



Microplastics In Europe's Freshwater Ecosystems:
from sources to solutions

REPORT ON CURRENT RISK PERCEPTIONS AND MENTAL MODELS

DELIVERABLE D4.1

Main Author: University of Bergen (UiB)

Date: 31/07/2021

Dissemination Level: Public

Project LimnoPlast – Microplastics in Europe’s freshwater ecosystems: From source to solutions

Grant Agreement no. 860720

H2020-MSCA-ITN-2019

LimnoPlast: Microplastics in Europe’s Freshwater Ecosystems: from sources to solutions

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 860720

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Table 1. Document Factsheet

| Document Factsheet | |
|---------------------|---|
| Project duration | From November 2019 to December 2023 |
| Project website | https://www.limnoplant-itn.eu/ |
| Document | D4.1: Report on current risk perceptions and mental models |
| Work Package | WP4: SOCIETY: Societal, political and legal context of MP |
| Version | 2.3 |
| Version date | 31/07/2021 |
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| Reviewers | Lead Partner (UBT) |
| Type of deliverable | R |
| Dissemination level | PU Public |

Table 2. Document History

| Document History | | | |
|------------------|------------|-------------------|-------------|
| Version | Date | Main modification | Beneficiary |
| Draft 1 | 27/05/2021 | --- | UiB |
| Draft 2 | 03/06/2021 | --- | UiB |
| Consolidated | 21/07/2021 | --- | UiB |
| Final Draft | 22/07/2021 | --- | UiB |
| Final | 31/07/2021 | --- | UiB, UBT |
| Draft 1 | 27/05/2021 | --- | UiB |

Abbreviations

MP: Microplastics

Beneficiaries

| # | Short Name | Full legal name |
|----|------------|---|
| 1 | UBT | Universität Bayreuth |
| 2 | AAU | Aalborg Universitet |
| 3 | ENPC | Ecole Nationale des Ponts et Chaussees |
| 4 | EVONIK | Evonik Technology & Infrastructure GmbH |
| 5 | Fraunhofer | Fraunhofer UMSICHT |
| 6 | HHL | HHL Gemeinnützige GmbH |
| 7 | KI (NIC) | Kemijski institut (National Institute of Chemistry) |
| 8 | NTNU | Norges Teknisk-Naturvitenskapelige Universitet |
| 10 | UGOT | Goteborgs Universitet |
| 11 | UiB | Universitetet i Bergen |
| 12 | UoP | University of Plymouth |
| 13 | VUA | Stichting VU (Vrije University Amsterdam) |
| 14 | Univie | University of Vienna |

PUBLISHABLE SUMMARY

The LimnoPlast project aims to tackle the issue of microplastics (MP) pollution in freshwater systems in a holistic manner. On that note, the current report focuses mainly on the psychological literature on the subject, intending to provide a comprehensive review of the current literature regarding risk perceptions and mental models, and how these relate to the issue of MP in freshwater systems. People's risk perceptions and mental models of MP are pivotal aspects to consider when developing appropriate risk communication strategies and behavior change interventions that address this global challenge.

The first section outlines how the current report fits within the LimnoPlast project, its approach and objectives, as well as how the insights gained from this report are related to other project deliverables. The second section addresses the concept and structure of environmental risk perception, followed by a discussion of different factors that may contribute to shaping these perceptions. Additional focus is placed on the concept of mental models, broadly described as people's intuitive mental representations of certain events.

An increasing share of the public appears to be concerned about MP, including their potentially harmful impacts on the environment and human health. Risk perceptions are important in this context given their role in shaping public responses to environmental challenges. It is crucial to understand the human dimension of MP in order to attempt to find possible solutions to the problem of MP mobilizing public engagement. The employment of the mental model approach to risk communication might be appropriate for this endeavor.



TABLE OF CONTENTS

| | |
|---|----|
| Abbreviations | 3 |
| Beneficiaries | 3 |
| Publishable Summary | 4 |
| Table of Contents | 5 |
| 1 Introduction | 6 |
| 1.1 Approach of the report..... | 6 |
| 1.2 Objectives of the report..... | 6 |
| 2. Risk perceptions regarding (micro)plastics | 7 |
| 2.1 Hazard characteristics | 7 |
| 2.2 Perceiver characteristics..... | 8 |
| 2.3. Heuristics..... | 10 |
| 2.4. Emotions | 11 |
| 2.5. Mental Models | 12 |
| 3. Conclusions..... | 14 |
| 4. Acknowledgements..... | 15 |
| 5. References | 16 |



1 INTRODUCTION

The LimnoPlast project investigates microplastics (MP) in Europe's freshwater systems, ranging from the sources to possible solutions to the MP problem. LimnoPlast aims to assess the sources and impacts of freshwater MP by analyzing three major urban areas as plastic pollution hotspots. Research on innovative technological solutions will also be carried out, including processes to remove MP from municipal and industrial wastewater as well as environmentally sound polymers. Additionally, LimnoPlast aims to promote societal change by understanding the economic, legislative, and social context of freshwater MP.

