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

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ABSTRACT

Recent water analysis performed in senior residences showed high levels of water pollution due to pharmaceutical waste. The way people perceive pharmaceuticals' environmental risk can contribute to reverse this problem, but it is still relatively unknown which factors influence their perception. The present study is two-fold. We first focused on exploring the levels of knowledge regarding environment/water pollution due to pharmaceutical residue of the groups responsible for prescribing (health professionals), handling (staff), and consuming pharmaceuticals on a daily basis (seniors) in senior residences. Secondly, we assessed their environmental risk perception of four pharmaceutical 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 vs. sufficiency of knowledge). Data was collected in multiple senior homes located in three Southwestern European countries – Portugal, Spain, and France ($N=300$), using self-report surveys. Results show that across all groups, current knowledge was perceived to be low and the need to know more was perceived to be high. Results further indicate that participants made use of irrelevant information to assess the environmental risk of the pharmaceuticals. Prescribed pharmaceuticals and/or medication used to treat severe diseases were perceived as being more hazardous for the environment. Moreover, only for disease severity did this effect occur mostly in the deficit of knowledge group. These misconceptions might discourage stakeholders to take a more active role in reducing the impact of pharmaceutical residues in the environment/water sources, causing them to overlook this crisis.

Keywords: environmental risk perception, pharmaceutical residues, water pollution, prescription medication, disease severity

1. INTRODUCTION

The dissemination of pharmaceutical residues in the environment has become a major crisis in recent years, contributing to the pollution of water sources worldwide. Traces of such residues have been found in surface and ground waters, wastewaters and, to a lesser extent, in drinking water (World Health Organization, 2012). Conventional water treatments do not 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 (WWTPs) particularly challenging (Li et al., 2020; Quesada et al., 2019). As such, pharmaceutical waste is frequently released alongside with treated water into water canals (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. Regardless, 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 particular for human health, the prolonged exposure to these residues can increase resistance to antibiotics and create endocrine disruption effects (Palma et al., 2020).

With water scarcity being a recurrent 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. The 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 pharmaceuticals' environmental risk, in

an often overlooked source of water pollution due to pharmaceutical residue, that is, senior residences.

Given the health benefits, taking medication is part of a great number of people's daily routine. In Europe, approximately 5000 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 next decades (Gómez-Canela et al., 2019), mostly due to the growing burden of treatments for chronic diseases, as well as the increase in life expectancy and elderly population around the world (Quesada et al., 2019). The higher the consumption levels, the more likely for the pharmaceutical residues to pollute the environment and reach different water sources. Other influencing factors like 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 observed increase in consumption (Quesada et al., 2019). In fact, it is not uncommon for people to purchase medication and have leftovers stored in their households. In recent studies, 61% (Vatovec et al., 2017) and 75% (Chung et al., 2019) of the participants reported having unwanted and unused leftover pharmaceuticals at home, including both prescribed and over-the-counter medication (Chung et al., 2019; Vatovec et al., 2017). This excess of pharmaceutical leftovers often results from actions like 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 conducted 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 wastewaters 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 behaviors. Kotchen and colleagues (2009) found that only 43% of the participants knew that pharmaceutical residues can be found in wastewaters and surface waters. 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 leftovers in the trash, sink, or toilet) and three times more likely to choose ecofriendly 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 the water pollution due to the presence of pharmaceutical residues in the environment. Yet, little is known about which factors influence people's perception of pharmaceuticals' environmental risk.

Previous research conducted in Southwestern Europe 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 knowledge in order to properly deal with the health and environmental risks imposed by this presence. In Lima and colleagues' study (2020), despite the lack of knowledge, participants still managed to assess the environmental risks and presented medium to high risk perceptions that were based in 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 under uncertainty, 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 recent study by Luís and colleagues (2020) demonstrated that experts showed higher levels of risk perception when assessing the negative impact that pharmaceutical waste hold for the environment than lay people.

