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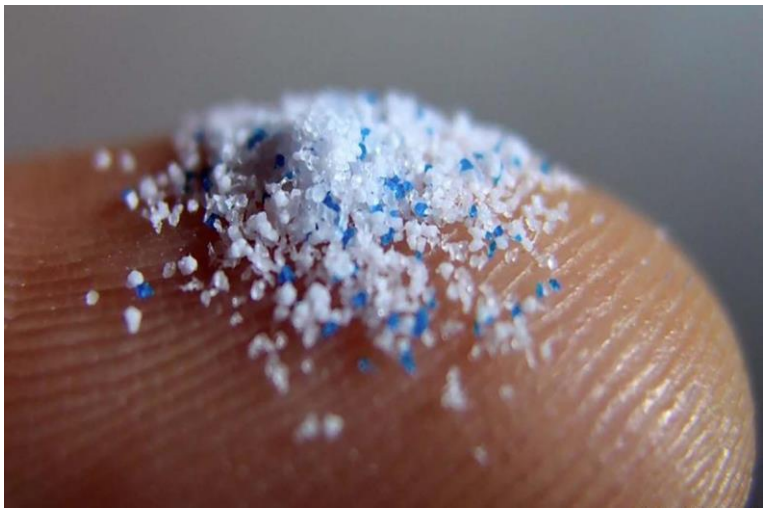

MASTER THESIS

DEALING WITH MICROPLASTIC POLLUTION IN THE NETHERLANDS: HUMAN HEALTH RISK ASSESSMENT AND POLICY MAKING APPROACHES

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PREFACE

Two thousand twenty is a year that will remain in history and marks a before and after in the modern world. After a hundred years, in the middle of modernity, the whole world is facing a pandemic. This situation unrevealed the real value of Public Health and awoke the vulnerability of humankind. This study exposes other potential global risk for human health: Microplastics. This thesis tries, to a lesser or greater extent, to present evidence, analysis and integrate insights from my background as a Biotechnology Engineer to address microplastics problematic from the perspective of human health risk.

I feel grateful to have the chance to complete this thesis as part of the master's program, Environmental and Energy Management from the University of Twente.

I would like to give special appreciation to both of my supervisors: Prof. Dr. Joy S. Clancy and Dr. M. Laura Franco-García, for their constant support and guidance. Their instruction made this thesis a journey of success. Also, I would like to thank Dr. Frans Coenen and Marielle Feenstra for their advice and initial insight about Microplastics regulations in the Netherlands. Last but not least, special gratitude goes to my family, who, even from the other side of the Atlantic, they always support my career journey.

Finally, I quoted from Mahatma Gandhi, *"It is Health that is the real wealth and not pieces of gold and silver."*

ABBREVIATIONS

ABS- Acrylonitrile-butadienestyrene

BPA- bisphenol A

ECHA - European Chemical Agency

EFSA - European Food Safety Authority

EU - European Union

LCA- Life Cycle Assessment

MPs- Microplastics

PAHs -Polycyclic aromatic hydrocarbons

PMPs- Primary Microplastics

POPs- Persistent Organic Pollutant

SMPs- Secondary Microplastics

WHO- World Health Organization

WWTP- Waste Water Treatment Plant

PCP- Personal care products

RIVM - Rijksinstituut voor Volksgezondheid en Milieu - National Institute for Public Health and the Environment

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GLOSSARY OF TERMS

Cosmetic : *"a product (excluding pure soap) intended to be applied to the human body for cleansing, beautifying, promoting attractiveness, or altering the appearance"* (FDA, 2020)

Cytotoxicity: In vitro test to determine if a particular item might cause any cell death as a consequence of toxic substances or from direct contact (Ramakrishna et al., 2015)

Detergents: *"any substance or mixture containing soaps and/or other surfactants intended for washing and cleaning processes"* (RIVM, 2016)

Disruption of the immune system: Described as alteration of the normal functionality of the immune system (Prata et al., 2019)

Oxidative stress*: "disturbance in the balance between the production of reactive oxygen species (free radicals) and antioxidant defences"* (Betteridge, 2000)

Toxicity: *"Deleterious or adverse biological effects elicited by a chemical, physical, or biological agent"* (EPA, 2020).