Part of the project's efforts to transform science into specific solutions include suggesting appropriate risk communication strategies and societal interventions to tackle MP. Understanding people's risk perceptions and mental models related to the issue of MP can be informative for the development of such risk communication strategies and eventually behavior change interventions.

1.1 Approach of the report

A systematic literature search was conducted with an initial emphasis on risk perceptions in the social and behavioral sciences, focusing on the concept of risk, its structure, relevant theories on risk perception, different classifications, how it is thought to affect behavior, and decision making and factors that might influence it. The same search was done for mental models to understand what they consist of, what information they can provide, and the different contexts they have been studied in.

The search focuses on environmental risk perception more generally, as well as on literature employing a mental model approach to understand public perceptions about environmental issues. This provided an understanding of how risk perception has been studied in the environmental field and how it could be examined in the future regarding MP specifically. Understanding how risk perception is investigated with respect to similar environmental issues can be of great value for designing future social science research in the field of MP. Lastly, the search focused on studies of risk perception and mental models regarding plastic pollution and MP specifically.

Although psychological research on MP is scarce (Pahl & Wiles, 2017), the last decade has witnessed a growth in studies addressing individual perceptions about plastics (e.g., bioplastics; Dilkes-Hoffman et al., 2019b) and associated behaviors (e.g., plastic bag use; O'Brien & Thondhlana, 2019). In this way, the report addresses knowledge gaps concerning laypersons' and various stakeholders' risk perceptions about MP.

1.2 Objectives of the report

This report contributes to work package WP4 SOCIETY. The specific objective is to provide an overview of relevant literature on environmental risk perception and mental models, and how this can inform the development of potential solutions to the issue of MP. This report is particularly linked with the other deliverables from WP4 SOCIETY: D.4.2., which will discuss options for behavior change interventions regarding MP; D.4.3, which will examine existing European and international legal frameworks regulating MP; D.4.4, which will consist of a socio-ecological analysis of freshwater MP and policy-relevant recommendations; and finally, D.5.4., which will consist of the development of a risk communication and behavior change strategy to tackle the problem of MP.

2. RISK PERCEPTIONS REGARDING (MICRO)PLASTICS

Risk can be understood as the possibility that human actions, situations or events might lead to consequences that affect aspects of what humans value (Renn & Rohrman, 2000). This implies that humans make causal connections between actions or events and analyze implicit messages in order to reduce undesirable effects by modifying their causes (Renn & Rohrman, 2000). In this context, risk can also be defined as the probability of physical, social or financial harm/detriment/loss due to a hazard within a particular time period (Renn & Rohrman, 2000), and as a feature of all human actions, which have effects that are uncertain to some degree and yield some kind of benefit or cost (Eiser, 2004).

Risk perception involves implicit or explicit judgements of the likelihood or uncertainty as well as the desirability or undesirability of such effects.¹ These judgements are argued to be based on expectancies derived from previous experience as well as from information communicated by others (Eiser, 2004). The formal definition of risk often entails the magnitude and probability of harmful consequences (Aven & Renn, 2009), and risk perceptions include these dimensions along with perceptions of familiarity and controllability, dread and catastrophic potential, as well as affective and emotional responses (Finucane, Alhakami, Slovic, & Johnson, 2000; Slovic, 2000; 2016). Risk perceptions deviate from numerical risk estimates because they are not exclusively determined by statistics and probabilities, but also by qualitative factors related to the risks and those perceiving them (Kortenkamp & Moore, 2011). The actual damage that might result from risky behavior is more than just a mental construct; nevertheless, concepts to predict the likelihood of hazardous events depend on mental models, which are constructed based on knowledge and beliefs (Kortenkamp & Moore, 2011).

In sum, the determinants of risk judgments are numerous and interrelated. Socio-psychological factors have substantial influence on the evaluation of risks; therefore, the subjective concept of "risk" should be seen as a multifaceted/multidimensional construct (Renn & Rohrman, 2000). In the following sections, several factors that may affect risk perceptions regarding MP will be discussed in more detail.

