Judging pharmaceutical environmental risk by its cover? The effects of prescription medication and disease severity on environmental risk perception

ABSTRACT

Recent wastewater analyses performed in care homes for the elderly showed high levels of water pollution resulting from pharmaceutical waste. The way people perceive the environmental risk of pharmaceuticals can contribute to reversing this problem, but the factors that influence risk perception remain relatively unknown. The aims of the study are two-fold. We first focused on exploring the levels of knowledge regarding environment/water pollution due to pharmaceutical residues from the groups responsible for prescribing (health professionals), handling (staff), and consuming pharmaceuticals (residents) in care homes for the elderly. Secondly, we assessed the environmental risk perception of pharmaceuticals based on two main factors: prescription medication (non-prescribed versus prescribed) and disease severity (milder versus severe disease), accounting for their level of knowledge (deficit versus sufficiency of knowledge). The study was designed based on correlational research. Data was collected in homes for the elderly located in three Southwestern European countries (N=300), using self-report surveys. Current knowledge was perceived to be low and the need to know more was perceived to be high, across all groups. As hypothesized, results indicated that to assess the environmental risk, participants made use of information that was unrelated to pharmaceutical persistence, bioaccumulation and toxicity (PBT). Prescribed pharmaceuticals and/or medication used to treat severe diseases were perceived as being more hazardous for the environment. Simple main effects analysis comparing between knowledge levels confirmed that this effect occurred mostly when participants had knowledge deficit for disease severity but not for prescription medication. These misconceptions might discourage taking an active role in reducing the impact of pharmaceutical residues in the environment.

Keywords: pharmaceuticals in the environment, risk perception, PBT

1. INTRODUCTION

The dissemination of pharmaceutical residues in the environment has become a major issue in recent years, contributing to the pollution of water sources worldwide, and is only likely to get worse over time (Lacorte et al., 2018). The goal of this work was to contribute to risk management strategies, in particular to the European Union Strategic Approach to Pharmaceuticals in the Environment (European Commission, 2019, 2020), by exploring the factors underlying risk perception among individuals responsible for prescribing, handling, and consuming pharmaceuticals in care homes for the elderly in Southwestern Europe. In particular, we explored if when individuals lack knowledge on the risk of pharmaceuticals in the environment, they base their risk perception on two salient characteristics of the pharmaceuticals (prescription and disease severity), neither of which are relevant for estimating their environmental impact.

Traces of pharmaceutical residues have been found in surface and ground water, wastewater and, to a lesser extent, in drinking water (World Health Organization, 2012). Conventional water treatments fail to effectively and completely eliminate pharmaceutical waste. Each substance has a different chemical composition and action mechanism that, through either unsafe disposal practices or human excretion, undergoes several chemical reactions, making its detection, quantification, and subsequent removal in wastewater treatment plants particularly challenging (Li et al., 2020; Quesada et al., 2019). As such, pharmaceutical waste is frequently released alongside treated water into watercourses (e.g., rivers). The continuous release over the years also increases the risk of pharmaceuticals persisting and accumulating in the environment (Quesada et al., 2019). There are still several uncertainties regarding the concentration of pharmaceutical residues in water sources. Nevertheless, studies have been showing that even in low concentrations, these residues are toxic to aquatic life (Li et al., 2020), causing biological and physiological changes in organisms, such as algae, mollusks, crustaceans, and fish (Eades and Waring, 2010; Ebert et al., 2011; Galus et al., 2013; Li et al., 2020; Palma et al., 2020). In the case of human health, prolonged exposure to these residues can increase resistance to antibiotics, create endocrine disruption effects (Palma et al., 2020), and disease outbreaks (Khan et al., 2021).

With water scarcity being a recurrent and aggravated problem, there is a greater need to use treated wastewater to accommodate basic human needs (Nassiri Koopaei et al., 2017). As such, solutions that focus on prevention rather than just intervention are in high demand. This present study seeks to contribute to the prevention of this problem by exploring the underlying factors that influence people's risk perception. As an innovative perspective, we aim to address the role of medication characteristics in the perception of environmental risk from pharmaceuticals, in a frequently overlooked source of water pollution stemming from pharmaceutical residues, namely, care homes for the elderly.

