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Lay people and experts' risk perception of pharmaceuticals in the environment in Southwestern Europe

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This study aims to contribute to the risk management of pharmaceuticals in the environment, illustrating risk perceptions of lay people and experts from Southwestern Europe (Portugal, Spain, and France). The psychometric paradigm was applied to assess risk regarding four hazards: pharmaceuticals in the environment (i.e., broadly framed), pharmaceuticals in treated wastewater, pharmaceuticals in drinking water, and pharmaceuticals in crops. Two factors explained most of the variance of risk assessments: dread and unknown. The dread factor combined immediacy and severity of effects, and the old nature of hazards. Pharmaceuticals in crops and drinking water scored higher in this factor, as did experts and French respondents. The unknown factor differentiated between the assessments of lay people and experts. Lay people assessed the hazards as being more known by those who were exposed but less known by science; and exposure was perceived as more voluntary and the risk as more controllable. Even though pharmaceutical residues are present in much higher concentrations in treated wastewater, risk assessments were overall higher for drinking water and crops. Moreover, data also revealed risk management preferences: whereas lay people preferred technological and awareness-type measures, experts preferred measures to improve the disposal of pharmaceutical waste and health-type measures.

1. Introduction

The presence of pharmaceuticals in the environment is a problem of increasing concern and likely to be amplified in the future (Lacorte et al., 2017). The goal of this work is to contribute to risk communication and management strategies by 1) illustrating the risk assessments of lay people and experts from three Southwestern European countries of pharmaceuticals in the environment, pharmaceuticals in treated wastewater, pharmaceuticals in drinking water, and pharmaceuticals in crops and 2) exploring which measures are preferred to reduce the presence of pharmaceuticals in the environment.

1.1. Pharmaceuticals in the environment: risk analysis

The pharmaceutical industry developed rapidly and continuously after World War II, having had a huge impact on public health. A collateral effect of this development was the contamination of aquatic environments, which are nowadays the receptacle of mixtures of drugs that are continuously released into them on a global scale (Boxall, 2004).

Caldwell (2015) suggests that the vast majority of pharmaceuticals found in water systems are the result of their consumption and excretion into sewer and wastewater treatment systems. Given the widespread consumption of pharmaceuticals in developed countries, it is likely that pharmaceutical residues are present in the wastewater of all households where individuals consume pharmaceuticals. The second major

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pathway is through the improper disposal of unused or expired medicines by consumers who flush them down toilets or pour them into drains (Caldwell, 2015). Although there are indicators of the amount of pharmaceuticals that individuals separate and return to the pharmacies, the extent of improper disposal of unused medicines is currently unknown and it might represent between 5% and 10% of the pharmaceuticals in the environment. The third major pathway is through wastewater discharged from manufacturing sites (Caldwell, 2015).

Pharmaceuticals are just partially removed in typical wastewater treatment processes rendering their fate clearly of importance (Nassiri Koopaei and Abdollahi, 2017). Studies suggest that approximately 10% of the human pharmaceutical products that have been investigated so far pose an environmental risk. Examples are the morphological and reproductive changes in some species of fish due to the presence of oestrogens in water (e.g., Green et al., 2015). As far as adverse impacts on human health (via the environment) are concerned, various studies indicate that these are very unlikely from direct exposure to trace concentrations of pharmaceuticals that could potentially be found in drinking water (see World Health Organization, 2012) and crops (Wu et al., 2015). The data available indicates that the concentrations of pharmaceuticals in surface water and groundwater sources impacted by wastewater discharges are typically less than 0.1 µg/l, which is the European Medicines Agency threshold for risk evaluation of pharmaceuticals in surface waters. Concentrations in drinking water are generally lower, below 0.05 µg/l (World Health Organization, 2012). Pharmaceuticals reach crops through the application of biosolids or irrigation with treated wastewater (e.g., Wu et al., 2015). There are fewer studies in this area, but studies suggest that crops, such as corn, lettuce, potato, cabbage, green onion, or radish, might uptake pharmaceuticals through roots and accumulate them in different concentrations (usually low) and have negative effects on crops growth (Al-Farsi et al., 2018; Wu et al., 2015).

Although the concentration of pharmaceuticals is typically not high in drinking water and crops, researchers highlight that there are many uncertainties and knowledge gaps. The presence and effects of transformation products, metabolites, the interaction effects between pharmaceuticals, and the effects of chronic exposure in ecosystems and for human health are not yet known. Lastly, it is important to note that this risk will likely be amplified due to the increase of population and life expectancy (Lacorte et al., 2017), and due to water scarcity (Nassiri Koopaei and Abdollahi, 2017). Elderly people usually consume a higher diversity and quantity of pharmaceuticals. Water scarcity will lead to higher concentration of pharmaceuticals in drinking water and will increase the need to use treated wastewater. Indeed, the use of treated wastewater has been identified as one of the ways of addressing water demands. Treated wastewater might become a water source for food production and human usage. However, many contaminants, such as pharmaceutical residues, might be present in treated wastewater, and their risks are not yet well-known (Nassiri Koopaei and Abdollahi, 2017).

Therefore, precautionary management action has been set into motion to reduce the release of pharmaceuticals into the environment (Kümmerer, 2010) and the European Commission recently developed a strategic approach to pollution from pharmaceutical substances (2019).

1.2. *Pharmaceuticals in the environment: risk perception*

The presence of pharmaceuticals in the environment is an emergent risk. Studies indicate lack of public knowledge on this issue and on the proper disposal of unused pharmaceuticals (e.g., AlAzmi et al., 2017; Bound et al., 2006). The need for caution in introducing measures that interfere with health issues is frequently emphasised (e.g., Dohle et al., 2013; Götz et al., 2019). For example, Dohle et al. (2013) have experimentally demonstrated that, when balancing human health and the environment, people considered that the patient's health should be considered first, particularly for severe diseases. Research has also

focused on the public awareness of pharmaceuticals in drinking water in particular. It is assumed that, even if pharmaceutical residues are present in very low concentrations and might not pose a high risk to human health, their presence influences people's perception of water quality (Hartmann et al., 2018; Schriks et al., 2010).

Research with experts (e.g., health professionals, industry, researchers, decision makers) has been conducted to evaluate the role they might have in encouraging the proper use and disposal of pharmaceuticals, and to investigate which paths of risk assessment and management are preferred. For instance, Abahussain et al. (2012) assessed the perceptions and practices of disposal by pharmacists in Kuwait and illustrated their willingness to implement collection schemes.

Regarding risk management strategies, Doerr-MacEwen and Haight (2006) described that experts from Canada, USA, and Europe generally believed that pharmaceuticals in the environment represented a concern for both human and ecosystem health, although they were more concerned about impacts on aquatic ecosystems. They further believed that advanced wastewater treatment technology, education of medical professionals to reduce overprescription, pharmaceutical-return programs coupled with public education, and requirements for all municipalities to have a minimum of secondary wastewater treatment were the most effective management strategies to reduce the environmental impacts of pharmaceuticals. Götz et al. (2019) work illustrated that experts from UK, Hungary, and Germany perceived pharmaceutical residues as an environmental risk. Whether or not they perceived it as a risk to human health varied from country to country.