2.1 Hazard characteristics

There are cases in which people are wary of hazards that experts agree do not cause much significant harm, while in other cases, people are ready and willing to expose themselves to hazards that result in large numbers of fatalities each year (Siegrist & Arvai, 2020). Such divergences can be at least partially explained by specific characteristics of the hazards themselves. The core variables in risk perception research are (perceived) magnitude of the risk and risk acceptance (Renn & Rohrman, 2000). Nonetheless, in most studies, many more risk-related aspects are included, such as qualitative features of the hazard (e.g., familiarity with the risk or associated fear), benefits (e.g., attractiveness of the risky activity), personal relation to the hazard (e.g., whether one voluntarily exposes oneself to it, degree of worry about the risk etc.), and acceptability facets (e.g., willingness to pay or desired level of restrictions) (Renn & Rohrman, 2000).

The psychometric paradigm (Fischhoff, Slovic, & Lichtenstein, 1979) suggests that different types of hazards can be mapped onto two dimensions, labelled as dread risk and unknown risk, respectively.² The first dimension includes features such as uncontrollable, catastrophic, dreaded, involuntary, fatal, inequitable, global, and difficult to reduce, whereas the second dimension includes unknown extreme risks that are unobservable, not understood by science, new, and have delayed effects (Kortenkamp & Moore, 2011). Risks with effects that are perceived as far off in time or as occurring in a faraway place are also included within this dimension (Eyal, Liberman, & Trope, 2008). Other investigations have identified more dimensions that are relevant for environmental challenges, such as whether people have moral concerns related to the risk and whether people feel that issues of equity are related to the risk (e.g., Bostrom et al., 2020). Another important factor discussed in the context of risk acceptance is whether the source of the risk is natural versus human/technological, as people tend to rank natural hazards lowest in risk magnitude ratings. These hazards seem to be perceived and evaluated as more tolerable than those stemming from human activities or technologies, even though objective risk assessments might not differ much (Renn & Rohrman, 2000).

¹ Slovic (1999) argued that "danger" is a reality, but "risk" is socially constructed.

² For empirical evidence, see Slovic (1987) and Teigen et al. (1988).

The ubiquity of MP in aquatic ecosystems has provoked a broad public debate concerning the unsustainable use and environmental impact of plastics (Kramm & Völker, 2018). However, as stated above, there are cases where the public perception of a particular hazard does not match experts' understanding of its impacts. While the environmental impacts of MP are not at all clear from a scientific perspective at present, public awareness of overall plastic pollution is widespread (Völker et al., 2020). In fact, most EU citizens worry about the consequences of plastics for the environment (87%) and for their own health (74%) (European Commission, 2017). Meanwhile, there has been ongoing debate about the relevance of this issue compared to other environmental challenges (Backhaus & Wagner, 2020), with some scholars arguing that the levels of environmental toxicity detected so far are too low to be of significant concern (Triebkorn et al., 2019). The disparity between experts and public opinion can potentially be problematic when it results in policies and decisions that are disproportionate or not supported by science (Rist et al., 2018).

As for the issue of MP, the level of perceived risk might be explained in part by known/dread factors from the psychometric paradigm. With respect to the dread risk dimension, plastic and MP pollution are likely to be considered dreadful hazards given that plastic pollution is a form of involuntary exposure for animals and plants in the environment and a problem at a global scale. With respect to the unknown risk dimension, MP are a quite new hazard (Pahl and Wyles, 2017) that is not well understood by science, since research on them is still in its infancy (Völker et al., 2020). This should lead people to perceive this hazard as less known. Moreover, MP are not easily observable (Pahl & Wyles, 2017), which should also make people lean more towards the unknown end of the spectrum. Additionally, regarding the sources of MP, since hazards stemming from human activities are perceived as riskier and less tolerable (Renn & Rohrmann, 2000), the fact that MP are a human-caused hazard might contribute to the high levels of perceived risk that have been reported.

2.2 Perceiver characteristics

Perceivers of risk differ on a wide range of variables that tend to be quite stable over time and might influence risk perceptions (Siegrist & Árvai, 2020). Many such variables have been studied extensively in order to explain and predict individual differences in risk perceptions, and the most relevant ones and their implications for perceptions of plastic pollution are highlighted in the sections below.