When thinking about medication, individuals tend to focus on more immediate and accessible information that might influence their judgements, 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 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 as treatment. 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 pharmaceuticals' risks and benefits is likely to be influenced by the degree 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. Complementary, 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 unconsciously 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 (P), bioaccumulative (B), and toxic (T) for the environment/water sources, as these are considered intrinsic properties of pharmaceutical compounds. A higher PBT classification is associated with a more hazardous active ingredient for the environment (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 next decades. By 2050, the population aged 65 years or above is expected to reach 16%, almost double of 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 senior residences and nursing homes where they can 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) senior residences tend to cluster in urban areas, (b) these infrastructures accommodate a large number of elderly residents (around 50 to 150 seniors), (c) and elders are often subject 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 elders living in senior residences are typically released to the sewage grid, thus representing a continuous input of pharmaceutical residues in urban wastewaters (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 wastewaters in residences for the elderly population.

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

wastewaters). We aim to investigate if people rely on irrelevant criteria to evaluate pharmaceuticals' environmental risk, namely prescription medication and disease severity.

We included three groups based on their type of contact with pharmaceuticals in senior residences: health professionals, staff, and senior residents. Health professionals (e.g., doctors and nurses) are responsible for assessing elders' health condition and/or prescribe the needed medication, whereas the staff is typically in charge of assisting the seniors in their daily lives, including handling and helping them take their medication. We also selected four active pharmaceutical ingredients considering the higher residual levels detected in wastewaters in multiple senior residences located in Southwestern European countries. 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). Each of these pharmaceuticals have distinctive levels of risk for the environment/urban wastewaters, according to their PBT classification. Specifically, between non-prescribed medication, amylmetacresol (milder health condition) has a higher PBT risk than acetylsalicylic acid (severe health condition). For prescribed medication, lercanidipine (milder health condition) is more hazardous for the environment than ifosfamide (severe health condition; Innovec'EAU, 2018).

First, we explore the levels of perceived current knowledge and need for more knowledge and determine the perceived sufficiency of knowledge (low versus high) to adequately deal with this environmental problem. Secondly, we analyze the effects of prescription medication and disease severity on the assessment of the environmental impact for each pharmaceutical, according to the level of sufficiency of knowledge. We expect that in the

absence of knowledge about the active ingredients' chemical composition, individuals will assess its' environmental risk based on irrelevant characteristics that do not influence it, for instance, whether they are prescribed or non-prescribed pharmaceuticals 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 that believe to have sufficient knowledge.

Thus, our hypotheses are:

H1: Prescribed pharmaceuticals are perceived to have a higher environmental impact than non-prescribed pharmaceuticals, particularly in the deficit of knowledge group.

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 recruited in multiple senior residences located in three countries, namely Spain (45.7%), Portugal (33%), and France (21.3%). Eligibility criteria included working or living in senior residences. 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. On average, health professionals and staff had been working in these residences for eight years ($SD=8.72$) and seniors had been living there for three years ($SD=3.63$) at the time of the study. All the senior residents had been prescribed with at least one type of medication since relocating to these residences.

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 paper surveys, as part of a large-scale Southwestern Europe project. For this study, we used the measures to evaluate environmental knowledge and environmental risk perception regarding the potential of each selected active ingredient to have a negative impact in the environment/urban wastewaters. Surveys were completed during break times at the senior residences. Health professionals and staff answered individually, while seniors had the assistance of a researcher to facilitate their participation and comprehension of the survey. Measures were adapted from Lima and collaborators' study (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 WWTPs”. Shortly after, they were asked to answer two items to measure their environmental risk knowledge regarding pharmaceutical waste. 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.

We calculated the difference between perceived current knowledge and 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. 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, namely 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 (see Table 2). 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

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 to 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 senior residents, with a test value of zero as baseline, confirmed that all groups felt the need to acquire more knowledge. This need was, however, stronger for the staff group, followed by the senior residents' group. The results are summarized in Table 2.

There were no significant differences between the three Southwestern Europe countries under study (i.e., Spain, Portugal, and France) regarding risk perception, as determined by a one-way ANOVA. Country groups did not differ in the perception of environmental risk posed by non-prescribed medication for milder health conditions (amylmetacresol), $F(2, 281)=2.09$, $p=.125$, $\eta^2=.02$; non-prescribed medication for severe conditions (acetylsalicylic acid), $F(2, 281)=2.11$, $p=.111$, $\eta^2=.02$; prescribed medication for milder conditions (lercanidipine), $F(2, 281)=1.75$, $p=.176$, $\eta^2=.01$; or prescribed medication for severe conditions (ifosfamide), $F(2, 281)= 2.74$, $p=.066$, $\eta^2=.02$.