1.2.1. *Psychometric paradigm*

The main goal of this study is to describe and compare risk assessments of lay people and experts on pharmaceuticals in the environment. We followed on the psychometric paradigm (Fischhoff et al., 1978), which is a classic approach in risk perception that aims to unveil the factors that determine risk perception. It is assumed that risk is subjectively defined by individuals, reflecting a wide array of psychological, social, institutional, and cultural factors that can be quantified using an appropriate psychometric survey method. Nine characteristics are gathered to explain risk perception, such as the dread associated with a given hazard. Empirical data (Fischhoff et al., 1978) showed that, when the risk characteristics of different activities and hazards were factor-analysed, two major factors (dread and unknown) accounted for most of the variance emerged, and that these factors predicted individual risk perception. The more dreadful and unknown a risk or technology is, the more people should oppose it, request for its mitigation, or act in order to mitigate risk. Although there are some criticisms to this approach that need to be taken into account (see Sjöberg et al., 2004), the psychometric paradigm has been validated many times, and risk perception is usually well explained by the aforementioned factors. In addition, as Clahsen and colleagues suggest (2019), this paradigm allows analysing whether there are significant differences in societal risk perceptions that might be related to differences in decision making processes among countries.

Slovic et al. (1979) suggested there are differences between lay people's and experts' assessments. They showed that, when experts judged risk, they did so in a narrow way and their responses were highly correlated with technical estimates of annual fatalities, whereas lay people's responses were correlated with the factors of the psychometric paradigm. However, posterior studies indicated that experts' ratings were explicable by the psychometric model characteristics in a manner similar to those of other respondents (Sjöberg, 2002). Differences emerged only when experts assessed the specific risks they were responsible for assessing or managing. As the presence of pharmaceuticals in the environment poses risks across different topics (e.g., pharmacy, water, agriculture, environmental health), the psychometric paradigm should be useful to illustrate the assessments of the different experts.

It is important to say that the study of divergences between experts

and lay people (e.g., Sjöberg, 1998) created a debate about the appropriateness of using expert evaluations alone for policy decisions, which usually follows the risk assessment paradigm that clearly distinguished between technical risk assessment and risk management (e.g., as originally outlined by the U.S. National Research Council, 1983). However, many studies illustrate that the engagement of the public and stakeholders in all phases of decision-making is not only a democratic right but also improves the quality of the processes (e.g., Luís et al., 2018; Luís et al., 2015; Mata et al., 2006).

1.3. The current study

The European Commission Directive 2008/105/EC (amended by Directive, 2013/39/EU) obliged the development of a strategic approach to pharmaceuticals in the environment that was finalized in March 2019 and identifies six action areas concerning all stages of the pharmaceutical life cycle, where improvements can be made. The main goal of this study is to contribute to the successful implementation of this strategy by describing and comparing perceptions towards risk and risk management measures of lay people and experts from three southwestern European countries on four hazards of pharmaceuticals in the environment. The nature of the study is mostly descriptive and exploratory. Nonetheless, we have some expectations that are described in the sections below.

1.3.1. Lay people and experts

Lay people, i.e. the public in general, and experts are expected to have different risk assessments of pharmaceuticals in the environment. Pharmaceuticals started being massively used after World War II, and their presence in the environment was acknowledged by researchers back in the 70s (e.g., Tabak and Bunch, 1970). However, this issue has only recently been recognized by institutions and publicly discussed, and most lay people are not aware of this risk (Götz et al., 2019). The effects of pharmaceuticals in the environment are also delayed in time. This might cause additional difficulties in recognising them because the association between the initial events (use/disposal of pharmaceuticals) and their delayed effects (e.g., alterations in fish, antibiotic resistance) is not immediate.

Experts should be knowledgeable of their field of expertise and have more scientific and technological literacy than lay people in general. As such, their assessments of risk should be higher overall, and they should differentiate more between the hazards related to pharmaceuticals in the environment than lay people.

1.3.2. Pharmaceuticals in the environment, treated wastewater, drinking water, and crops

We explored whether there could be differences in targeting a more general hazard (pharmaceuticals in the environment) or specific hazards (pharmaceuticals in treated wastewater, drinking water, crops).

Pharmaceuticals in the environment is an emerging and complex theme. Framing it in a general manner does not direct individuals to concrete hazards and, therefore, individuals might not understand it and underestimate its risk. Regarding the three specific hazards, the paths through which pharmaceutical residues can pose a risk to the environment and to health is more intuitive for drinking water and crops than for treated wastewater. The fate and uses of treated wastewater appear to be disconnected from people and their environment because people do not engage physically or mentally with the management of their excretions, particularly in urban developed contexts (del Carmen Morales et al., 2014). As such, people might also underestimate this hazard. To sum up, even though pharmaceutical residues tend to be present in much higher concentrations in treated wastewater than in drinking water and crops, we expected risk assessments to be higher for drinking water and crops than for treated wastewater and pharmaceuticals in the environment in general.

1.3.3. Portugal, Spain, and France

We explored the risk assessments of people from three countries of Southwestern Europe that share borders: Portugal, Spain, and France. The strategic approach to pharmaceuticals in the environment (European Commission, 2019) outlines a set of actions addressing the multifaceted challenges that the release of pharmaceuticals poses to the environment. It identifies six action areas concerning all stages of the pharmaceutical life cycle, where improvements can be made, including actions such as raise awareness and promote prudent use, improve training and risk assessment, gather monitoring data, incentivise “green design”, reduce emissions from manufacturing, reduce waste and improve wastewater treatment. As such, it is important to assess how experts and lay people of the three countries perceived different types of measures.

The risk management strategies that have already been implemented relate mostly to the proper disposal of pharmaceutical waste. Directive 2004/27/EC (relating to medicinal products for human use) introduced an obligation to implement appropriate collection schemes for unused pharmaceutical products destined for human consumption. However, this directive did not provide any guidelines on the implementation of those schemes and a few studies have pointed to significant differences between countries. Although the consumption of pharmaceuticals in Portugal, Spain, and France illustrates a similar pattern (Eurostat, 2014a, 2014b), there are differences in the amount of pharmaceutical waste that is returned to pharmacies to be recycled. Indicators from 2017 showed that people in France returned more pharmaceuticals (164 g per capita, CYCLAMED, 2017) than people in Spain and Portugal (92 g per capita, SIGRE, 2017; VALORMED, 2017). It is possible that differences in the amount of pharmaceutical waste returned to pharmacies are related to differences in risk assessments of pharmaceuticals in the environment. In this vein, people from France should assess higher risk than people from Portugal and Spain. However, it should be noted that the amount of pharmaceutical waste might be a crude indicator of societal differences in risk assessments. As such, the study of differences between countries was mostly exploratory.