Given the health benefits, taking medication is part of the daily routine of a great number of people. In Europe, approximately 5,000 different types of medication can be used to treat mild and severe diseases (Hughes et al., 2013). Additionally, a large quantity of pharmaceuticals is consumed each year (Lacorte et al., 2018). This number is expected to steadily rise over the coming decades (Gómez-Canela et al., 2019), mostly due to the growing burden of treatments for chronic diseases, coupled with the increase in life expectancy and consequently elderly population around the world (Quesada et al., 2019). The higher the consumption levels, the more likely it is that pharmaceutical residues pollute the environment and reach different water sources. Other influencing factors such as mass production, decreases in manufacturing cost, and affordable prices also make medication more accessible to everyone, increasing the demand and, thereby, considerably contributing to the evident increase in consumption (Quesada et al., 2019). In fact, it is not uncommon for people to purchase medication and have unused quantities stored in their cupboards. In recent studies, 61% (Vatovec et al., 2017) and 75% (Chung et al., 2019) of the participants reported having unwanted and unused pharmaceuticals at home, including both prescribed and over-the-counter medication (Chung et al., 2019; Vatovec et al., 2017). This pharmaceutical hoarding often results from actions such as over-purchasing by consumers, over-prescribing by health professionals, over-dispensing by the pharmacy or manufacturer, medication expiration date, undesired or ineffective results, and non-compliance with medical treatments (Vatovec et al., 2017).

Extensive work has been carried out to explore the occurrence, dissemination, and removal strategies of pharmaceutical residues in water sources. One of the main pathways is the unsafe disposal practices of the excess of pharmaceuticals, such as flushing them down the toilet or sink (World Health Organization, 2012). Another pathway is the human metabolic excretion, as the body only absorbs a small portion, and the rest is excreted through urine and feces, reaching the wastewater as unaltered or processed compounds. Other common dissemination pathways are associated with agriculture, industrial activities, hospital discharged effluents, and medical waste (Lacorte et al., 2018; Quesada et al., 2019). Meanwhile, people do not seem to be fully aware of the consequences that pharmaceutical waste entail for the environment/water sources (Götz et al., 2019) and are likely to be unfamiliar with how their actions contribute to the problem, inadvertently engaging in riskier disposal behavior. Kotchen and colleagues (2009) found that only 43% of the participants knew that pharmaceutical residues can be found in wastewater and surface water. Researchers also found that environmental awareness has a direct impact on pharmaceutical disposal practices. Participants that knew about this environmental issue were less likely to engage in unsafe disposal practices (e.g., discarding pharmaceutical stock in the trash, sink, or toilet) and three times more likely to choose eco-friendly disposal options (e.g., returning the medication to the pharmacy or hazardous waste centers; Kotchen et al., 2009). These results strongly indicate that uncertainty and lack of knowledge can significantly contribute to water pollution due to the presence of pharmaceutical residues in the environment. However, little is known about which factors influence people's perception of' environmental risk from pharmaceuticals.

Previous research conducted in Southwestern Europe (Lima et al., 2020) showed that participants had low factual knowledge, also known as objective knowledge, and low perceived knowledge, also referred to as subjective knowledge, about the presence of pharmaceuticals in the environment, and reported needing more information in order to properly deal with the health and environmental risks imposed by this presence. In Lima and colleagues (2020), despite the lack of knowledge, participants still managed to assess the environmental risks and presented medium to high risk perceptions that were based on trust assessments. That is, when participants had a higher trust in the authorities to manage the risk, they also revealed a higher environmental risk perception (Lima et al., 2020). Accordingly, a substantial body of research has been showing that when uncertain, people make risk assessments using inductive reasoning and heuristics, especially when they do not have enough time, knowledge, or motivation to make an informed assessment (e.g., Visschers et al., 2007). However, trust in the authorities only explained participants' risk perception to a small extent (Lima et al., 2020), remaining unknown what other sources of information people intuitively use to assess the environmental risk of pharmaceuticals. Moreover, different groups appear to perceive this risk differently. A study by Luís and colleagues (2020) demonstrated that experts estimate higher environmental risks of pharmaceutical waste than lay people.

When thinking about medication, individuals tend to focus on more immediate and accessible information that might influence their judgment, for instance, medication prescription, uses, and health benefits. Research has been showing that non-prescribed and prescribed pharmaceuticals are assessed differently. Lynch and Berry's study (2007) illustrates that prescribed medicine was thought to be more effective, but also more likely to lead to side effects and dependency than non-prescribed medication. In another study, Bound and colleagues (2006) also found that medication that is used regularly and non-prescribed medication (e.g., painkillers) are perceived as less potent and subsequently less threatening to the environment in comparison to unfamiliar and/or prescribed medication (e.g., antiepileptics). These results suggest that the most accessible information plays an important role in environmental risk assessment. Nonetheless, these studies do not differentiate between other relevant characteristics, such as medication prescription and the severity of the diseases they are used to treat. It might be the case that these variables are being confounded, as the pharmaceuticals that are used to treat severe diseases typically fall on the prescribed medication category, though there are cases where non-prescribed medication is used to treat relatively severe conditions, as the case of vitamin C recommend for scurvy.