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. The results are summarized in Table 3 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, $F(1,284)=0.41$, $p=.523$, $95\%CI[-0.44,0.23]$. 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, $95\%CI[-0.71,-0.38]$. 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, $F(1,287)=0.46$, $p=.501$, $95\%CI[-0.54,0.27]$. 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, $95\%CI[-0.98,-0.58]$. The second hypothesis (H2) was fully corroborated. 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, $F(1,291) = 7.42$, $p = .007$, $95\%CI[-0.89,-0.14]$. 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[-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[-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[-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[-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[-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 pharmaceuticals' environmental risk. The aim of the study was to contribute to this area by exploring how key people – health professionals, staff, and seniors - in senior residences assess the environmental risks of four active pharmaceutical ingredients with different profiles: two prescribed and two non-prescribed medication recommended either for the treatment of milder health conditions or severe diseases.

Data shows low current knowledge and high 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 wastewaters (e.g., senior residences), as health professionals are responsible for medicating people and, consequently, play an important role in which and how many pharmaceuticals are going to be consumed by a single person. Additionally, it is extremely likely that they prioritize health benefits over environmental risks in order to ensure the best treatment for seniors and promote their health, which is congruent with Dohle and colleagues' findings (2013). This result might also help explain why health professionals do not attempt to look for better alternatives that could attenuate this environmental crisis. In future studies, it would be relevant to better understand why health professionals do not appear to be as motivated to further their knowledge regarding pharmaceuticals' environmental risk. A shift in their perception could result in them actively looking for alternative medication that provides identical health results with a lower environmental impact. Such action would comply with the European Union Strategic Approach to Pharmaceuticals in the Environment goal to ensure that new medicine options, more environmentally-friendly, are just as effective and safe for humans than the ones previously used as treatment (European Commission, 2019). Conversely, staff and senior residents present a lower level of current knowledge and higher need for knowledge. Staff is responsible for handling and disposing the excess of medication, including assisting seniors in taking the right dosage and on time. It is possible that staff might not engage in more sustainable behaviors and/or safer disposal practices because they are unacquainted with the consequences that pharmaceuticals hold for the environment/water sources, and the same effect might be happening for senior residents. Though educating staff and seniors represents only the first

step, it is crucial to for them to fully comprehend which characteristics determine 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 (e.g., found in seniors' diapers). Moreover, as regular consumers, the senior residents have the potential to initiate a bottom-up approach that could have a positive impact in two ways. By asking their doctors for more sustainable medication, they are acting as an advocate for this environmental crisis raising health professionals' awareness, but they are also giving themselves the opportunity to actively work towards prevention.

As expected, results also show that participants based their risk assessments on irrelevant, easily accessible information, such as 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 water sources and cannot be used to effectively determine its' environmental risk. However, both factors were equally important to participants when making these assessments.

In particular for prescription medication, participants did perceive prescribed medication to have a more hazardous impact on the environment/water sources, but their risk assessments did not vary according to their level of knowledge (low versus high), partially corroborating H1. The opposite effect was observed for disease severity, as H2 was fully corroborated. Medication used for severe diseases was considered to pose a higher risk for the environment/water sources, but this effect was stronger for individuals with a deficit of knowledge. Overall, this finding is aligned with Lima and collaborators' study (2020), suggesting that despite the lack of knowledge, individuals are still able to make their risk assessments. For health professionals specifically, considering their education and work

requirements, it is plausible to assume that they are required to know more about the technical information about each medication, making this information more salient to them. Besides, they may lack specific training about the environmental impact of pharmaceuticals, thus relying more in their area of expertise to make risk assessments. This pattern was also observed in Luís and collaborators' study (2020).

Furthermore, disease severity revealed a higher explanatory effect, indicating that participants could infer more effortlessly about the health condition than the prescription conditions of the medication. This notion is consistent with data reported by Lewith and Chan (2002), as the severity of the disease is prioritized when evaluating different types of medicine and is taken into account in people's choice of medication. Future research should explore the effects of demystifying these factors.