2. Method

2.1. Participants

The sample of lay people was recruited using the online platform Qualtrics Panels. Five hundred and nine participants from Portugal (30.8%), Spain (35.6%), and France (33.6%) responded to the survey. Respondents provided their informed consent to participate in the research and were paid for their participation. The sample was recruited aiming for similar quotas for sex (50.7% were female), age groups (30.5% were between 18 and 29 years old; 26.3% were between 30 and 49 years old; 29.1% were between 50 and 64 years old; but only 14.1% were more than 65 years old), and educational level (33.6% had lower education; 33.8% had medium education; and 32.6% had higher education). To increase the representativeness of the sample in respect to these characteristics, we weighted the data of each country for sex, age groups, and education, based on the Eurostat information for the population. All analyses were conducted with weighted data.

The survey was disseminated through experts using a mixed strategy approach. Experts were invited to respond through addressed e-mails, mailing lists, and by telephone. Respondents' anonymity was safeguarded to increase the response rate. Experts from all three countries on the following topics were approached: environmental health agencies, public health agencies, government agencies for pharmaceuticals, government agencies for the environment, health professionals, pharmacy, industry, academia, and also from non-governmental agencies and associations. Therefore, the sample of experts includes not only experts on pharmaceuticals in the environment but also experts on the topics that cross this thematic and therefore should be involved in the risk management processes. One-hundred and fifty experts

responded: 24.7% from Portugal, 48% from Spain, and 27.3% from France. Respondents provided their informed consent to participate in the research. Most of the experts were female (64.6%), middle-aged (29.4% were between 18 and 29 years old; 44.4% were between 30 and 49 years old; 24.6% were between 50 and 64 years old; 1.6% were more than 65 years old), and practically all had a higher educational level (0.8% had medium education level).

2.2. Procedure and materials

2.2.1. Questionnaire

The survey assessed characteristics of the psychometric approach, environmental and health risk perception towards pharmaceuticals in the environment, wastewater, drinking water, crops, and the perceived effectiveness of measures to mitigate pharmaceuticals in the environment.

Using the psychometric paradigm (e.g., Fischhoff et al., 1978), individuals were asked to rate the risk of pharmaceuticals in the environment, wastewater, drinking water, and crops, in scales pertaining to psychometric characteristics, which ranged from 1 to 7. The chronic vs. catastrophic potential of the risk was not assessed because pre-tests alerted that individuals perceived that this question was irrelevant and, therefore, its inclusion could diminish the face validity of the survey.

Risk magnitude was assessed as an indicator of risk perception. It was measured by asking the level of risk for the environment and for health of pharmaceuticals in the environment, wastewater, drinking water, and crops, using a 7-point scale ranging from 1 (very low) to 7 (very high).

To assess which measures individuals perceived as contributing most effectively to reducing pharmaceutical residues in the environment, individuals were asked to choose 4 out of 10 measures. This measure follows on the work of Götz et al. (2019) that considered 10 measures that we classified in 4 types: awareness, regulations, technological, health area.

3. Results

3.1. Psychometric paradigm

We entered the psychometric characteristics in a principal component analysis. Risk assessments of pharmaceuticals in the environment, in treated wastewater, in drinking water, and in crops were pooled across type of respondent (lay people and experts) and country (Portugal, Spain, and France). Data was adequate for analysis: the Kaiser-Meyer-Olkin measure was above 0.60, Bartlett's test of sphericity was significant, and communalities values ranged between 0.64 and 0.90. Two factors explaining 76.04% of variance emerged and were labelled based on the psychometric approach tradition (Table 1).

Factor 1, dread, combined the immediacy of the effect of the risk, the

Table 1

Factor Loadings and Eigenvalues based on a Principal Component Analysis with Varimax Rotation.

Psychometric characteristics	Factor Loadings	
	Dread	Unknown
Immediacy of effect (immediate/delayed)	-.92	.24
Nature of risk (common/dread)	.88	-.02
Severity of consequences (no fatalities/fatalities)	.77	-.20
Newness of risk (new/old)	.68	.53
Known by exposed (known/not known)	-.12	.94
Voluntariness of risk (voluntary/involuntary)	-.40	.82
Known by science (known/not known)	-.23	-.73
Control over risk (uncontrollable/controllable)	.46	-.71
Eigenvalues	3.69	2.40
% of variance	46.08	29.96

Note: Variables range between 1 and 7. Factor loadings over 0.50 appear in bold.

dreadful nature of the risk, the severity of the consequences, and the relative old nature of the risk, explaining 46% of data variance. This last characteristic, old nature of the risk, was also described by Factor 2. Factor 2, unknown, combined lack of knowledge by those exposed to risk, involuntariness of risk exposure, no personal control over risk, and, unexpectedly, knowledge on behalf of science, accounting for 30% of data variance. The factorial analytical representation is shown in Fig. 1.

3.1.1. Lay people and experts

As expected, the risk assessments of experts were overall higher than those of lay people. In the upper right of Fig. 1, which indicates the highest scores in both factor dread and factor unknown, only the scores of experts are represented. Oppositely, in the lower left of the Figure, which indicates the lowest scores in both factor dread and factor unknown, only the scores of lay people are represented.

Experts had also more differentiated assessments than lay people, but only in the dread factor. In this factor, the range of the assessments of experts was much wider than the range of the assessments of lay people (respectively, the range of the scores were 4.00 and 1.11; the difference between the ranges of experts and lay people was 2.89). The lowest score in the dread factor was of experts from Portugal towards pharmaceuticals in treated wastewater, and the highest was of experts from France regarding pharmaceuticals in crops.

In the unknown factor, lay people's assessments were slightly more differentiated than experts' assessments (the range of scores were 1.56 and 0.74, respectively; the difference between the ranges of lay people and experts was 0.82). The lowest score on the unknown factor is of lay people from France regarding pharmaceuticals in the environment, and the highest is of experts from France regarding pharmaceuticals in drinking water.

The unknown factor clearly distinguishes between the assessments of lay people and experts: lay people scored at its lower end (upper and lower left of Fig. 1) and experts scored at its higher end (upper and lower right of Fig. 1). In comparison to experts, lay people perceived relatively higher knowledge by those exposed to risk and voluntariness of risk exposure, lower knowledge on behalf of science, and higher personal control over risk.

3.1.2. Pharmaceuticals in the environment, drinking water, treated wastewater, and crops

We explored how individuals assessed the four hazards to know if there were differences in targeting more general or more specific hazards. We expected the assessments of risk to be higher for drinking water and crops than for treated wastewater and pharmaceuticals in the environment in general. Our expectation was only partially corroborated. In the upper right of Fig. 1 (highest factor dread and unknown) scored not only drinking water and crops but also pharmaceuticals in the environment and in treated wastewater (by experts from France). Likewise, in the lower left of Fig. 1 (lowest factor dread and unknown) scored not only pharmaceuticals in the environment in general and treated wastewater, but also pharmaceuticals in crops and in drinking water (by lay people from Portugal).