Translocation: associated with the transport of something from one place to another (Prata et al., 2019)

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ABSTRACT

Microplastics (MPs), the so-called plastic particles under 5mm in size, are recent ubiquitous pollution in the environment. Recently, concerns about implications in human health regarding these particles have arisen interest in the scientific community and governments. Scientific literature in recent years presents evidence that MPs can be a potential threat to human health. This research aims to analyse the situation of Microplastics in the Netherlands by conducting a Health Risk Assessment in combination with the analysis of measures implemented, which helps to assess MPs in the country adequately. The research methodology contemplated in-depth desk research with scientific literature, reports from ministry, NGO´s, and in-depth interviews with experts in the topic.

Moreover, the combination of both research methods led to recommendations to all stakeholders involved in Microplastics pollution. Findings showed that there is a significant lack of data regarding MPs testing methods, exposure, and concentration rates in humans. Experts said that this lack of information made it impossible to assess a MPs risk assessment fully. In the Netherlands, since 2014, measures to address MPs pollution were implemented and improved over time. Finally, this research concludes that MPs pollution is a complex issue in which actions should involve human health and its environmental consequences, which also concerns all countries involving producers, policy makers, product designers and consumers.

Key words: Microplastics, pollution, exposure, particles, Risk Assessment, stakeholders.

CHAPTER 1- INTRODUCTION

1.1 BACKGROUND

When we think of plastic, people automatically attribute the name as a specific material. However, plastics can be composed of several materials with specific and individual characteristics, which are specially designed for the intended purpose of use (Plastics Europe, 2019). In recent years, plastics started arising a global concern due to its prominent presence as contaminant in the world's oceans. (Law et al., 2010) In addition, it is estimated that every day, around 27,000 tonnes of plastics leak into the ocean waters, which corresponds to almost 10 million tonnes per year (Boucher & Friot, 2017). However, a modern world is not feasible without plastics, and we cannot have advanced medicine, computers and communication.

Plastic Production and Demand

In 2018, global plastics production climbed up to 360 million tonnes and, in Europe Plastic production account for almost 62 million tonnes. A closer look in the Netherlands market, plastic demands are estimated to be 4,3%, and it has increased by more than 20% since 2010. It is considered that the most significant plastic producer is the packaging industry, with a share of 35%. Plastic production brings to European society over 1.6 million jobs and turnover to the economy of more than 360 billion euros. In 2018, Europeans used around 51.2 tonnes of plastics, more specifically in the Netherlands, the country covers 4.3% of total demand (Plastics Europe, 2019).

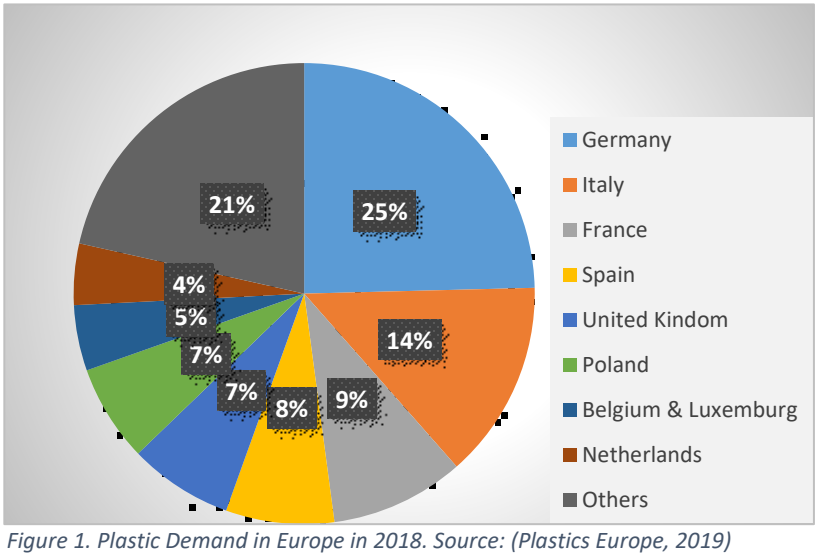

Figure 1. Plastic Demand in Europe in 2018. Source: (Plastics Europe, 2019)

What are Microplastics (MPs)?