2.2.1 Socio-demographics

Gender appears frequently to be weakly associated with risk perceptions (Cullen et al., 2018; Rivers, Arvai & Slovic, 2010); in addition, small or non-significant effects have been found for age (Bearth et al., 2019) as well as for income (Nardi et al., 2020) and education (Bearth et al., 2019; Nardi et al., 2020). However, some studies have yielded more information about the relationship between risk perceptions and demographic characteristics. For example, in studies by Finucane and colleagues (2000), white women perceived significantly higher levels of risk across different hazards compared to white males, while the same was not found for nonwhite women and men. This indicates that gender and/or racial identity per se might not drive risk perceptions to the same extent as other psychological or cultural features (Rivers et al., 2010). There is also a notion that white males tend to have lower risk perceptions than white females, nonwhite males and nonwhite females across different hazards (cf. white male effect; Kortenkamp & Moore, 2011).

Unsurprisingly, gender effects have been found for environmental risks such as climate change (Finucane et al., 2000), and plastics-related issues. For instance, in a study by Deng et al. (2020), males had a lower average score than females regarding willingness to reduce MP emissions. Although differences in knowledge have been argued to be a reason for gender differences in environmental risk perceptions, females exhibited higher nuclear risk perceptions even in a sample of scientists (Barke et al., 1997). Therefore, it has been argued that there is more support for differences due to race and gender as explanations for differences in environmental risk perceptions than there is for differences in knowledge (Davidson et al., 1996).

Furthermore, environmental risk perception differs based on respondents' socioeconomic background (Bickerstaff, 2004). People with a lower social status and fewer privileges tend to be in a position of less power and control. They are argued to be more vulnerable to economic stressors and therefore perceive the world as a more dangerous place (Finucane et al., 2000). A similar trend was reported by Deng et al. (2020), who noted that people with lower education had higher levels of worry about MP, while people with higher education were not as concerned. The authors argued that this was due to a more comprehensive understanding of MP, which

in turn might have reduced unnecessary concerns. Nonetheless, another study by Henderson and Green (2020) concluded that people with high environmental awareness are also more concerned and know more about MP.

2.2.2 Knowledge and reasoning

It is a common finding in the literature that laypeople and experts tend to differ in their level of perceived risk regarding the risk event in question (Savadori et al., 2004; Siegrist et al., 2018). Sjöberg (1998) classified comparisons of experts' and laypeople's risk perceptions into three types: similar assessments for well-known risks; lower risk perceptions by laypeople for hazards which they have some control over, such as smoking or drinking; and lower risk perceptions by experts for complex topics such as nuclear power. These differences can be accounted for in part by factors stemming from the psychometric model, including familiarity, controllability, and knowledge. The knowledge deficit model argues that if laypeople increased their knowledge, they would reach similar conclusions to those of experts, and therefore, general knowledge and risk perception should correlate (Bubela et al., 2009). In its simple form, however, the knowledge deficit model did not garner much empirical evidence and there is research that casts doubt on it (Kellstedt et al., 2008).

Regarding the issue of MP, Deng et al. (2020) investigated perceptions of MP among residents of Shanghai (China), showing that higher education was associated with lower levels of perceived risk regarding MP. While the majority of people became worried or even overly worried when informed about possible impacts of MP, increased knowledge about the issue was also associated with a greater willingness to take action to tackle the problem (Deng et al., 2020). Moreover, Henderson and Green (2020) investigated people's knowledge and understanding of MP in the United Kingdom. A particular focus was placed on the role of the media in framing perceptions, involving participants with no knowledge of MP as well as participants with a special interest in MP. The findings shed light on the importance of environmental awareness and how lack of awareness of the plastics problem represents a barrier to change (Henderson & Green, 2020). These findings highlight the importance and benefits of citizen science activities, which can raise awareness and knowledge about plastic litter. For instance, participation in beach clean-ups and other coastal activities has been shown to be associated with pro-environmental intentions and higher marine awareness (Wyles et al., 2017).

Recent findings by Kramm, Völker and Werschköller (2021) showed that 80% of the German public had heard of MP, hence indicating that the public is becoming more aware of MP. The same investigation also found that level of education was important for MP awareness, since 90% of people considered to have a high level of education reported having heard of MP, whereas only 65% of those considered to have low education reported having heard of them. Their results also indicated that higher environmental awareness tends to be associated with higher risk perceptions and that the more frequently one hears about MP, the higher perceived risk about MP (Kramm, Völker & Werschköller, 2021).

As a study by Grünzner, Pahl, White and Thompson (2021) shows, experts (researchers working primarily on plastics) are more highly concerned about the risks of MP for the natural environment than they are about their risks for human health. Accordingly, MP have often been depicted in the media as something to be concerned about, as a risk for the environment (Völker et al., 2020). Nonetheless, some recent reports show that laypeople are highly worried about MP risks to the natural environment (European Commission, 2020) but also quite concerned about possible health risks (German Federal Institute for Risk Assessment, 2020).