Our psychometric factors combined types of respondent and countries. Therefore, we further explore if there were consistent differences in the factors across these variables (Fig. 1). In the dread factor, the hazards that scored relatively higher were indeed drinking water and crops, both for lay people and experts from Portugal, Spain, and France. However, in the unknown factor the results were less straightforward. The hazard that scored higher was pharmaceuticals in drinking water for all but experts from Portugal, and crops in pharmaceuticals only scored as second higher for lay people from France.

3.1.3. Portugal, Spain, and France

Based on the amount of pharmaceutical waste that is returned to pharmacies, we explored if individuals from France assessed higher risk. Our expectation was only partially corroborated. In the upper right of

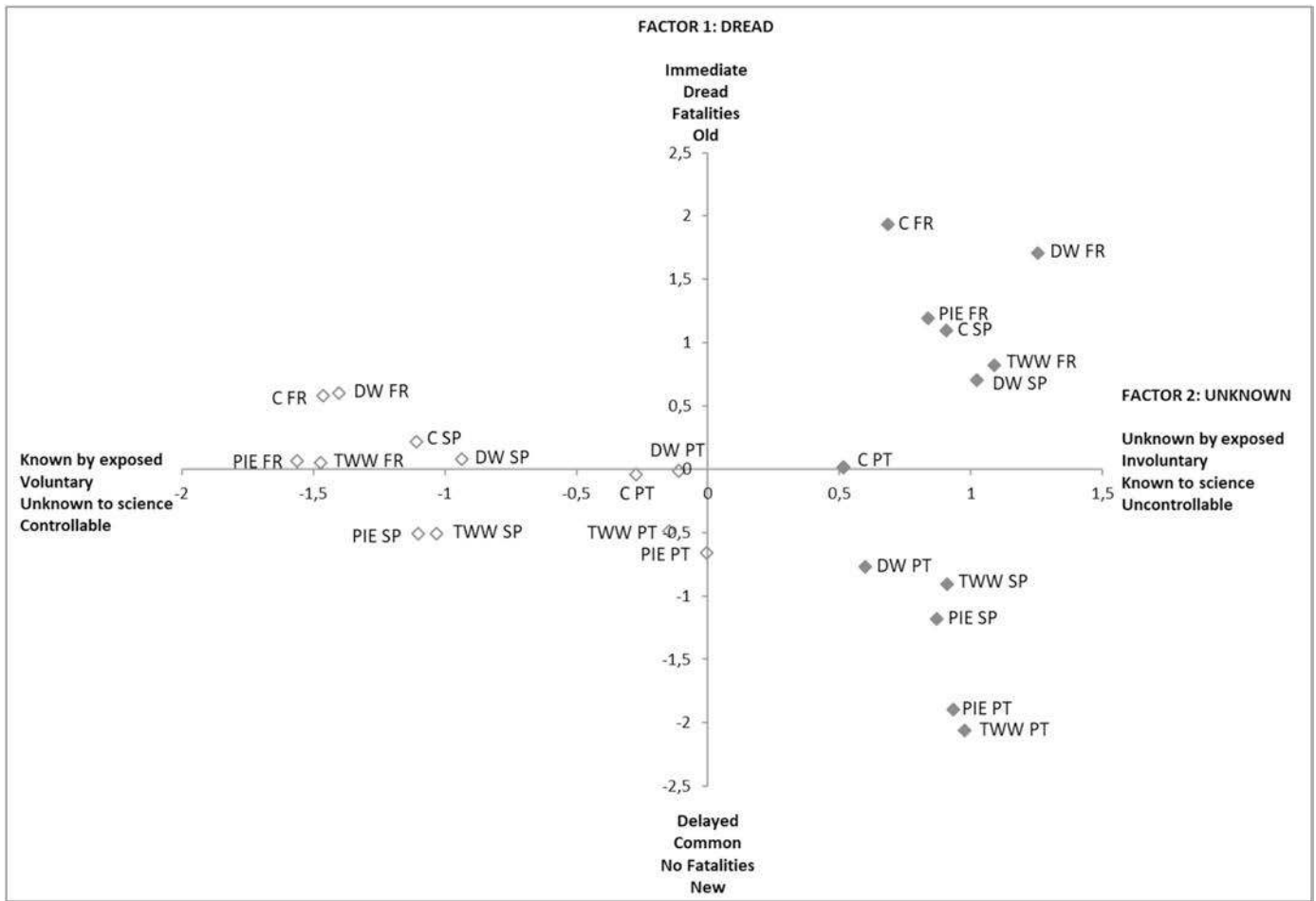


Fig. 1. Spatial representation of the hazards by type of respondent and country in Factor 1 (Dread) and Factor 2 (Unknown). Unfilled bullets represent the responses of lay people, filled bullets represent the responses of experts. PIE =Pharmaceuticals in the Environment. TWW = Treated Wastewater. DW = Drinking water. C = Crops. PT = Portugal. SP = Spain. FR = France.

Table 2
Descriptive Statistics and ANOVA's for Risk Perception Magnitude by type of respondent and country.

Groups	Environmental Risk Perception				Health Risk Perception			
	PIE	Treated wastewater	Drinking water	Crops	PIE	Treated wastewater	Drinking water	Crops
Lay people								
Portugal	6.00 (1.31) ^a	5.48 (1.31)	5.52 (1.31)	5.48 (1.38)	5.48 (1.31)	5.17 (1.11)	5.91 (1.12) ^a	5.96 (1.11) ^a
Spain	4.87 (1.77) ^b	5.01 (1.66)	4.81 (1.85)	4.97 (1.74)	4.86 (1.72)	4.97 (1.73)	5.01 (1.72) ^b	5.14 (1.66) ^{a,b}
France	5.25 (1.57) ^a	5.22 (1.52)	5.27 (1.46)	5.21 (1.45)	4.77 (1.69)	4.85 (1.67)	4.74 (1.56) ^b	4.84 (1.66) ^b
Total	5.14 (1.66)	5.15 (1.57)	5.10 (1.63)	5.13 (1.57)	4.84 (1.69)	4.91 (1.67)	4.91 (1.63)	5.02 (1.65)
Expert								
Portugal	5.71 (1.46)	5.65 (1.45)	5.29 (1.49)	5.55 (1.48)	5.41 (1.29)	5.34 (1.40)	5.69 (1.51) ^a	6.06 (1.08) ^a
Spain	5.80 (1.31)	5.77 (1.49)	5.61 (1.43)	5.61 (1.33)	5.34 (1.48)	5.52 (1.45)	6.05 (1.36) ^a	6.23 (1.00) ^a
France	6.20 (0.99)	6.11 (0.96)	5.63 (1.63)	5.40 (1.68)	4.83 (1.62)	4.94 (1.80)	4.26 (1.98) ^b	4.43 (1.72) ^b
Total	5.88 (1.61)	5.83 (1.36)	5.54 (1.50)	5.54 (1.46)	5.22 (1.48)	5.32 (1.55)	5.48 (1.74)	5.71 (1.46)
Source	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2
Country	3.55*	.012	1.29	.005	0.92	.003	0.46	.002
Respondent	7.87**	.014	11.05**	.019	2.63	.005	2.64	.005
Country X Respondent	16.88*	.012	1.09	.004	2.34	.008	1.16	.004
Simple effects								
Lay people	6.66**	.023	-	-	-	-	6.19**	.021
Expert	1.01	.003	-	-	-	-	14.44***	.048
							6.35**	.022
							16.34***	.055

Note. Standard deviations appear in parentheses following means. Risk perception response scales range from 1 to 7. Means with different superscript letters within the same column are significantly different from each other, based on simple main effect analyses that were conducted for the significant interaction effects of country, separately for lay people and experts (Sidak paired comparisons, $p < .050$). PIE = Pharmaceuticals in the Environment.