Therefore, disease severity is another potential explanatory variable, given that the perception of pharmaceutical risks and benefits is likely to be influenced by the degree to which a disease impacts one’s life. When evaluating conventional and alternative medicines, the type of disease associated to each medication appears to be the most relevant criterion (Lewith & Chan, 2002). Two previous studies help support this notion. Slovic and colleagues (2007) showed that most prescribed medication was perceived as low in risk and high in benefit. In a complementary manner, Dohle and colleagues (2013) demonstrated that the environmental impact of pharmaceuticals is less likely to be taken into consideration in decisions concerning medication used to treat severe diseases (e.g., cancer), with the health of the patient being prioritized. However, when the medication is associated with less severe health conditions, individuals are more willing to weigh both health benefits and environmental risks (Dohle et al., 2013). As such, it is plausible to theorize that pharmaceuticals used to treat severe diseases might be perceived as being more threatening for the environment than pharmaceuticals used for milder health conditions. These associations might be activated when encountering medication from one or the other category and used as a foundation to make risk assessments under uncertainty. Thus, risk assessments might rely on these factors that are not always aligned with the objective environmental risk of pharmaceutical residues. In point of fact, to determine the objective environmental risk, one must consider the PBT criterion, accounting for the chemical composition of the active ingredient. The PBT criterion classifies the environmental risk of each pharmaceutical based on its potential to be persistent in air, water, soil, and sediment (P), its potential for bioaccumulation in aquatic ecosystems (B), and its chronic toxicity to fish (T). A higher PBT classification is associated with a more hazardous active ingredient for the environment (e.g., Li et al., 2020).

The elderly population is known to consume a high quantity of medication daily (Gómez-Canela et al., 2019). Countries worldwide are being affected by population ageing, with projections indicating that this phenomenon will escalate over the coming decades. By 2050, the population aged 65 years or above is expected to reach 16%, almost double the proportion registered in 2019 (United Nations, 2019). In the western world, it is common for the elderly population with some level of impairment and/or health decline to live in care homes for the elderly and nursing homes where they may have access to specialized personal and medical care to live comfortably (Lacorte et al., 2018). As a consequence, these institutions have been emerging in recent years as a critical, urban source of water pollution due to pharmaceutical waste in Southwestern Europe, mainly because: (a) care homes for the elderly tend to cluster in urban areas, (b) these infrastructures accommodate a large number of elderly residents (around 50 to 150), (c) and the elderly are often recipients of polymedication, with a much higher amount in comparison to the healthy population (an average of 5 to 10 pills per day; Gómez-Canela et al., 2019; Lacorte et al., 2018). Pharmaceuticals consumed by the elderly living in care homes are typically released to the sewage network, thus representing a continuous input of pharmaceutical residues in urban wastewater (Gómez-Canela et al., 2019).

Taking these numbers into account, the potential for pharmaceutical waste to reach the environment/urban water sources in these institutions is particularly concerning. Herein, we focus on the dissemination of pharmaceutical residues in wastewater in care homes for the elderly.

1.1. Current Study and Hypothesis

The present study explores the levels of knowledge and environmental risk assessments associated with the presence of pharmaceuticals in the environment (particularly, in urban wastewater). We aim to investigate if people rely on irrelevant criteria to evaluate the environmental risk of pharmaceuticals, namely prescription medication and disease severity.

We included three groups based on their type of contact with pharmaceuticals in care homes for the elderly: health professionals, staff, and residents. Health professionals (e.g., doctors and nurses) are responsible for assessing the health condition of the elderly and/or prescribe the necessary medication, whereas the staff are typically in charge of assisting the elderly in their daily lives, including handling their medication and helping them take it.

We also selected four active pharmaceutical ingredients that had been detected in wastewater in several care homes for the elderly located in Southwestern European countries (Portugal, Spain, and France) and/or classified as hazardous substances (Innovec'EAU, 2018). Of the selected ingredients (see Table 1), two are associated with non-prescribed medication, namely amylmetacresol, used for a milder health condition (e.g., sore throat), and acetylsalicylic acid, used for relatively more severe conditions (e.g., fever). The other two are linked with prescribed medication: lercanidipine is used for milder diseases (e.g., hypertension) and ifosfamide is used to treat diseases often considered more severe (e.g., cancer). Previous studies show that individuals have relatively higher risk perception of the health conditions treated by acetylsalicylic acid and ifosfamide than of the health conditions treated by amylmetacresol and lercanidipine (Camilo & Lima, 2010). Each of these pharmaceuticals has distinctive levels of risk for the environment/urban wastewater, according to their PBT classification (see Table 1). Among non-prescribed medication, amylmetacresol (milder health condition) is more hazardous: it is neither persistent, nor bioaccumulative but it is toxic. Among prescribed medication, lercanidipine (milder health condition) is more hazardous: it is persistent, bioaccumulative and toxic (PBT profiler; Innovec'EAU, 2018).

Initially, we explored if there were differences in risk perception between the groups (health professionals, staff, and residents) from the three countries (Portugal, Spain, France). A previous study by Luís and colleagues (2020) comparing the environmental risk perception of pharmaceuticals between experts and lay people from these countries suggests there might be differences. In particular, lay people from Spain, had lower risk perception than individuals from the other two countries.