People with higher levels of scientific reasoning have been found to be more likely to perceive risks consistently with the scientific evidence regarding those risks (Siegrist & Árvai, 2020).³ However, some people are skeptical of science and may hold beliefs that lack a scientific basis, a common example of which are so-called "new age beliefs" (Sjöberg & Wahlberg, 2002). Sjöberg and Wahlberg (2002) investigated risk perception in relation to these beliefs, including traditional folk superstition, belief in paranormal phenomena and use of alternative healing practices. New age beliefs correlated negatively with educational level and were positively related to concerns over tampering with nature; new age beliefs explained 15% of the variance in perceived risk, with higher consciousness beliefs and beliefs in paranormal phenomena the most powerful explanatory factors

³ Nevertheless, risk perceptions among people with high scientific reasoning ability may not correspond to the actual scientific evidence if people have already made up their minds that the hazard is of high or low risk (Drummond & Fischhoff, 2019).

(Sjöberg & Wahlberg, 2002). People with such beliefs tend to hold higher risk perceptions regarding environmental hazards such as climate change and nuclear waste (Siegrist & Arvai, 2020).

2.2.3. Fairness, value orientations and worldviews

Regarding perceptions of environmental risks, people tend to care less about statistics, such as the number of casualties due to a hazard, and more about issues such as justice, fairness and duties to future generations (Moore, 2009). Within the psychometric model, the dread component of risk contains aspects related to ethical issues resulting from unequal distributions and lack of informed consent regarding risk exposure (Slovic, 1987). Additionally, moral evaluations of risks have proven to be a strong predictor of acceptability and perceived risk (e.g., Sjöberg & Drottz-Sjöberg, 2001); likewise, environmental injustice has been found to predict risk perceptions (Satterfield et al., 2004).

Cultural worldviews are defined as the pattern of beliefs and value orientations shared by people in a collective, or orienting inclinations which guide thoughts and behaviors (Mead & Mëtraux, 1954). Such worldviews are argued to have a strong influence on risk perceptions; individuals and collectives ascribe to one or a series of prominent value orientations, particularly hierarchism, individualism and egalitarianism (cf. cultural theory of risk; Douglas and Wildawsky, 1982). Later research expanded value orientations to include egoism, altruism, and most interestingly for environmental risks, biospherism (e.g., De Groot & Steg, 2007). These studies have pointed to a weaker relationship between worldviews and risk perceptions overall, albeit with two particular environmental hazards as noteworthy exceptions: nuclear power and climate change (Siegrist & Arvai, 2020).

There are no studies on perceptions of MP that explored value orientations or worldviews. Nevertheless, in studies involving the risk of nuclear power, altruistic and biospheric values tended to be negatively associated with perceived risks (Siegrist & Arvai, 2020). For climate change, on the contrary, biospherism, and to a lesser extent egoism, have been positively associated with perceived risk (Van der Linden, 2015). Other evidence suggests that biospheric values may partially undergird climate change worry, whilst being directly and positively related to personal climate mitigation behaviors (Bouman et al., 2020).

2.3. Heuristics

Prospect theory (Kahnemann & Tversky, 1979) postulates that people tend to overweight small probabilities and underweight larger probabilities, depending on the type of decision they are making. Specifically, people overweight small probabilities when simply presented with descriptions of these probabilities yet tend to underweight small probabilities when they are learned through experience (Kahnemann & Tversky, 1979). It is important to mention that people often lack the in-depth knowledge needed to evaluate hazards comprehensively, as indicated by studies addressing technologies (Connor & Siegrist, 2011) and climate change (Shi et al. 2016).

The elaboration likelihood model (Petty & Cacioppo, 1986; for an application in the environmental context see Meijnders, Midden & Wilke, 2001) argues that lack of motivation or knowledge leads to usage of a peripheral cognitive route, where heuristics are prominent. Heuristics are argued to work through attribute substitution (Kahneman & Frederick, 2005). When evaluating a hazard, an attribute that is not cognitively accessible, such as the probability of being exposed to the hazard, is substituted with a related attribute that is more easily accessed, such as recollection of concrete examples of that hazard (Siegrist & Arvai, 2020). For example, someone is more likely to evaluate the hazard of plastic pollution based on number of the times they spotted plastic floating in the sea rather than the actual statistical probability of exposure to plastic pollution.