* $p < .050$, ** $p < .010$, *** $p < .001$.

Fig. 1 (highest factor dread and unknown) scored not only respondents from France but also from Spain (of experts on pharmaceuticals in crops and drinking water). However, in the lower left of Fig. 1 (lowest factor dread and unknown) scored only respondents from Portugal and Spain.

Again, we further explore if there were consistent differences in the factors across types of respondent and hazards (Fig. 1). In the dread factor, both experts and lay people from France scored higher than experts and lay people from Portugal and Spain in all four hazards. However, in the unknown factor, experts from France only scored higher in pharmaceuticals in drinking water and treated wastewater. In addition, lay people from France scored lower in the unknown factor than lay people from Portugal and Spain in all four hazards.

3.2. Risk perception

A 2 X (respondent type: lay people vs. expert) X 3 (country: Portugal vs. Spain vs. France) ANOVA was employed to compare risk perception between groups. Results are presented in Table 2. Environmental risk perception towards pharmaceuticals in the environment, wastewater, drinking water, and crops was medium/high. There are no large differences among results. Lay people perceived lower environmental risk of pharmaceuticals in the environment than experts, particularly Spanish respondents, and perceived lower environmental risk of pharmaceuticals in treated wastewater than experts.

Health risk perception towards pharmaceuticals in the environment, wastewater, drinking water, and crops was also medium/high. Lay people perceived lower health risk of pharmaceuticals in drinking water and crops than experts. However, French respondents, both lay people and experts, tend to perceive lower risk of pharmaceuticals in drinking water and crops than respondents of Portugal and Spain.

3.3. Measures to reduce the presence of pharmaceuticals in the environment

Among the four measures that individuals assessed as most effective in reducing pharmaceutical residues in the environment, the measure most experts of the three countries chose was an awareness-type measure (“raising public awareness about how pharmaceuticals should be disposed of”). Lay people also indicated a preference for this measure and further pointed out two technology-type measures (“intensified development of environmentally-friendly pharmaceuticals”, and “intensified water treatment”) and a regulation-type measure, which was strongly preferred by respondents from France (“standardized regulation for the disposal of unused pharmaceuticals”). Health-type measures tended to be the least chosen, particularly by lay people (Table 3).

To further observe to what extent the different measures were most preferred by each of the groups, an analysis of simple correspondences with the SPAD package was carried out using a 6 × 10 frequency matrix, where the rows were a combination of the three countries and the two types of individuals – lay people and experts - and the columns were the 10 measures. The results of this analysis allow us to relate the measures with respect to the six groups (3 countries X 2 types of individuals) on two factors that explain 83.31% of the variance. Fig. 2 shows how the abscissa axis organizes the participants in two different spaces, regardless of the country to which they belong. One to the right of the ordinate axis, characteristic of the lay people and the other to the left of the axis corresponding to the experts. Each one of the ten measures distributed in the analytic space appears in a way that its position is established by the frequency associated to each of the six groups. The shorter the distance between a measure and a group, the more it relates to that group than to the others.

Within the expert group, those from Portugal and France are relatively more similar and related to health-type measures (“promoting non-medical treatment and prevention”, “changing prescription behavior”) and to one regulation-type measure (“standardized

Table 3

Preference of measures to reduce pharmaceutical residues in the environment.

Measure	Lay people			Expert		
	PT	SP	FR	PT	SP	FR
Awareness						
Raising public awareness about how pharmaceuticals should be disposed of	76.2	47.6	56.5	62.2	77.8	61.0
Raising public awareness about the presence of pharmaceuticals in the environment	40.6	36.1	40.1	29.7	47.2	29.3
Regulations						
Standardized regulation for the disposal of unused pharmaceuticals	42.8	50.0	59.1	48.6	54.2	56.1
Introducing an ecolabel for environmentally- friendly pharmaceuticals	45.5	37.1	32.5	18.9	18.1	12.2
Technology						
Intensified development of environmentally- friendly pharmaceuticals	73.4	53.3	47.5	40.5	50.0	48.8
Intensified waste/drinking water treatment	72.5	44.7	46.1	35.1	25.0	34.1
Developing an environmental classification system for pharmaceuticals	20.8	31.9	29.6	27.0	16.7	19.5
Health area changes						
Continuing education and training for doctors and pharmacists	14.0	21.5	19.2	32.4	51.4	36.6
Changing prescription behavior	16.4	15.4	29.9	29.7	22.2	31.7
Promoting non-medical treatment and prevention	13.9	31.8	20.8	21.6	20.8	26.8

Note: Responses are in percentage. PT = Portugal. SP = Spain. FR = France.

regulation for the disposal of unused pharmaceuticals”). Experts from Spain related more to a different health-type measure (“continuing education and training for doctors and pharmacists”) and to an awareness-type measure (“raising public awareness about how pharmaceuticals should be disposed of”).

Among lay people, those from Portugal and Spain are more similar and are related to various types of measures: awareness-type (“raising public awareness about the presence of pharmaceuticals in the environment”), regulation-type (“introducing an ecolabel for environmentally-friendly pharmaceuticals”), and technological-type measures (“intensified development of environmentally-friendly pharmaceuticals”). Lay people from France related more to technological measures (“intensified development of environmentally-friendly pharmaceuticals”, “developing an environmental classification system for pharmaceuticals”).