Secondly, we explored the levels of perceived current knowledge and the need for more knowledge, while determining the perceived sufficiency of knowledge (low versus high) to adequately deal with this environmental problem. This facilitated the analysis of the effects of prescription medication and disease severity on the assessment of the environmental impact for each pharmaceutical, according to the level of knowledge sufficiency. We expected that in the absence of knowledge about the chemicals PBT classification, individuals will assess the environmental risk based on more salient characteristics of pharmaceuticals: whether they are prescribed or non-prescribed and if they are recommended as a treatment for milder or severe diseases. We also expect that these differences will occur mostly for individuals that present a higher perception of knowledge deficit in comparison to individuals believed to have sufficient knowledge.

Thus, our hypotheses are:

H1: Prescribed pharmaceuticals are perceived to have a higher environmental impact than non-prescribed pharmaceuticals, and this effect will be stronger for individuals with a knowledge deficit.

H2: Pharmaceuticals used to treat relatively more severe diseases are perceived to have a higher environmental risk than pharmaceuticals used for milder health conditions, and this effect will be stronger for individuals with a knowledge deficit.

2. METHOD

2.1. Participants

Three hundred participants were selected from in several care homes for the elderly located in three countries, namely Portugal (33%), Spain (45.7%), and France (21.3%). Eligibility criteria included working or living in the care homes. The majority were female (78.6%), with ages ranging between 18 and 100 years old (M = 52.2, SD = 19.17), of which 15% were health professionals, 44.7% were staff, and 40.3% were residents. In all three groups the sample has more staff than residents, and more residents than experts. A chi-square test indicated that the three groups are not equally distributed in the three countries, $\chi 2(4, N = 300) = 10.13$, p = .038. The main discrepancy is observed in the number of experts per country. In the Portuguese sample the percentage of experts in lower than was expected (6.1% of the Portuguese Sample) and lower than in the other countries (20.4% in Spain and 17.2% in France). On average, health professionals and staff had been working in these residences for eight years (SD = 8.72) and residents had been living there for three years (SD = 3.63) at the time of the study. All the residents had been prescribed with at least one type of medication since relocating to these care homes.

2.2. Procedure and Materials

All participants gave their consent to participate in the study and were informed that their answers were anonymous and confidential. Assurance was also given that they could withdraw (participation and/or data) from the study at any time. Data was collected through written surveys, between March and September 2019, as part of a larger-scale European project. For this study, we used the measures to evaluate environmental knowledge and environmental risk perception of the four active pharmaceutical ingredients. Surveys were completed during break times at the residences. Health professionals and staff answered individually, while the residents had the assistance of a researcher to facilitate their participation and comprehension of the survey. Measures were adapted from the study by Lima and colleagues (2020).

2.2.1. Environmental knowledge

Participants were first informed that "after medication is consumed, pharmaceutical residues can be expelled through urine and feces. A large proportion of these residues are not treated in wastewater treatment plants". Shortly after, they were asked to answer two items to measure their environmental risk knowledge regarding pharmaceuticals in the environment. The first item assessed perceived current knowledge (i.e., "how much do you think you currently know about the risk of water pollution due to excreted pharmaceutical residues"), on a seven-point Likert-type scale, ranging from 1 (I know a lot) to 7 (I do not know). This item was reverse-coded, so that higher values indicate more current knowledge. The second item assessed the need for knowledge in order to properly deal with this environmental crisis (i.e., "how much knowledge do you think you need to adequately address the risk of water pollution due to excreted pharmaceutical residues"), on a scale from 1 (I do not need more knowledge) to 7 (I need a lot more knowledge). Higher values indicate a greater need to have more knowledge. Perceived knowledge and need for knowledge measures had been adapted from Griffin and colleagues (1999) to measure of risk information sufficiency.

We calculated the difference between perceived current knowledge and the need for knowledge, as an indicator of perceived sufficiency of knowledge. The variable varies between -6 and 6. Lower values (closer to -6) indicate that individuals perceive to have a deficit of knowledge, while higher values indicate that individuals feel like they have sufficient knowledge to deal with the risk posed by pharmaceuticals in the environment. The variable was dichotomized on a scale, where 1 corresponds to the deficit of knowledge group (values between -6 and 0) and 2 corresponds to the sufficiency of knowledge group (values between 1 and 6).

2.2.2. Environmental risk perception

Environmental risk perception was measured for each selected active ingredient (amylmetacresol, acetylsalicylic acid, lercanidipine, and ifosfamide). First, participants read a brief description about the prescription condition (prescribed vs. non-prescribed) and the use of the pharmaceutical to treat milder or severe diseases, with a photograph of a commercial product using the active ingredient. Next, they were asked to rate the level of the environmental risk of each active ingredient (e.g., "do you think the presence of acetylsalicylic acid in the environment, due to excretion [urine and feces], presents a high or low risk for the environment"). Items were measured using a seven-point Likert-type response scale, ranging from 1 (low risk) and 7 (high risk). Higher values indicate a higher perception of environmental impact for each active ingredient.