As part of plastic pollution, other emergent contaminant started calling attention to the scientific community, politicians, and ecologists. The presence of small plastic particles in ocean sediments, marine biota, water column, air, freshwater including drinking water and the food chain (Alexy et al., 2019; Rios Mendoza et al., 2018) became a concern due to the potential implications for the environment and human health (Rios Mendoza et al., 2018). Despite there is no universally accepted definition regarding the size of Microplastics (MPs) (Van Cauwenberghe et al., 2015), in this research, MPs are considered particles with 5mm size since most of the scholars have considered that as standard for research (Andrady, 2011). These particles can be categorized as primary and secondary MPs, which are further explained in Chapter 2.

Transfer of MPs

MPs are considered ubiquitous in the environment (Toussaint et al., 2019); this means they can be found everywhere from food, water sources, sediments to terrestrial, and aquatic organisms. MPs can pass through existing Wastewater Treatment Plants (WWTP) filters and can be present in treated wastewater, drinking water and fresh water sources (Toussaint et al.2019); (WHO,2019); Leslie et al., (2017).

Transfer of MPs within the food chain

MPs can impact human health when freshwater sources and marine species ingest them during the daily diet, also can accumulate in the food chain in several ways (Galloway, 2015). Food can contain MPs when it is contaminated indirectly; this can happen when the aquatic organism ingests MPs and, are transferred to humans through the food chain. (Toussaint et al., 2019).

Possible effects of MPs in human health

Effects on human health regarding MPs pollution have been studied extensively. For instance, there is a risk that should not be underestimated, several researchers concluded that MPs are also capable of adsorbing and concentrating polluting substances present in the environment (Antunes et al. 2013; Teuten et al.,2009, Retrieved from Bellas & Gil, 2020). Moreover, some studies had described that MPs interact with other kinds of pollutants, such as metals, pesticides, and pharmaceuticals (Bellas & Gil, 2020). In this scenario, if MPs are absorbed, and they interacted with

other potentially harmful chemicals, further then they are ingested by humans, also representing potential risks for human health.

MPs pollution in the Netherlands

Particularly in The Netherlands, the Government has shown concern about MPs in the Dutch Marine environment since these particles are mostly part of the marine litter. Recently, The National Institute for Public Health and the Environment (RIVM), started evaluating the potential risks of MPs in the Dutch environment by evaluating the possible emissions and mitigation.

1.2 PROBLEM STATEMENT

Microplastics(MPs) are a well-known source of ubiquitous pollution that harms the environment and might have potential risks for human health. These small particles cannot be filtered in Waste Water Treatment Plants (WWTP) and, therefore are released to the environment through several pathways. Also, there is enough evidence that shows MPs are present in freshwater sources like rivers, and constant exposure to this kind of pollutant represents a potential risk for human health since these particles are ingested and inhaled indirectly. Despite the considerable concern to address MPs problem, initiatives for this problem are still focused on the marine environment pollution and marine litter impacts. Still, they do not address the indirect risks in Human health, and Public Health policies have little information about this subject. Thus, this is the gap in the literature that this study will try to contribute to, by analysing the potential routes and effects in human health to give some recommendations for further public health policy making.

1.3 RESEARCH OBJECTIVE

The objective of this research is to propose recommendations to the actors involved in Microplastics pollution to reduce the impact of MPs on human health in the Netherlands.

1.4 RESEARCH QUESTIONS

The following research questions are derived from the problem statement and the main research question is: What initiatives can contribute to reduce the impact of MP pollution in the Netherlands?

RQ.1. What are the most important sources of MPs in the Netherlands?

RQ.2 What is the potential human health risk of MPs pollution in The Netherlands?

RQ.3 How are policies addressing MPs risks in the Netherlands?

RQ.4 How can MPs pollution be strategically addressed in the Netherlands?