4. Discussion

4.1. Risk perception of pharmaceuticals in the environment

4.1.1. Lay people and experts

The psychometric analysis combined different respondents, countries, and hazards. The differences that were illustrated more pristinely were between lay people and experts, suggesting this factor was the most relevant. In comparison to experts, lay people perceived higher knowledge by those exposed, higher voluntary exposure and control over hazards, thereby suggesting higher individual agency to deal with risk, but also that these hazards are less known by science. This last result is at odds with previous findings likely because lay people and experts’ assessments are not typically analysed together. Indeed, the unknown factor signals possible controversies between experts and lay

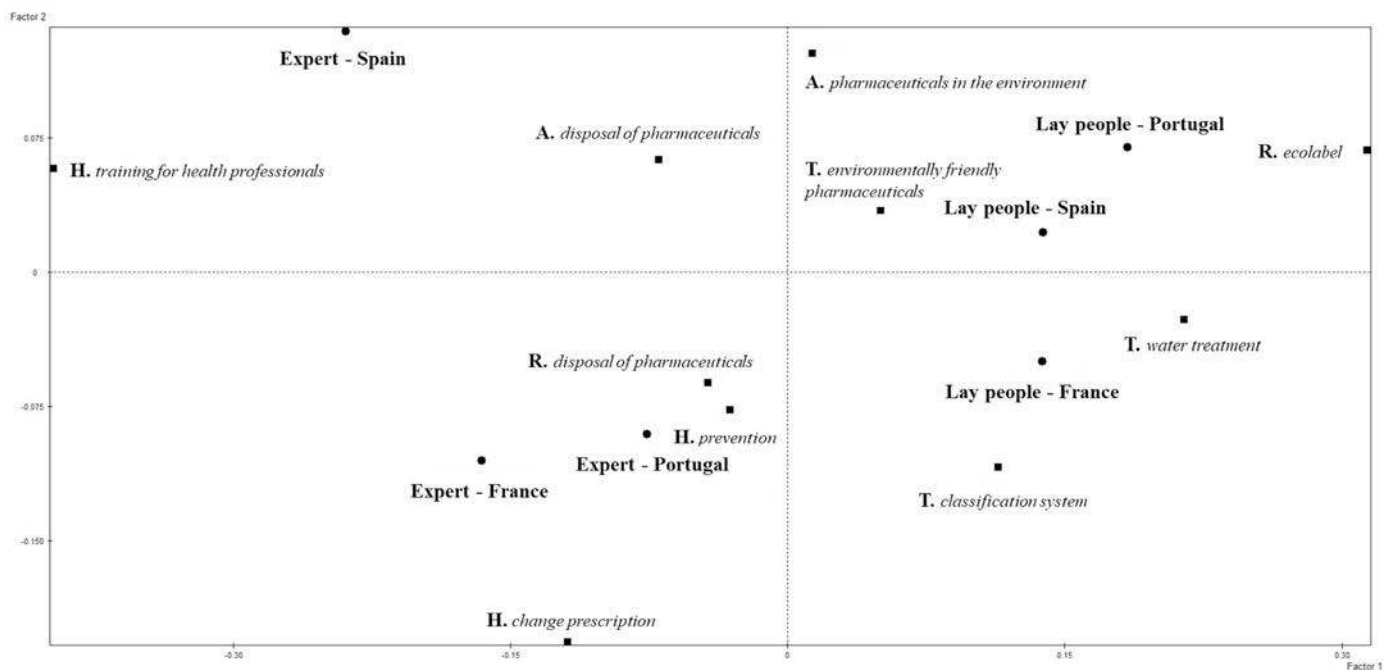


Fig. 2. Spatial representation of the measures preferred by type of respondent and country. A. = Awareness-type. R. = Regulations-type. T. = Technology-type. H. = Health-type.

people. For instance, if experts highlight scientific knowledge and minimize individual agency, from their perspective the focus of risk communication should be on the promotion of awareness and scientific knowledge. However, if lay people are interested in individual agency, not discussing it will make risk communication ineffective. The actions that can be taken by the individuals should be also be discussed (e.g., the proper disposal of pharmaceuticals, see Lima et al., 2020), as well as what can be done to reduce personal exposure and control hazards, in a realistic manner that does not reduce individual agency. In addition, when communicating scientific knowledge, the uncertainty and knowledge gaps on pharmaceuticals in the environment should also be discussed, highlighting how these influence risk management decisions in order to promote transparency and public trust (Markon et al., 2013).

Lay people tended to perceive lower risk of pharmaceuticals in the environment than experts, particularly the environmental risks of pharmaceuticals in the environment and in treated wastewater. This result differs from studies on chemophobia, i.e., an irrational fear of chemicals among lay people, such as food additives (e.g., Siegrist and Bearth, 2019). It suggests that chemophobia might depend on the perceived benefits of the chemicals. When it comes to pharmaceuticals, the health benefits might override its' environmental risk.

4.1.2. Pharmaceuticals in the environment, drinking water, treated wastewater, and crops

The psychometric analysis illustrates that assessments of pharmaceuticals in the environment and in treated wastewater were relatively similar. This suggests that when the hazard was framed generally (pharmaceuticals in the environment), people inferred that the issue was about pharmaceuticals in treated wastewater, and/or that people made similar assessments when the hazards were abstract. Pharmaceuticals in drinking water scored higher than all other hazards in the dread and the unknown factor (except for experts from Portugal), and pharmaceuticals in crops scored higher than pharmaceuticals in treated wastewater and pharmaceuticals in the environment in the dread factor.

These results suggest that risk communication should be specific and also focus on pharmaceuticals in drinking water and crops. Even if the presence of pharmaceuticals in drinking water or crops is residual, and

much lower than in treated wastewater, it should not be ignored. Firstly, because there are uncertainties and knowledge gaps in this area that should be acknowledge and discussed. Secondly, because studies have shown that the presence of traces of contaminants in drinking water influence the perception of its quality, even when they do not pose a risk, and might lead consumers to alternatives (such as bottled water or sweetened beverages) that are linked to other environmental and health issues (de França Doria, 2010; Hartmann et al., 2018).

4.1.3. Portugal, Spain, and France

Comparing between countries, it is noticeable that people from France have a distinct profile of people from Portugal and Spain: both experts and lay people scored relatively higher in the dread factor and, when distinguishing between environmental and health impacts, they perceive lower health risk of pharmaceuticals in drinking water and crops. As such, this result is consistent with data indicating that in France people separate more pharmaceutical waste and might be more aware that the current main problem is environmental and related to wastewater. Regarding the unknown factor, lay people from France actually scored at its lower limit in the four hazards. This result was unexpected. However, if we follow on our previous interpretation that scoring lower in the unknown factor might indicate lay people's individual agency to deal with risk, this result is also consistent with the data on the separation of pharmaceutical waste.

Even though the results might be, overall, consistent with our expectation, two issues should be highlighted. Firstly, the relation between risk management of pharmaceutical waste and individuals' perceptions and behaviours might be complex and bidirectional. It is likely a result of top-down type influences (e.g., awareness raising campaigns that promote knowledge, implementation of measures, social norms) and bottom-up influences (e.g., the enactment of changes in beliefs and practices that were already under way, nongovernmental initiatives) (Clahsen et al., 2019; Luís and Palma-Oliveira, 2016). Second, at the individual-level we do not have data that allow us to infer what is underlying these differences. For instance, they might underlie differences in the individuals' understanding of the issue of pharmaceuticals in the environment (and, therefore, of knowledge and risk perception) that are

related to risk management processes, or they might reflect differences in the social norms towards separating waste in general (organic, plastic, pharmaceutical, etc.) which are not necessarily related to a greater understanding of pharmaceuticals in the environment.