3. RESULTS

A MANOVA was used to compare the three countries under study (Spain, Portugal, and France) and the three groups (health professionals, staff, and residents) on the four dependent measures of risk perception. There were no significant differences between countries regarding risk perception. Respondents from the three countries did not differ in the perception of environmental risk posed by non-prescribed medication for milder health conditions (amylmetacresol), $F(2, 275) = 2.09$, $p = .125$, $\eta^2 = .02$; non-prescribed medication for severe conditions (acetylsalicylic acid), $F(2, 275) = 2.27$, $p = .106$, $\eta^2 = .02$; prescribed medication for milder conditions (lercanidipine), $F(2, 275) = 2.06$, $p = .130$, $\eta^2 = .02$; or prescribed medication for severe conditions (ifosfamide), $F(2, 274) = 1.80$, $= .167$, $\eta^2 = .01$. The perception of risk for non-prescribed medication for severe conditions (acetylsalicylic acid), $F(2, 274) = 3.67$, $p = .027$, $\eta^2 = .03$, prescribed medication for milder conditions (lercanidipine), $F(2, 275) = 7.27$, $p < .001$, $\eta^2 = .05$; or prescribed medication for severe conditions (ifosfamide), $F(2, 274) = 3.05$, $p = .049$, $\eta^2 = .02$, varied as a function of group (health professionals, staff, and residents). However, pairwise comparisons performed with a Scheffe test indicates that only staff differ significantly from residents in the perception of the risk posed by prescribed medication for milder conditions (lercanidipine), 95% *CI* for mean differences [-1.33, -0.32], with staff perceiving a greater risk than residents (see Table 2). The perception of risk of non-prescribed medication for milder health conditions (amylmetacresol) did not differ significantly between groups, $F(2, 274) = 2.51$, $p = .083$, $\eta^2 = .02$.

The interaction between country and group was not significant for non-prescribed medication for milder health conditions (amylmetacresol) and prescribed medication for milder conditions (lercanidipine), $F(4, 274) = 0.33$, $p = .855$, $\eta^2 = .01$, $F(4, 274) = 0.48$, $p = .748$, $\eta^2 = .01$ respectively. However, we found a significant interaction for non-prescribed medication for severe conditions (acetylsalicylic acid) and for prescribed medication for severe conditions (ifosfamide), $F(4, 274) = 3.28$, $p = .012$, $\eta^2 = .05$, $F(4, 274) = 4.71$, $p = .001$, $\eta^2 = .05$ respectively. Spanish residents found the risk of acetylsalicylic acid and ifosfamide to be higher than the Portuguese ($p = .035$, $p = .027$) and French residents ($p = .036$, $p = .003$) (Table 2).

This result suggests there are no large or systematic differences between countries and groups. Nonetheless, there are differences, suggesting that future risk communications should be tailored to be more effective.

3.1 Knowledge on the Environmental Risk of Pharmaceuticals in the Environment

Descriptive analysis revealed that the current knowledge about the environmental impact of pharmaceutical residues was perceived to be low, with a mean result below the scale's median point (M = 2.73, SD = 1.72). This result indicates that participants believed they know very little about the risk that pharmaceuticals hold for the environment/water sources. In contrast, the need for knowledge was high on average (M = 5.38, SD = 1.73), suggesting that participants felt that they needed to learn more about this problem in order to adequately deal with it. One-sample t-tests to assess the differences between current perceived knowledge and need for knowledge for health professionals, staff, and residents, with a test value of zero as baseline, confirmed that all groups felt the need to acquire more knowledge. This need was stronger for the staff group, followed by the residents group. The results are summarized in Table 3.

3.2 The Effect of Prescription of Medication on Environmental Risk Perception

To test the hypotheses according to which, in the absence of knowledge about the pharmaceuticals' PBT classification, individuals would assess the environmental risks based on irrelevant information about the pharmaceuticals, we conducted a three-way repeated-measures ANOVA. The analysis examined the effect of prescription medication (non-prescribed versus prescribed pharmaceuticals, within factor), disease severity (pharmaceuticals used to treat milder versus severe diseases, within factor), and perceived sufficiency of knowledge (deficit versus sufficiency of knowledge) on the perception of environmental risk of pharmaceutical waste. We focused on perceived sufficiency of knowledge and disregarded user type (health professional, staff, resident) to run a more parsimonious model that tested directly the knowledge factor. The results are summarized in Table 4 and Figure 1.