1.5 STRUCTURE OF THIS REPORT

This report is divided into six chapters, in which Chapter 1 presents an introduction of the plastics problem, demand, and the first insight about what MPs pollution is and its potential health effects. This information contributing to problem-solving, are obtained after conducting the research. The problem statement leads to further research questions to address in this research. Chapter2 describes the literature review, which also is a starting point to answer the research questions and is the basis of the execution of this research. Chapter 3 presents the research design, which includes the research framework, analysis of data, validating, and analytical framework. Section 4 presents all findings; every finding is presented per research question. This chapter presents a compilation of desk research and outcomes from interviews. Moreover, Chapter 5 presents the discussion of this research in which all the findings are discussed and analysed. Finally, Chapter 6 answers the overall research question and presents the conclusions and recommendations for policy makers and stakeholders involved in MPs pollution.

CHAPTER 2- LITERATURE REVIEW

2.1 PLASTIC FORMATION AND CLASSIFICATION

Plastics have a history of over a hundred years; the earliest invention was conducted around 1855 (Plastics Europe, 2020b), and since then, plastics became an essential part of human life.

Plastics are made with several kinds of materials, but mostly from crude oil sources. In this sense, plastic categories can be sorted into two leading families: Thermoplastics and Thermosets (Plastics Europe, 2020). The first category is related to plastics that are soften when heated and can be recycled, this kind of plastics are used on carpets, clothes, and furniture. The second category is plastics, which are moulded and rigid, and they remain in that way, such as car bodies or work surfaces (Plastics Europe, 2020). Table 1 presents examples of what kind of plastics belong to each category.

Table 1. Plastic Family classification: Thermoplastics and Thermosets Source: Plastics Europe, (2020)

Examples of Thermoplastics	Examples of Thermosets
Acrylonitrile butadiene styrene (ABS)	Epoxide (EP)
Polycarbonate (PC)	Phenol-formaldehyde (PF)
Polyethylene (PE)	Polyurethane (PUR)
Polyethylene terephthalate (PET)	Unsaturated polyester resins (UP)
Polytetrafluoroethylene (PTFE)	
Polyvinyl chloride (PVC)	
Polymethyl methacrylate (PMMA)	
Polypropylene (PP)	
Polystyrene (PS)	
Expanded Polystyrene (EPS	

The Plastics Europe organization presents the most common types of plastics and some applications. Appendix 1 shows the description and classification of each type of plastic.

2.2 PLASTICS ADDITIVES

When plastics are manufactured, more specifically, in the polymerization process, some solvents, catalysts, and other additives are used to give plastics a specific characteristic. Some examples of these additives are stabilizers, flame retardants, pigments, and fillers (Lithner et al., 2011).

These additives have the particularity of transforming the nature of the final plastic. There is a vast list of additives used in plastic production, and some plastics use more than others. For instance, Polyvinylchloride (PVC) is the plastics that use more additives in its manufacturing process, which includes some phalates that are added to give more flexibility (Galloway, 2015). The risk for humans is that harmful chemicals can leach from these plastics. Some of these chemicals are retardants from ABS or urethane foam and bisphenol A (BPA) from polycarbonate. These additives are a constant concern for human health since some of these additives can also be transferred through food packaging into the food chain (Galloway, 2015).

Additives enhance the properties of the plastic but there are considered a potential environmental pollutant and a risk for humans. For instance, (BPA), which is a retardant and used as an additive in several plastics products, has been proved to be an endocrine disruptor. That means the substance can alter hormone activity that leads to several diseases such as breast cancer, reproductive issues, learning problems, and metabolic disorders. Furthermore, phthalates and flame retardants are also additives that concern human health. They can have similar effects as BPA, such as reproductive problems and cancer. Some regulations, such as in the EU, are enforcing the limited use of these additives (Campanale et al., 2020).