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. To facilitate the application of the surveys across countries and groups, the presentation order of the four active ingredients was not randomized, which should be considered as a limitation of the study. Nevertheless, our findings can be groundbreaking, and help prevent and/or reduce the presence of pharmaceutical residues in the environment at a key source, that is, unsustainable human behavior. Another main goal of the recently proposed Strategic Approach is to identify current knowledge gaps and recommend solutions to fill in these gaps (European Commission, 2019). These results contribute to this goal by identifying two additional informational factors that people are instinctively and erroneously using to make their judgements on pharmaceuticals' environmental risk. Additionally, they also highlight the importance to continue evaluating environmental risk perception as a way to understand how much people actually know about this topic. Without knowledge about the objective impact of pharmaceutical waste (i.e., PBT classification), is it

not possible for people to make an informed decision. Besides, knowing which and how psychosocial factors might influence people's willingness and motivation to select more environmentally-friendly medication, or even to engage in risk mitigating behaviors regarding pharmaceuticals leftovers in a non-harmful way for the environment, is equally important.

There are several stakeholders in this field whose behavior can help reverse this trend, whether because they are responsible for prescribing medication, in charge of disposing of excess pharmaceuticals or by-products (e.g., diapers), or can take the initiative to look for more sustainable, non-prescribed medication. Some may even have the power to advocate against high environmental impact pharmaceuticals and pressure the industry to take the environmental impact more into consideration. However, if people are unfamiliar with this impact or even assess it incorrectly, no action will be taken. Risk communications must take into account that people do not seem to know much about the environmental consequences of pharmaceuticals' consumption 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, making them overlook this environmental crisis. A starting point for future interventions would be to educate people that work or live in senior residences and nursing homes given their role as a critical source of water pollution due to pharmaceutical residues in urban areas.

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Table 1

Pharmaceutical active ingredients description, prescription conditions, and common associated diseases

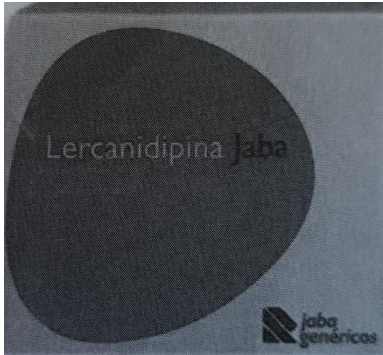
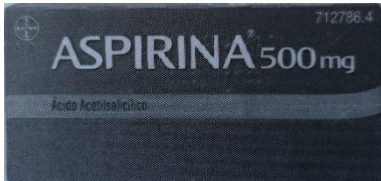
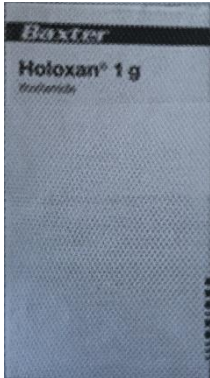
Medication prescription		
Disease severity	Non-prescribed	Prescribed
Mild	Amylmetacresol: used to treat mouth inflammation and throat infections, including sore throats 	Lercanidipine: indicated for the treatment of hypertension 
Severe	Acetylsalicylic acid: used to treat pain, fever, and inflammation 	Ifosfamide: indicated for the treatment of several tumors, as chemotherapy 

Table 2

Differences between current perceived knowledge and need for knowledge on pharmaceuticals' environmental risk perception

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

* $p < 0.05$

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

Table 3

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	Upper bound
Knowledge deficit	<i>Non-</i>	<i>Mild</i>	3.83 (1.64)	0.13	4.55	5.08
	<i>prescribed</i>	<i>Severe</i>	4.81 (1.65)	0.13	3.57	4.09
	<i>Prescribed</i>	<i>Mild</i>	4.43 (1.62)	0.13	4.18	4.68
		<i>Severe</i>	5.66 (1.56)	0.13	5.41	5.91
Knowledge sufficiency	<i>Non-</i>	<i>Mild</i>	3.65 (1.72)	0.15	3.83	4.43
	<i>prescribed</i>	<i>Severe</i>	4.13 (1.61)	0.15	3.35	3.95
	<i>Prescribed</i>	<i>Mild</i>	4.12 (1.60)	0.15	3.84	4.41
		<i>Severe</i>	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