4.2. Measures to reduce the presence of pharmaceuticals in the environment

The major pathway through which pharmaceuticals for human consumption reach the environment is through their ingestion and excretion (Caldwell, 2015). Nonetheless, two of the highest-ranking measures were related to the improper disposal of pharmaceuticals: “raising public awareness about how pharmaceuticals should be disposed of” and “standardized regulation for the disposal of unused pharmaceuticals” This suggests that risk communication on pharmaceuticals in the environment should also focus on discussing how human consumption and excretion of pharmaceuticals contribute to this problem.

Health-type measures were the least preferred and appeared to be chosen when the dread factor and the unknown factors were higher, i.e., when people are more likely to perceive higher risk and advocate for risk regulation. The disfavour for these measures is aligned with the research of Dohle et al. (2013), which illustrated that people consider that the health benefits of pharmaceuticals are much more relevant than possible environmental risks, particularly when it comes to prescribed pharmaceuticals. This result also supports the strategic approach of the European Commission (2019) of ensuring that actions to reduce the presence of pharmaceuticals in the environment do not jeopardise access to safe and effective pharmaceutical treatments.

Lastly, the simple correspondence analysis pinpointed differences between lay people and experts, and between countries, that allow understanding and anticipating which measures are perceived as needed and might be better accepted. Comparing between experts and lay people, whereas experts preferred health-type measures and measures related to improving the disposal of pharmaceutical waste, lay people preferred technological and awareness-type measures. Experts are much more likely to know about the efficacy and constraints of the technological solutions and, as such, might prefer reducing the consumption of pharmaceuticals and improving the measures that have already been implemented. Lay people appear to show their need for knowledge and trust on the efficacy of technological measures to solve this problem. We would like to note that technological measures can be highly appealing because they allow solving a problem while maintaining current lifestyle. However, as Heikkurinen illustrates (2018), technological solutions alone do not support the societal and individual changes that might be needed to deal with global environmental problems.

Differences between countries are likely related to the risk management practices, as earlier suggested. In this study, lay people from Portugal and Spain appear to consider awareness raising as much more needed than lay people from France, where the amount of pharmaceutical waste returned to pharmacy is higher.

4.3. Limitations

The main limitation of this study is related to the samples of experts. These samples were not homogenous: we contacted experts on different topics as the issue of pharmaceuticals in the environment is highly interdisciplinary. Nevertheless, we consider that it was relevant and adequate to represent the different experts that should be engaged in risk management. Also, the psychometric paradigm analyses were based on aggregated data. Caution is needed regarding the ecological fallacy, as results based on aggregated measures do not provide information about individuals (Marris et al., 1997).

5. Conclusions

The main goal of this study was to contribute towards a successful implementation of the European approach to pharmaceuticals in the environment. The engagement of the public in risk management, along with different types of experts, improves the quality of decision making, contributes to achieving a greater acceptance of regulations, and enhances the understanding of the issue of pharmaceuticals in the environment. Divergencies between lay people and experts from different European countries might undermine engagement and, therefore, need to be identified and considered in risk management processes.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Abahussain, E., Waheedi, M., Koshy, S., 2012. Practice, awareness and opinion of pharmacists toward disposal of unwanted medications in Kuwait. *Saudi Pharmaceut. J.* 20, 195–201. <https://doi.org/10.1016/J.JSPS.2012.04.001>.
- Al-Farsi, R., Ahmed, M., Al-Busaidi, A., Choudri, B.S., 2018. Assessing the presence of pharmaceuticals in soil and plants irrigated with treated wastewater in Oman. *Int. J. Recycl. Org. Waste Agric.* 7, 165–172. <https://doi.org/10.1007/s40093-018-0202-1>.
- AlAzmi, A., AlHamdan, H., Abualezz, R., Bahadig, F., Abonofal, N., Osman, M., 2017. Patients' knowledge and attitude toward the disposal of medications. *J. Pharm. (Lahore)* 2017, 1–9. <https://doi.org/10.1155/2017/8516741>.
- Bound, J.P., Kitsou, K., Voulvoulis, N., 2006. Household Disposal of Pharmaceuticals and Perception of Risk to the Environment, vol. 21, pp. 301–307. <https://doi.org/10.1016/j.etap.2005.09.006>.
- Boxall, A.B.A., 2004. The environmental side effects of medication. *EMBO Rep.* 5, 1110–1116. <https://doi.org/10.1038/sj.embor.7400307>.
- Caldwell, D.J., 2015. Sources of Pharmaceutical Residues in the Environment and Their Control, pp. 92–119. <https://doi.org/10.1039/9781782622345-00092>.
- Clahsen, S.C.S., van Kamp, I., Hakkert, B.C., Vermeire, T.G., Piersma, A.H., Lebre, E., 2019. Why do countries regulate environmental health risks differently? A theoretical perspective. *Risk Anal.* 39, 439–461. <https://doi.org/10.1111/risa.13165>.
- CYCLAMED, 2017. Chiffres de collecte des MNU - Médicaments périmés ou non = retour en pharmacie - Cyclamed [WWW Document]. URL. <https://www.cyclamed.org/association/chiffres> (accessed 8.10.18).
- de França Doria, M., 2010. Factors influencing public perception of drinking water quality. *Water Pol.* 12, 1. <https://doi.org/10.2166/wp.2009.051>.
- del Carmen Morales, M., Harris, L., Öberg, G., 2014. Citizenshit: the right to flush and the urban sanitation imaginary. *Environ. Plann.* <https://doi.org/10.1068/a130331p>.
- Doerr-MacEwen, N.A., Haight, M.E., 2006. Expert stakeholders' views on the management of human pharmaceuticals in the environment. *Environ. Manag.* 38, 853–866. <https://doi.org/10.1007/s00267-005-0306-z>.
- Dohle, S., Campbell, V.E.A., Arvai, J.L., 2013. Consumer-perceived risks and choices about pharmaceuticals in the environment: a cross-sectional study. *Environ. Health* 12, 45. <https://doi.org/10.1186/1476-069X-12-45>.
- European Commission, 2019. European Union Strategic Approach to Pharmaceuticals in the Environment.
- Eurostat, 2014a. Self-reported use of prescribed medicines by sex, age and educational attainment level [WWW Document]. URL. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hlth_ehis_md1e&lang=en (accessed 7.30.18).
- Eurostat, 2014b. Self-reported use of non-prescribed medicines by sex, age and educational attainment level [WWW Document]. URL. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hlth_ehis_md2e&lang=en (accessed 7.30.18).

- Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., Combs, B., 1978. How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Pol. Sci.* 9, 127–152. <https://doi.org/10.1007/BF00143739>.
- Götz, K., Courtier, A., Stein, M., Strelau, L., Sunderer, G., Vidaurre, R., Winker, M., 2019. Risk perception of pharmaceutical residues in the aquatic environment and precautionary measures. In: Roig, B., Weiss, K., Thireau, V. (Eds.), *Management of Emerging Public Health Issues and Risks*. Academic Press, pp. 189–224. <https://doi.org/10.1016/B978-0-12-813290-6.00008-1>.
- Green, C., Brian, J., Kanda, R., Scholze, M., Williams, R., Jobling, S., 2015. Environmental concentrations of anti-androgenic pharmaceuticals do not impact sexual disruption in fish alone or in combination with steroid oestrogens. *Aquat. Toxicol.* 160, 117–127. <https://doi.org/10.1016/j.aquatox.2014.12.022>.
- Hartmann, J., van der Aa, M., Wuijts, S., de Roda Husman, A.M., van der Hoek, J.P., 2018. Risk governance of potential emerging risks to drinking water quality: analysing current practices. *Environ. Sci. Pol.* 84, 97–104. <https://doi.org/10.1016/J.ENVSCL.2018.02.015>.
- Heikkurinen, P., 2018. Degrowth by means of technology? A treatise for an ethos of releasement. *J. Clean. Prod.* <https://doi.org/10.1016/j.jclepro.2016.07.070>.
- Kümmerer, K., 2010. Pharmaceuticals in the environment. *Annu. Rev. Environ. Resour.* 35, 57–75. <https://doi.org/10.1146/annurev-environ-052809-161223>.
- Lacorte, S., Luis, S., Gómez-Canela, C., Sala-Comorera, T., Courtier, A., Roig, B., Oliveira-Brett, A.M., Joannis-Cassan, C., Aragonés, J.I., Poggio, L., Noguer, T., Lima, L., Barata, C., Calas-Blanchard, C., 2017. Pharmaceuticals released from senior residences: occurrence and risk evaluation. *Environ. Sci. Pollut. Res.* 1–12 <https://doi.org/10.1007/s11356-017-9755-1>.
- Lima, M.L., Luís, S., Poggio, L., Aragonés, J.I., Courtier, A., Roig, B., Calas-Blanchard, C., 2020. The importance of household pharmaceutical products disposal and its risk management: example from Southwestern Europe. *Waste Manag.* 104, 139–147. <https://doi.org/10.1016/j.wasman.2020.01.008>.
- Luís, S., Lima, M.L., Roseta-Palma, C., Rodrigues, N., P Sousa, L., Freitas, F., L Alves, F., Lillebø, A.I., Parrod, C., Jolivet, V., Paramana, T., Alexandrakis, G., Poulos, S., 2018. Psychosocial drivers for change: understanding and promoting stakeholder engagement in local adaptation to climate change in three European Mediterranean case studies. *J. Environ. Manag.* 223, 165–174. <https://doi.org/10.1016/J.JENVMAN.2018.06.020>.
- Luís, S., Neves, A.-C., Palma-Oliveira, J., 2015. From dry land to water: psychosocial impact on the lakeside villages of the Alqueva dam/Desde tierra firme al agua: impacto psicosocial en los pueblos junto de la presa de Alqueva. *Psychology* 6, 8–34. <https://doi.org/10.1080/21711976.2014.1002207>.
- Luís, S., Palma-Oliveira, J., 2016. Public policy and social norms: the case of a nationwide smoking ban among college students. *Psychol. Publ. Pol. Law* 22, 22–30. <https://doi.org/10.1037/law0000064>.
- Markon, M.-P.L., Crowe, J., Lemyre, L., 2013. Examining Uncertainties in Government Risk Communication: Citizens' Expectations. <https://doi.org/10.1080/13698575.2013.796344>.
- Marris, C., Langford, I., Saunderson, T., O Riordan, T., 1997. Exploring the "psychometric paradigm": comparisons between aggregate and individual analyses. *Risk Anal.* 17, 303–312.
- Mata, A., Antunes, D., de Carvalho, R.G., Palma-Oliveira, J.M., Lino, J., Luis, S., Marques, N., Silveira, C., Alves, I., 2006. Psychosocial monitoring: understanding irrational people. *Saf. Reliab. Manag. Risk* 1–3 2, 1327–1332 n2822.
- Nassiri Koopaei, N., Abdollahi, M., 2017. Health risks associated with the pharmaceuticals in wastewater. *Daru* 25, 9. <https://doi.org/10.1186/s40199-017-0176-y>.
- National Research Council, 1983. *Risk Assessment in the Federal Government: Managing the Process*. National Academy Press, Washington, DC.
- Schriks, M., Heringa, M.B., van der Kooi, M.M.E., de Voegt, P., van Wezel, A.P., 2010. Toxicological relevance of emerging contaminants for drinking water quality. *Water Res.* 44, 461–476. <https://doi.org/10.1016/J.WATRES.2009.08.023>.
- Siegrist, M., Bearth, A., 2019. Chemophobia in Europe and reasons for biased risk perceptions. *Nat. Chem.* <https://doi.org/10.1038/s41557-019-0377-8>.
- SIGRE, 2017. El sistema SIGRE en cifras.Laboratorios, farmacias, almacenes, recogida-Sigre [WWW Document]. URL. <https://www.sigre.es/sigre/cifras/> (accessed 8.10.18).
- Sjöberg, L., 2002. The allegedly simple structure of experts' risk perception: an urban legend in risk research. *Sci. Technol. Hum. Val.* 27, 443–459. <https://doi.org/10.1177/016224302236176>.
- Sjöberg, L., 1998. Risk perception: experts and the public. *Eur. Psychol.* 3, 1–12. <https://doi.org/10.1027/1016-9040.3.1.1>.
- Sjöberg, L., Moen, B.-E., Rundmo, T., 2004. Explaining Risk Perception. An Evaluation of the Psychometric Paradigm in Risk Perception Research, Rotunde Publikasjoner Rotunde. Rotunde Publikasjoner, Trondheim. <https://doi.org/10.1080/135753097348447>.
- Slovic, P., Fischhoff, B., Lichtenstein, S., 1979. Rating the risks. *Environ.: Sci. Pol. Sustain. Dev.* 21, 14–39. <https://doi.org/10.1080/00139157.1979.9933091>.
- Tabak, H.H., Bunch, R.L., 1970. Steroid hormones as water pollutants. I. Metabolism of natural and synthetic ovulation-inhibiting hormones by microorganisms of activated sludge and primary settled sewage. *Dev. Ind. Microbiol.* 11, 367–376.
- VALORMED, 2017. *Relatório de Actividades - Resumo*. Algés.
- World Health Organization, 2012. *Pharmaceuticals in Drinking-Water*. Geneva.
- Wu, X., Dodgen, L.K., Conkle, J.L., Gan, J., 2015. Plant uptake of pharmaceutical and personal care products from recycled water and biosolids: a review. *Sci. Total Environ.* 536, 655–666. <https://doi.org/10.1016/J.SCITOTENV.2015.07.129>.