2.3.1. Availability heuristic

The availability heuristic is used when people utilize the “ease” with which examples or occurrences can be brought to mind to assess the probability of an event (Tversky & Kahneman, 1974). For instance, someone might assess the risk of MP negatively affecting the environment by thinking about how often they hear in the news that MP have been found in their local area. The availability heuristic has been examined with respect to environmental hazards such as flooding (e.g., Tanner & Arvai, 2018), with people who could remember floods perceiving higher risk compared to those who could not remember such events. One might speculate that use

of this heuristic might similarly affect laypeople's perceived risk when it comes to MP. Support is provided by literature indicating that this heuristic may influence risk perception regarding climate change (Demskei et al., 2017).

2.3.2. Affect heuristic

The affect heuristic maintains that the affective component elicited by a hazard influences risk perception (Finucane et al., 2000). People are argued to base their judgements about risks and benefits on their affective reactions (Slovic, 1999), and that there is an affect "pool" that contains positive and negative markers associated with all mental images (Slovic et al., 2004). Studies investigating this principle suggest that the valence of spontaneous associations is associated with risk perceptions and acceptance of risk (Siegrist & Arvai, 2020). The problem is that the affect heuristic might result in biased judgements (Nakayachi, 2013) by ignoring information that would have been useful to formulate more accurate risk judgements (Sunstein, 2003). Accordingly, one possible explanation for the fact that people have been reported to perceive MP as more harmful than what the scientific evidence appears to indicate at this stage (Catarino et al., 2021) could be the existence of a negative affective valence associated with MP, such that people are biased to think negatively about their impacts and ignore certain information, in this case current uncertainty about their impacts, particularly on human health. Furthermore, questions about the causal direction of these associations might be posed. It is hard to exclude the possibility that risk perception might drive affective responses and not the other way around (Siegrist & Arvai, 2020).

2.3.3. Natural-is-better heuristic

In Western countries, nature is generally perceived as benevolent (Scott & Rozin, 2020). The natural-is-better heuristic is defined as neglecting the positive effects of human intervention and negative impacts of natural processes (Siegrist & Hartmann, 2020). Research in this vein shows that synthetic chemicals are much more negatively perceived than natural chemicals (Saleh et al., 2019), especially among individuals with high biospheric values (Campbell-Arvai, 2019). It follows that people might evaluate the issue of MP more negatively because they result from a human process that reduces naturalness. Supporting evidence stems from studies showing that MP are indeed perceived quite negatively (e.g., Deng et al., 2020) and that microbeads are perceived as an "unnatural", unacceptable risk (Anderson et al., 2016).

2.4. Emotions

Risk perception used to be seen as exclusively cognitive, and emotions were not considered in this field for a long time (Böhm & Brun, 2008). An early study by Johnson and Tversky (1983) showed that people's current mood affected their risk judgements, highlighting that we hardly ever react to threats in an emotionally neutral state, and emotions affect how we perceive risks. Emotions have since then come to be considered important factors that affect risk perceptions and evaluations (Böhm & Tanner, 2019). The previous section discussed how affect might root judgements about risks and benefits; however, there exists an important distinction between general affect and specific emotions or appraisals (e.g., Lerner & Keltner, 2001).

Emotions can be connected to complex reasoning; each emotion carries a certain meaning and reflects a cognitive structure or viewpoint (Böhm, 2003; Böhm & Pfister, 2000, 2017). For example, worry anticipates something bad that might happen in the future; outrage concerns assigning blame to other people; disappointment means that an outcome has fallen short of expectations; regret arises from a sense of responsibility; pity is a social emotion; guilt is more focused on ourselves and our own actions, when we feel we acted in a way that violates a moral norm; fear is similar to worry because it has to do with anticipation of future harm, but is more short-term-focused; hope reflects the belief that there is still a chance to achieve positive outcomes; and lastly, pride is felt when an accomplishment has been achieved (Böhm, 2003; Böhm & Pfister, 2000, 2017). Specific emotions are oftentimes explained through the appraisal theoretical framework (Frijda, 2007).

Böhm and Pfister (Böhm, 2003; 2000, 2017) conceptualized a dual-process model of risk evaluation involving two fundamental appraisal dimensions linked to specific emotions, namely consequences and morality. Fear is an emotion related to consequences, whereas outrage and guilt have more to do with the perception that moral norms have been violated (Böhm, 2003; Böhm & Pfister, 2000, 2017). Each dimension is associated with