Simple main effects analysis revealed a significant difference between prescribed and non-prescribed pharmaceuticals, $F(1,282) = 80.39$; $p < .000$; $\eta^2 = .22$. We were expecting that prescribed pharmaceuticals would be considered to have a higher environmental impact than non-prescribed, and that this difference would occur mostly in the deficit of knowledge group (H1). To test this hypothesis, we performed planned contrasts via one-way ANOVAs, according to the procedures described by Wiens and Nilsson (2017). H1 was partially corroborated. The results of the analysis indicate that the perception of the impact of prescribed and non-prescribed pharmaceuticals used to treat milder diseases did not differ for individuals with high and low levels of knowledge, $F(1,284) = 0.41$, $p = .523$, 95% CI for mean differences [-0.44,0.23]. In both groups, non-prescribed pharmaceuticals were perceived to have a lower environmental risk than prescribed pharmaceuticals, $M = 3.74$, $SD = 1.68$, $M = 4.28$, $SD = 1.62$ respectively, 95% for mean differences CI [-0.71,-0.38]. Likewise, in the assessment of medication used to treat severe diseases, the perception of the environmental impact of prescribed and non-prescribed pharmaceuticals did not differ for individuals with high and low levels of knowledge, $F(1,287) = 0.46$, $p = .501$, 95% CI for mean differences [-0.54,0.27]. In both groups, non-prescribed pharmaceuticals were perceived to have a lower environmental risk than prescribed pharmaceuticals, $M = 4.52$, $SD = 1.73$, $M = 5.30$, $SD = 1.70$ respectively, 95% CI for mean differences [-0.98,-0.58].

3.3 The Effect of Disease Severity on Environmental Risk Perception

The second hypothesis (H2) was fully corroborated (see Table 4 and Figure 1). We were expecting that pharmaceuticals used to treat severe health conditions would be considered to have a higher environmental impact than pharmaceuticals used for milder conditions, and that this difference would occur mostly in the deficit of knowledge group. Results show that disease severity had a significant main effect, *F*(1,281) = 111.22; $p < .001$; $\eta^2 = .28$. Planned contrasts performed via a one-way ANOVA (Wiens & Nilsson, 2017) demonstrate that the perception of the environmental risk of non-prescribed pharmaceuticals used to treat milder and severe diseases was significantly different for individuals with high and low levels of knowledge, *F*(1,291) = 7.42, *p* = .007, 95% CI for mean differences [-0.89,-0.14]. According to our expectations, pharmaceuticals used to treat milder diseases were perceived as having a lower environmental impact than pharmaceuticals used for severe health conditions. This effect was observed in both levels of knowledge, but it was stronger for individuals with perceived knowledge deficit. In this condition, mean values were *M* = 3.82, *SD* = 1.64 for pharmaceuticals for milder diseases, and *M* = 4.82, *SD* = 1.65 for pharmaceuticals for severe diseases, 95% CI for mean differences [-1.25,-0.76]. For the perceived sufficiency of knowledge group, the mean values were *M* = 3.57, *SD* =1.76 for pharmaceuticals for milder health conditions, and *M* = 4.05, *SD*=1.81 for pharmaceuticals for severe conditions, 95% CI for mean differences [-0.78,-0.20]. A similar effect was observed for prescribed medication. Pharmaceuticals used to treat severe conditions were perceived to have a significantly higher environmental risk than pharmaceuticals used for milder health conditions. Again, this effect was observed in both levels of knowledge, but it was stronger when the perceived knowledge level was lower *F*(1,286) = 7.15, *p* = .008, 95% CI for mean differences [-0.86,-0.14]. In the knowledge deficit group, mean values were *M* = 4.40, *SD* = 1.63 for pharmaceuticals used for milder diseases illness, and *M* = 5.62, *SD* = 1.60 for pharmaceuticals used for severe diseases, 95% CI for mean differences [-1.48,-0.96]. For the perceived sufficiency of knowledge condition, the mean values were *M* = 4.15, *SD* = 1.61 for pharmaceuticals for milder diseases, and *M* = 4.85, *SD* = 1.73 for pharmaceuticals for severe diseases, 95% CI for mean differences [-0.98,-0.46].

4. DISCUSSION

The release of pharmaceutical waste in the environment, particularly in urban water sources, is a pressing global problem that is expected to get worse in the future. Little is known about which factors individuals rely on to assess the environmental risk pharmaceuticals. The aim of the study was to contribute to this area by exploring how key people – health professionals, staff, and residents – in care homes for the elderly assess the environmental risks of four active pharmaceutical ingredients with different profiles: two prescribed and two non-prescribed medications, recommended either for the treatment of milder health conditions or severe diseases.