2.3 MICROPLASTICS CLASSIFICATION

2.3.1 Primary Microplastics

Primary Microplastics (PMPs) are defined as particles which are manufactured as micro particles, its use is mainly for the cosmetic industry and personal care products, for instance, products like toothpaste, shower gel, scrubs (WHO, 2019; Leslie et al., 2011). Plastic ingredients are included in a wide range of cosmetics formulation, and these particles are also considered as PMPs. Its functions in those products can consist of film formation, viscosity regulation, skin conditioning, emulsion stabilizing, and many others. Personal care products that can include MPs in its formula are soap, shampoo, deodorant, toothpaste, wrinkle creams, moisturizers, shaving cream, among others (Leslie, 2014). When these products are used, MPs are rinsed off and end up in household wastewater streams. A fraction of MPs (from multiple sources) end up in wastewater streams and remain in sewage sludge, and the rest is released to surface waters via treated wastewater effluents Leslie, (2014). Other authors consider as Primary classification those MPs that are released directly into the environment such as Rubbing tires and textile fibres (Boucher & Friot, 2017).

2.3.2 Secondary Microplastics

Secondary Microplastics (SMPs) are defined as plastic particles which are formed by the fragmentation of larger plastic items such as bags, bottles, clothing, tires, and others (WHO, 2019). The rates and routes of transport of SMPs can include sea-based and land-based sources. The first one comprises plastic litter dumped overboard from ships and waste fishing gear. The second one, which eventually reaches the sea, includes human recreational activities, agricultural plastics, uncovered plastics landfills (Leslie et al., 2011). Other sources of secondary MPS are described in the literature are shipping and air emission of MPs possibly emitted during sandblasting during construction work. However, the atmospheric deposition of MPs in the sea is still unknown at present (Leslie et al., 2011). Figure 2 shows schematic representation of sources of plastics related to Primary and Secondary MPs emissions.

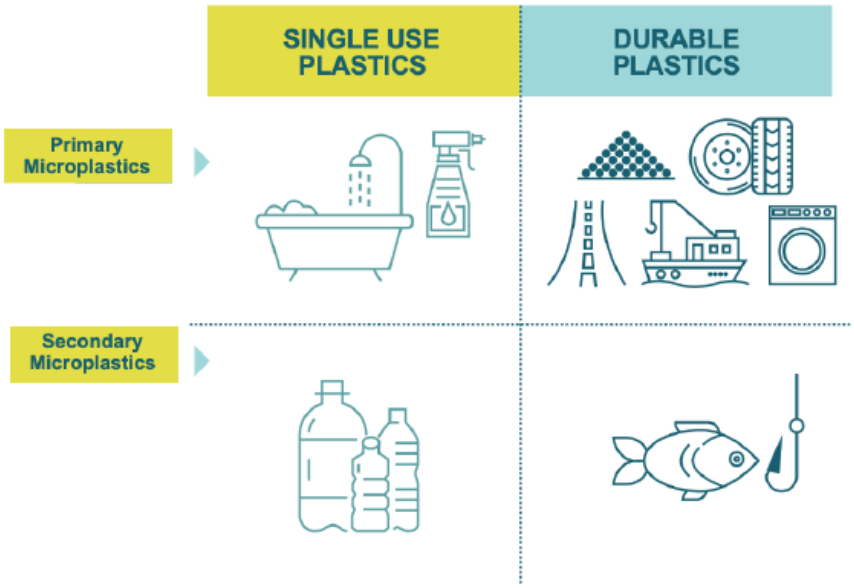

Figure 2. Primary and Secondary MPs. Source: adapted from (Peano et al., 2020)

2.4 WORLDWIDE MICROPLASTICS RELEASES AND SOURCES

Globally, the more significant amount of MPs comes from (PMPs), between 15% and 31% of all plastic pollution that is present in the environment could come from primary sources (Boucher & Friot, 2017). It is estimated that between 0.8 and 2.5 Mt/ year of primary MPs are released to the environment worldwide. On a European scale, primary MPs release accounts on average 0.95

million tonnes/year annually. However, plastics added in synthetic fibers for textiles or synthetic rubber for tires are not accounted for in those statistics (Boucher & Friot, 2017).

Tyres, synthetic textiles, marine coatings, road markings, personal care products, plastic pellets, and city dust are considered the main sources of MPs pollution in the world (Boucher & Friot, 2017). Of the primary MPs releases, 98% are originated from land-based activities, and the rest (2%) is originated from sea activities (Boucher & Friot, 2017). Figure 3 explains which source of MPs comes from which activity. In the case of secondary MPs, it is predicted that most of the releases come from mishandling plastic waste, but that also depends on waste management in each country. Figure 3 presents a schematic representation of MPs sources coming from on land and at sea activities.