characteristic behavioral tendencies. Typical consequentialist behavioral tendencies are mitigation and adaptation, while actions more tied to morality are punishment and redemption, targeting the actor or aggressor (Böhm & Pfister, 2017). A consequentialist focus could lead to judgements about the perceived risk of MP towards animals, which could trigger an emotion of fear and ultimately a behavioral tendency to help clean up a beach full of plastic litter. Research indeed shows that some of the first associations with MP tend to concern harmful impacts on wildlife (Deng et al., 2020; Henderson & Green, 2020). Since release of MP in the environment is evidently due to human activity, deontological evaluations might also be more intense than for natural hazards, such as flooding. This interpretation follows literature showing that deontological judgments tend to be more intense for human than for natural causation, whereas consequentialist evaluations tend to be more intense when the consequences affect humans as opposed to nature (Böhm & Pfister, 2000, 2017). Despite the scientific evidence being not yet clear with respect to harmful consequences of MP for human health (Catarino et al., 2021), the public is reportedly worried about human health effects (Deng et al., 2020; Henderson & Green, 2020). It is because of this that MP might actually trigger both deontological (outrage, guilt, etc.) and consequential (sadness, fear, etc.) emotions.

2.5. Mental Models

An important basis of people's risk perceptions is how they mentally represent the risk event in question (Bostrom, 2017; Böhm & Pfister, 2000, 2017). Such a mental representation is constructed from available information, of which the most important components are the causes and consequences ascribed to the risk event, commonly referred to as mental models⁴. A person's mental model about MP may convey the belief that MP are released into aquatic environments by washing fleece and synthetic clothing, and that they will result in harm to some fish species (see Figure 1). Laypeople's mental models tend to be less structured than those of experts (Bostrom, 2017). Inaccuracies in their mental models can lead people to make errors, which in the case of plastic can be seen in the development and promotion of certain actions and policies not fully supported by scientific evidence (Catarino et al., 2021). Common approaches to capture mental models about a given risk event are surveys (Bostrom, 2017), as well as thought listing and image association tasks (e.g., Smith & Joffe, 2013). Themes are inductively derived from open-ended responses to questions, for example tapping into the first things that come to people's minds when thinking of the environmental hazard; additional content analysis might refer to psychological theories (e.g., Böhm, Doran & Pfister, 2018).

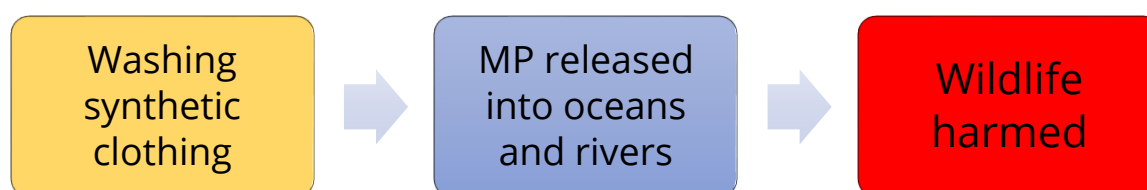


Figure 1. Sketch of possible mental model of MP

One manner to assess the utility of mental models is to employ them within a problem-solving or decision-making approach, a strategy exemplified by the mental model approach to risk communication (Morgan et al., 2002). The phases of this approach include, first, developing a conceptual model of the target system, like for instance MP, into a decision model representing how science may best inform policy and risk mitigation decisions. Hence, the conceptual model consists of decisions about risks and what could be done about them (Bostrom, 2017). Second, semi-structured interviews assessing mental models and related perceptions of the risks of the issue in question and how to mitigate those risks are content analyzed, comparing them with the

⁴ Mental models are conceived as simulations of the world fleshed out with our knowledge, inference engines and useful simplifications (Bostrom, 2017).

decision model (Bostrom, 2017). The interview protocols often include a think-aloud task, inspired by think-aloud studies used in other mental model approaches (Ericsson & Fox, 2011), but primarily consist of prompts asking participants to talk about the hazard. The analysis of the interviews is conceptually linked to the decision model, but open-ended (Bostrom, 2017). Third, the interviews might inform the design of survey instruments to survey larger samples, ideally representative of the groups for whom risk communication strategies are being developed (Bostrom, 2017). Another way to assess mental models regarding environmental issues is based on systems modelling and entails experiments in which individuals solve tasks such as dynamic greenhouse gas problems (e.g., Moxnes & Assuad, 2012).

Regarding what people's mental representations of MP might look like, Dilkes-Hoffman et al. (2019) asked members of the Australian public to state the first two words that came to mind when they heard the word "plastic". The most frequent words or concepts were general environmental statements, waste, pollution, ocean impacts, and animal impacts. Participants placed the main responsibility for reducing plastic waste on industry, followed by the government, and 80% expressed a desire to reduce their personal plastic use (Dilkes-Hoffman et al., 2019). Moreover, a study from Deng et al. (2020) in China found that MP seem to be viewed as accumulating mostly in the ocean. The respondents also referred to factory production of plastic particles as the main source of MP, although, overall, they did not seem to be fully aware of the origin of MP (Deng et al., 2020). In addition, a UK study by Henderson and Green (2020) reported that most respondents were unaware of MP, although environmentally conscious individuals had heard about microbeads through media reporting on new regulations. While some people made a connection between their personal use of plastics and ocean pollution, they appeared to miss links between macro- and microplastics (Henderson & Green, 2020).