Data shows low current knowledge and significant need to acquire more knowledge about the environmental risk associated with pharmaceutical residues across all groups. The health professional group presented the lowest need for knowledge despite the observed low levels of perceived current knowledge. Such levels pose a challenge to implemented (or soon-to-be implemented) measures to reduce the presence of pharmaceutical waste in urban wastewater (e.g., care homes for the elderly), as health professionals are responsible for medicating people and, consequently, might play an important role in promoting a prudent use of pharmaceuticals posing a risk to the environment. Additionally, it is likely that, as a result of their professional training, health professionals prioritize health benefits over environmental risks in order to ensure the best treatment for individuals, as found by Dohle and colleagues (2013). However, it should be highlighted that the presence of pharmaceuticals in the environment is not merely an environmental risk but also a public health risk (Khan et al., 2021). In future studies, it would be relevant to understand how to motivate health professionals to further their knowledge regarding the environmental risk of pharmaceuticals. Such action would comply with the European Union Strategic Approach to Pharmaceuticals in the Environment goals to increase awareness and promote prudent use of pharmaceuticals among healthcare professionals (2019, 2020). Indeed, an action plan with recommendations to explore in cooperation with the relevant stakeholders how to include the environmental aspects into medical training and professional development programs has been agreed on. Within this context, health professionals could lead to an increase in demand of greener pharmaceuticals, thereby contributing to supporting the development of pharmaceuticals intrinsically less harmful for the environment and promoting greener manufacturing (European Commission, 2019, 2020).

Conversely, staff and residents presented a lower level of current knowledge and higher need for knowledge. Staff and autonomous residents are responsible for the handling and disposal of the excess medication. It is possible that staff and residents might not engage in more sustainable behavior and/or safer disposal practices because they are unacquainted with the consequences that pharmaceuticals hold for the environment. Though raising the awareness of staff and residents represents only the first step, it is crucial for them to know about the environmental risk of pharmaceuticals and to be motivated to adhere to preventive measures. Staff, in particular, would then be able to take action regarding the disposal of the excess of medication or even pharmaceutical compounds. The residents, as consumers, by asking their doctors for more sustainable medication, might be crucial to bring bottom-up pressure to the prescription (and manufacturing) of greener pharmaceuticals.

As expected, results showed that participants based their risk assessments on irrelevant, easily accessible information: prescription medication (non-prescribed versus prescribed) and disease severity (milder versus severe). In point of fact, these characteristics do not influence the extent to which pharmaceutical waste negatively impacts the environment and cannot be used to effectively determine the environmental risk. However, both factors were important to participants when making these assessments. In concrete, individuals estimated that prescribed pharmaceuticals had a higher environmental risk than non-prescribed and estimated that pharmaceuticals for severe diseases had a higher environmental impact.

We further anticipated that these effects would occur because of the individual's lack of knowledge to adequately deal with the risk of pharmaceuticals in the environment. However, only the severity effect depended on knowledge: it was stronger when the perceived knowledge was lower. The prescription effect was similar for individuals with higher and lower perceived knowledge. This suggests that factors other than knowledge might help explain the prescription effect and that different strategies should be used to raise awareness of pharmaceuticals in the environment. An avenue for future studies would be to confirm and understand why non-prescribed pharmaceuticals appear to be more prone to heuristic-type reasoning (among people with both lower and higher knowledge) and how the prudent use of non-prescribed pharmaceuticals can be better promoted.

The present results should be interpreted with caution considering that, as a correlational study, it is not possible to establish causality, and the samples between groups and countries are not homogeneous. Furthermore, although we followed previous work on the risk perception of diseases to classify the severity of health conditions treated by the pharmaceuticals, and participants were given a brief description of the use of the pharmaceutical to treat milder or severe diseases, we did not check the participants' perception of severity in the present study. Therefore, we cannot rule out alternative explanations. Another limitation is that the presentation order of the four active ingredients was not randomized to facilitate the application of the surveys across countries and groups in accordance with the availability of the participants. Nevertheless, our findings are innovative, and might help prevent and/or reduce the presence of pharmaceutical residues in the environment. The Strategic Approach to Pharmaceuticals in the Environment also aims to raise public awareness and to identify current knowledge gaps and recommend solutions to fill these gaps (European Commission, 2019, 2020). Without knowledge about the risk posed by pharmaceuticals in the environment it is not possible for people to make an informed decision. These results contribute to these goals by identifying two additional informational factors that people are erroneously using to make their judgments on the environmental risk of pharmaceuticals.

There are several actors that can contribute to diminishing the presence of pharmaceuticals in the environment, whether because they might be responsible for prescribing medication, be in charge of disposing of excess pharmaceuticals or by-products (e.g., diapers), or take the initiative to look for greener medication. However, if individuals are not aware of this problem, no action will be taken. Risk communications must take into account that individuals in general do not know much about the environmental consequences of pharmaceuticals in the environment and often rely on information that is not pertinent for risk assessments. It is important to discuss not only how human behavior exacerbates the pollution due to pharmaceutical residues, significantly affecting the environment, but also how irrelevant information can inaccurately influence people's risk perception, leading them to overlook this environmental crisis.

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Table 1

Description of the pharmaceutical active ingredients, prescription conditions, common associated diseases, and Persistence, Bioaccumulation, and Toxicity (PBT profiler, Innovec'Eau, 2018).