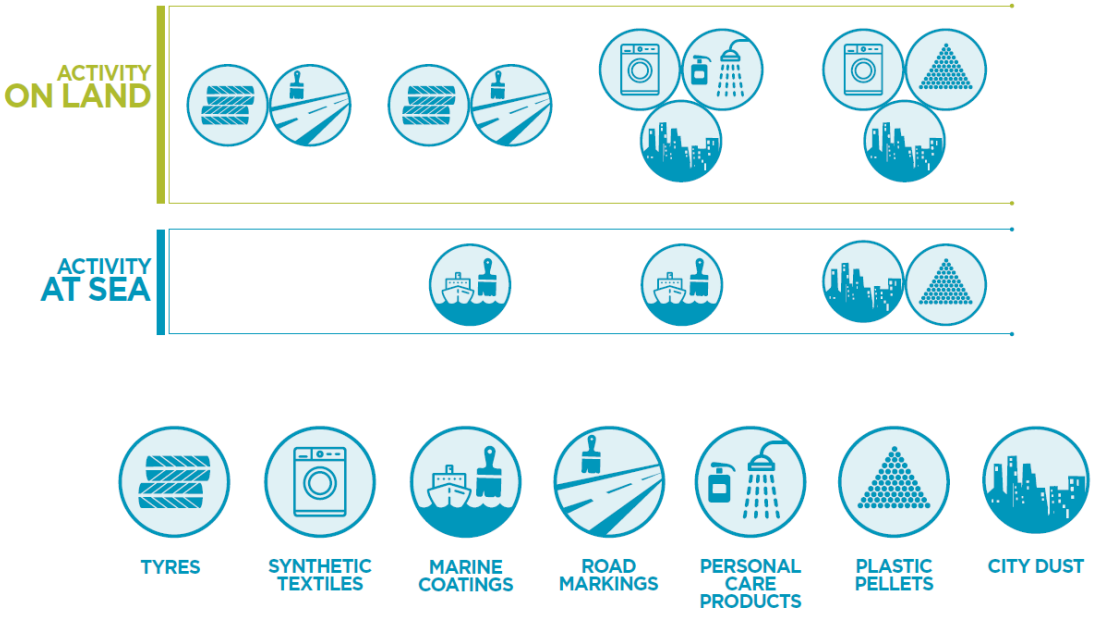

Figure 3. Microplastics Sources Worldwide. Source: (Boucher & Friot, 2017)

2.5 MICROPLASTICS ROUTES OF EXPOSURE TO HUMANS

Humans can be exposed to MPs by three means: inhalation, ingestion, and dermal contact. These routes can potentially lead to chronic inflammatory lesions (Prata et al., 2019; Revel et al., 2018). These three main routes are described as follows.

2.5.1 Ingestion

This route is considered the primary source of human exposure to MPs (Galloway, 2015). Some studies have shown that food and beverages can contain MPs. For instance, Koelmans et al., 2019 reported that there are a significant amount of studies that indicate the presence of MPs in freshwater and drinking water. However, the way the sample is managed can significantly differ from each research. In addition, it was reported that poor plastic quality such as recycled plastic could have more amount of MPs but, there is still a lack of quality data to reference MPs values (Zuccarello et al., 2019).

Furthermore, MPs have been reported in food chain items in the past years. For instance, Karami et al. found the presence of MPs in German beer and salt samples (Revel et al., 2018). There is extensive research that aquatic organism ingests MPs (Xu et al., 2020), and how this is introduced into the food chain. After ingestion, MPs particles reach the gastrointestinal system and can lead to inflammatory responses, increased permeability of the gut wall, and changes in gut microbe composition and metabolism (Salim et al., 2014).

2.5.2 Dermal contact

This route is associated with contact of skin with products that contain MPs. In this case, this route is highly linked to cosmetics and personal care products(PCP) that included MPs in its formulation, like facial scrubs (Prata et al., 2019). These particles are very small, usually no larger than a millimetre, and many of them are considered invisible (Leslie, 2014). Also, human dermal contact with MPs can also occur during washing or swimming in contaminated water . However, due to its size, MPs absorption through the skin is considered *"unlikely to occur"* (Revecurl et al., 2018). Still, there is an urgent need for further research in this area.