The few existing studies on perceptions of MP indicate considerable misconceptions, such as the recurrent association of MP with plastic islands (Henderson & Green 2020), and that an important fraction of the public might still be unaware of MP (Deng et al., 2020; Henderson and Green, 2020) – even though MP awareness is on the rise (Catarino et al., 2020). It is because of this that one might speculate that laypeople's mental models of MP are inaccurate. Notably, laypeople most commonly associate plastic and MP with pollution in the environment in general and the ocean in particular (Dilkes-Hoffman et al., 2019). Laypeople often seem to miss the fact that MP also migrate among the atmosphere, freshwater, soil and different creatures (Bin et al., 2020). Further research could investigate whether people are able to understand that MP can also be released into these environments and the impacts this could have, such as harmful effects on wildlife. Regarding human health effects, the public appears to be very concerned about these impacts, despite the fact that scientific evidence for such effects is still unclear (Catarino et al., 2020).

Plastic particles from factories are the main source of global plastic waste (Boucher & Friot, 2017), and the public has reportedly made associations between these particles and MP (Deng et al., 2020). It could be that the majority of the public understand that these particles are the main source of MP, as Deng et al. (2020) argued. Nonetheless, there are various other sources of MP that the public generally seems not to be aware of. For instance, the decomposition of synthetic textiles is another important source of MP in the ocean (Boucher & Friot, 2017), although the public does not make this association often (Deng et al., 2020). Additionally, the public often does not associate individual plastic consumption to the release of MP and thus ocean pollution (Henderson & Green, 2020); instead, they often ascribe responsibility to industry and governments (e.g., Dilkes-Hoffman et al., 2019).

Public awareness of MP is increasing (Catarino et al., 2021). People are in the meantime becoming more frequently exposed to the topic through the media, which is why people's awareness of the issue may continue to rise in the future. Media storytelling might indeed have a central role to play in shaping public understanding and bringing the topic to public attention in powerful ways (Henderson & Green, 2020). Employing a mental model approach to risk communication may provide valuable insights in how to address the gap between experts' and laypeople's knowledge (Pahl & Wyles, 2017). The mental models elicited from this research can be used to adapt messages to communicate the different risks posed by MP, and such communication can be evaluated via surveys or focus groups (Pahl & Wyles, 2017).

3. CONCLUSIONS

Given that MP are a human-caused environmental problem, understanding public perceptions about the issue can provide useful insights for attempts to reduce the amount of plastic waste in freshwater systems. This report outlined the role of risk perceptions, which in turn are affected by characteristics of the hazard and characteristics of the perceiver. Amid the latter, sociodemographic characteristics, knowledge and reasoning, as well as worldviews and values of the individuals perceiving the risk are highlighted. Other potential sources of influence include the use of heuristics as opposed to more complex information processing, the influence of emotions, and how people mentally represent the risk in terms of, amongst other things, its causes, consequences and possible solutions.

Investigating these mental representations of causal relationships, commonly described as mental models, will provide pivotal information to consider for future risk communication strategies as well as behavior change interventions. Exploratory approaches that allow researchers to elicit participants' in-depth thoughts can be used and combined with more standardized quantitative approaches to test the importance of social factors, such as perceived risk, for target outcomes. The mental model approach to risk communication is very well suited to bridge expert and non-expert perspectives on human-caused environmental issues such as MP.

Lastly, interdisciplinary research, combining findings from the natural sciences with insights from the social and behavioral sciences, should be undertaken to tackle the issue of MP in freshwater systems. The current report is related to the other contributions of the LimnoPlast project in the sense that knowledge about public perceptions of MP can provide crucial information for both researchers and policymakers. Since human behavior is the sole source of MP pollution, changing perceptions and behavior is key to tackling plastic litter in the natural environment.

4. ACKNOWLEDGEMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 860720. Responsibility for the information and views set out in this document lies entirely with the authors.

A revised version of this report will be published in the form of a book chapter in the book "Living in the Plastic Age. Perspectives from Humanities, Social Sciences and Natural Sciences", edited by Dr. Johanna Kramm and Dr. Carolin Völker.



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