	Medication prescription	
Disease severity	*Non-prescribed*	*Prescribed*
	Amylmetacresol	**Lercanidipine**
Mild	Used to treat mouth inflammation and throat infections, including sore throats PBT: not persistent, not bioaccumulative, **toxic**	Indicated for the treatment of hypertension PBT: **persistent, bioaccumulative, toxic**
	Acetylsalicylic acid	**Ifosfamide**
Severe	Used to treat pain, fever, and inflammation PBT: not persistent, not bioaccumulative, not toxic	Indicated for the treatment of several tumors, as chemotherapy PBT: not persistent, not bioaccumulative, **toxic**

Table 2

Perceived of environmental risk per country and group

Group	Medication prescription	Disease severity	Spain M (SD)	Portugal M (SD)	France M (SD)
Health professionals	*Non-prescribed*	*Mild*	3.68 (1.34)	3.50 (1.76)	4.45 (1.37)
		Severe	4.14 (1.35)	3.50 (1.64)	5.09 (1.30)
	Prescribed	*Mild*	4.21 (1.32)	3.67 (1.63)	4.82 (1.67)
		Severe	5.36 (1.37)	5.00 (2.28)	6.18 (1.25)
Staff	*Non-prescribed*	*Mild*	3.82 (1.59)	4.15 (1.41)	4.10 (1.73)
		Severe	4.74 (1.51)	4.61 |(1.45)	4.97 (1.59)
	Prescribed	*Mild*	4.51 (1.55)	4.78 (1.61)	4.87 (1.63)
		Severe	5.23 (1.57)	5.41 (1.38)	5.70 (1.37)
Residents	*Non-prescribed*	*Mild*	3.21 (1.59)	3.53 (2.17)	3.83 (1.85)
		Severe	4.98 (1.87)	3.86 (2.10)	3.70 (1.94)
	Prescribed	*Mild*	3.81 (1.36)	3.69 (2.11)	4.22 (1.45)
		Severe	5.85 (1.50)	4.42 (2.34)	4.57 (1.70)

Table 3

Perceived sufficiency of knowledge to deal with the risk of pharmaceuticals in the environment.

	Mean difference		*t*	95% CI	
	Mean	*SD*		Lower bound	Upper bound
Health professionals	-1.93	2.61	-4.98*	-2.72	-1.15
Staff	-3.01	2.44	-14.20*	-3.43	-2.59
Residents	-2.51	2.71	-10.20*	-2.30	-2.02

*$p<0.05$

Note: Higher absolute values indicate a higher need for knowledge.

Table 4

Effects of prescription medication, disease severity, and perceived knowledge on the environmental risk perception.

Group	Medication prescription	Disease severity	Mean (SD)	Standard error	95% CI Lower bound	95% CI Upper bound
Knowledge deficit	*Non-prescribed*	*Mild*	3.83 (1.64)	0.13	4.55	5.08
		Severe	4.81 (1.65)	0.13	3.57	4.09
	Prescribed	*Mild*	4.43 (1.62)	0.13	4.18	4.68
		Severe	5.66 (1.56)	0.13	5.41	5.91
Knowledge sufficiency	*Non-prescribed*	*Mild*	3.65 (1.72)	0.15	3.83	4.43
		Severe	4.13 (1.61)	0.15	3.35	3.95
	Prescribed	*Mild*	4.12 (1.60)	0.15	3.84	4.41
		Severe	4.84 (1.73)	0.15	4.55	5.13

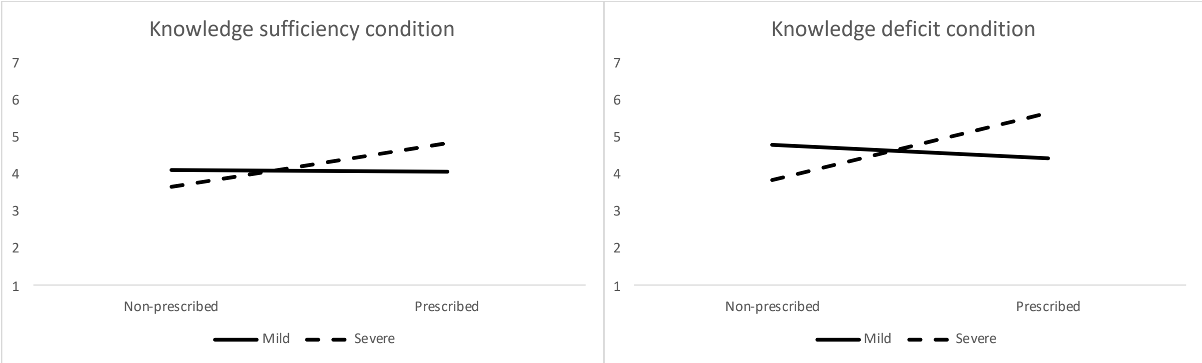

Figure 1

Perception of environmental risk associated to medication: mean results by type of prescription, severity of the disease and knowledge group.