk of antibiotics is higher than other groups possibly due to media exposure. Several antibiotics awareness campaigns have been launched worldwide. Social media platforms are now frequently utilized to address health related issues. These platforms are becoming increasingly popular in the countries of the Gulf Cooperation Council (GCC) including Saudi Arabia [23]. These platforms have unique characteristics for sharing open access information, providing a platform for dynamic conversations with communities and keeping users connected with their



**Table 2:** Pharmaceutical disposal practices and perceived risk of pharmaceuticals.

Disposal method	Perceived risk (%)					
	Antibiotics		Hormones		Pain killers	
	Hazardous 393 (51.2%)	Not hazardous 374 (48.8%)	Hazardous 254 (33.1%)	Not hazardous 513 (66.9%)	Hazardous 286 (37.3%)	Not hazardous 481 (62.7%)
Household trash	60.5	65.6	59.2	65.2	58.9	65.4
Toilet/sink	19.3	13.5	22.1	13	23.3	12.5
Return to pharmacy	7.5	2.8	1.8	2.6	2.1	2.4
Give to physician	1.1	5.3	5.9	6.9	5.7	7
Give to someone else	7.1	1.7	1.8	1.1	2.1	1
Burn	1.9	6.6	5.9	7.5	6.3	7.3
Never dispose	2.2	4.1	2.6	3.4	1.6	4
Other	0.4	0.4	0.7	0.3	-	0.4

The results are based on responses

topics of interest [23]. That is why Saudi Ministry of Health is using social media platforms alongside various other media platforms in a large scale public awareness campaign to raise awareness and provide guidance on appropriate antibiotic use in the general public and in the healthcare communities as well. Also, it was demonstrated that where the medicine is familiar such as hormones and pain killers, the perceived risk is lower. This is possibly because these groups of medicines are widely used and available over-the-counter, therefore perceived less hazardous to the environment. However, hormones and pain killers are the most frequently detected pharmaceuticals in the aquatic environment [24] and may pose harmful consequences, suggesting that people perception to risk is not always similar to the actual risks. Another study conducted in UK demonstrated that there was no link found between risk perception and education [22], however in this study a correlation was found between education and risk perception. Those possessing higher educational levels had higher perception of environmental risk of pharmaceuticals than others of lower educational level.

This study also revealed that the predominant methods for disposing unused pharmaceuticals are eco-unfriendly via domestic water streams or household waste. These routes of disposal are also common in other countries such as UK [22] and USA [25]. The selection of these methods of disposal could be explained as these are the most straightforward and least time and effort consuming methods of disposal or possibly people may feel that disposing pharmaceuticals via sewer systems or household waste is not threatening to the environment, especially when these pharmaceuticals are perceived not hazardous e.g. over-the-counter drugs. Also, the lack of knowledge regarding the sources of environmental contamination by pharmaceutical waste may be the cause of selecting these routes of disposal. In this study, household disposal was ranked third as a source of environmental contamination and people perceived that household disposal is a less significant source of environmental contamination compared to industrial waste or hospitals effluents. This perception may affect their behavior regarding disposal of pharmaceuticals into sewer systems or household waste.

When examining demographic factors that may be relevant to the choice of disposal methods, there was no link found between disposal practices and gender or age, however individuals possessing higher educational level were more likely to return unused pharmaceuticals to a pharmacy.

This study also reflects the public's enthusiasm to participate in disposal programs if one were established. Females were found to be more likely to state willingness than males.

Evidence for a correlation between risk perception and appropriate disposal was not found. Even with high level of perception to the risk, high proportion of drugs was disposed of in household waste or via the drain (Table 2). This might be explained as people feel that the risk is not sufficiently significant compared to other risks. Excessive warnings that are constantly around us may cause people to be risk overloaded and therefore the threat of a particular risk is lost among the other, especially when the consequences or predicted effects of the risk are delayed or not seen to have a direct impact on their health. Another explanation is people may feel that their contribution is too small and might be seen as negligible and they may think that the effect of one individual's action is unbeneficial and consequently they will lose the motivation to take the action or because they did not have enough incentive to change their disposal behavior. It seems that the choice of disposal methods is driven from individual's social and environmental responsibility rather than the perception of the risk.

The results of the survey demonstrated that most people had never received any information or instructions about proper disposal of unused pharmaceuticals, but interestingly we found that people who received instructions about proper disposal are more likely to return unused pharmaceuticals to a pharmacy. This reflects the role of education in changing people's behavior; hence information and education would breed public confidence as the more people understand about the issue, the more they tend to favor it. These findings may provide valuable insight for future disposal programs in the Middle East. Educating people on the proper ways of

disposing pharmaceuticals may be constructive and more beneficial than educating them about the risks associated with the occurrence of pharmaceuticals in the environment. Providing people with clear information about disposal methods may have more effect on changing disposal behavior than education about environmental risks of pharmaceuticals. This could be achieved by clearly labeling the drug packages showing up clearly instructions of proper disposal of unused medicines. A significant role can also be played by community pharmacists being on the forefront in guiding and providing proper education and awareness to the community. Thus, it is essential that their knowledge of proper pharmaceutical disposal to be complete, accurate and updated.

## Conclusion

The most favored methods of disposing unused pharmaceuticals are through household waste or sewer systems. Such practices are eco-unfriendly and may cause detrimental effects to humans and wildlife. Most people were aware about the harmfulness of pharmaceuticals to human health, however not all of them were aware of its associated risks to the environment. There is no definite correlation between perception of risks associated with pharmaceuticals and the choice of disposal methods. Our results suggest that highly educated people are more aware of pharmaceuticals risk and most people are willing to participate in disposal programs. These results may have implications for risk communication and management. Our findings revealed that it is more beneficial to educate people about the proper disposal rather than educating them about the risks associated with pharmaceuticals. Clear, distinct and visible instructions about proper disposal of pharmaceuticals should be available on the drug package labels. Also, healthcare practitioners and community pharmacists should be more proactive about educating patients about disposing unused medications in an eco-friendly manner. There is a pressing need for the establishment of pharmaceutical disposal programs in the Middle East as it provides a straightforward mechanism to help alleviate the problem. Minimizing pharmaceuticals that enter the environmental waterways could be more effective and less costly than extensive modifications of wastewater treatment plants or other remediation steps.

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