2.5.3 Inhalation

MPs have been detected in atmospheric dust, suggesting that this can be a possible source of inhalation exposure (Revel et al., 2018). MPs can be released to the air by numerous sources, including synthetic textiles, abrasion of materials such as car tires and resuspension of MPs in surfaces (Prata et al., 2019). Inhalation of MPs can lead to respiratory problems and disruptions in lung cells (Xu et al., 2019). In addition, other sources of exposure via air route are the presence of plastic fibres released from textiles. Also, MPs can be inhaled while moving in certain areas such as industrial areas or some specific workplaces where it was shown higher risks of MPs exposure. Moreover, MPs are also present in food that is exposed to air dust. (Toussaint et al., 2019). It has

been estimated that single inhalation of airborne MPS can be in a range of 26–130 MPs per day. However, this calculation may vary depending on sampling methodologies and some other factors such as cleaning habits, type of furniture, exposure activities (Prata et al., 2019), and location.

2.6 MICROPLASTICS TOXICITY

Plastic toxicity can be difficult to address, and some authors think that polymers used in plastics products are generally harmless (Hwang et al., 2019). Although plastics are chemically inert, a large number of organic compounds are used as additives as it was presented in section 2.2. In terms of toxicity, it has been studied that small plastics particles are ingested by zebrafish and can cause tissue damage. Moreover, MPs toxicity can be generally associated also to residual monomers such (BPA), which is present in plastics and can leach out when ingested. BPA can lead to anaemia, hepatic and renal injuries (Moselhy, 2015). Secondly, toxicity can be related to intermediate compounds like Polystyrene and other aromatic compounds that are released from partial degradation of plastics (Andrady, 2011).

In general, there are three major concerns regarding MPs effects on human health, such as physical effects, chemical toxicity, and bacteria adherence, which are explained in detail in section 4.2 Risk Assessment.

2.7 MICROPLASTICS ROUTES OF EXPOSURE

Once MPs have reached the human body, the particles can provoke several pathways that alter the normal homeostasis in the body. These pathways were reported by (Prata et al., 2019) (Figure 4) and are described as oxidative stress, cytotoxicity, translocation to other tissues, and disruption of the immune system. In this section, an overview of these pathways is presented. Figure 4 offers a graphical explanation for a better understanding of the effects and pathways in which MPs can affect human health, and Table 2 summarizes the mentioned pathways of exposure.

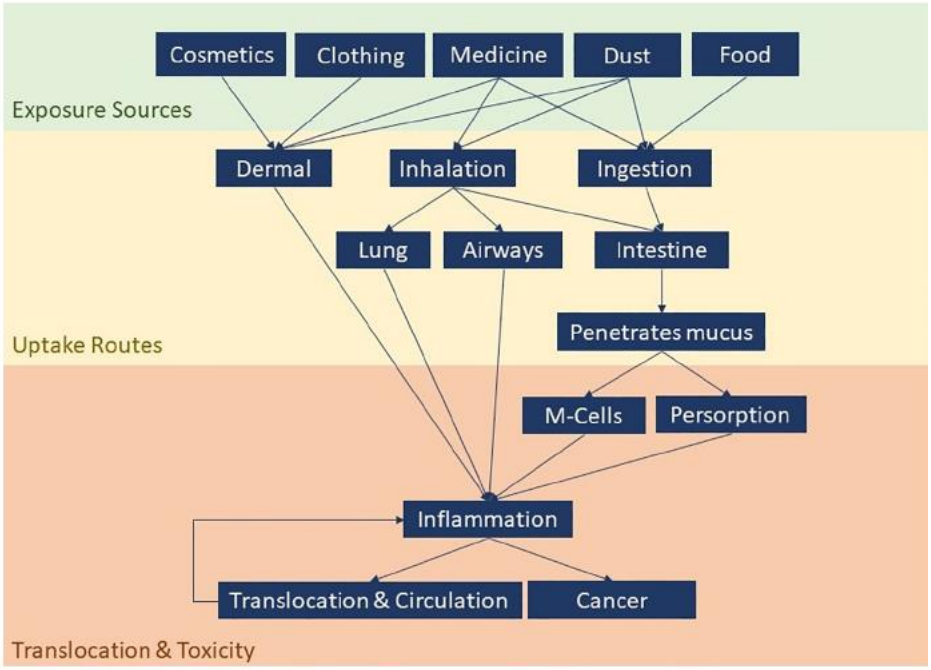

Figure 4.Pathways and MPs toxicity in the human body . Source: Prata et al.,2019.

Table 2. MPs pathways of exposure.

Pathway	Description	Source
Oxidative stress	When MPs enter the human body, some reactions can be triggered, which leads to inflammatory responses, this can lead to the increased incidence of degenerative diseases and even cancer, if under high concentrations and depending on an individual's susceptibility to react to MPS. It has been reported in the literature that MPS can provoke oxidative stress in mice and zebrafish.	(Prata et al., 2019)
Cytotoxicity	Several studies linked cytotoxicity to MPs.	(Hwang et al., 2019) ;(Schirinzi et al., 2017); (Xu et al., 2019)

Translocation	In the case of MPs, they can act in a specific area or transport to other tissues. This characteristic is more likely to occur during inflammation and can also lead to permeability in epithelial barriers. Translocation of MPs has reported in rats. Also, it has been reported that particles can be permeable in human placenta.	(Prata et al., 2019)
Disruption of the immune system	Particles are recognized by immune cells as intruders, which lead to activate immune activity. When particles produce oxidative stress or translocation, they also activate the immune system, as a consequence of this mechanism autoimmune responses are triggered which can lead to autoimmune diseases such as lupus, or rheumatic diseases	(Prata et al., 2019)

2.8 RISK ASSESSMENT METHODOLOGY

Risk assessment is a tool that can be used to determine the risks and potential impacts of a particular substance or chemical (World Health Organization, 2010). In this research, MPs and its Risk Assessment is addressed to identify the potential human health risk associated with this environmental problem. However, this tool is also challenging due to the complexity of MPs toxicology, its interaction with other contaminants, or the inclusion of health effects in different contaminant categories (Prata et al., 2019).

The World Health Organization(WHO) has been working extensively on risk assessment criteria. It has estimated that *"more than 25% of the global burden of disease is linked to environmental factors, including exposures to toxic chemicals*" (World Health Organization, 2010). To elaborate on an adequate human health risk assessment, WHO recommends the following three steps: identification, compilation, and integration of information on the health hazards; analyse human exposure and relationships among exposure, dose, and adverse effects of a specific chemical (World Health Organization, 2010). However, one obstacle is that often MPs are very different in terms of surface properties, weathering, and adsorbed chemicals and organisms, which sometimes lead to inaccurate conclusions. There is a concern in the scientific community where more studies are needed to fully understand the risk of MPs to human health, exposure, pathogenesis, and effects(Prata et al., 2019).

2.8.1 Risk Assessment Toolkit Framework.

To know which chemicals or substances can harm human health, WHO developed the "Human Health Risk Assessment Toolkit" (HHRAT). This tool is an instrument that is used by organizations that aim at helping people to make decisions about the use of chemicals. The HHRAT is meant to assess the significance of potential risks to human health associated with exposure to certain chemicals. This framework addresses four main steps: Hazard identification, Hazard Characterization, Exposure assessment, Risk Characterization (World Health Organization, 2010). Each stage aims to give detailed information about the chemical of study, and the intention is to provide evidence and support on how to handle hazardous materials. Table 3 presents the content and description of the information needed for each step of the Risk Assessment Toolkit.

Table 3. Description and content in Risk Assessment Steps Source: (World Health Organization, 2010)

Step	***Description***	***Content***
Problem formulation	Establishes the scope and objective of the assessment	Defining the question Prior knowledge Desired outcomes
Hazard identification	Identifies the type and nature of adverse health effects	Human studies Animal-based toxicology studies In vitro toxicology studies Structure–activity studies
Hazard characterization	Qualitative or quantitative description of inherent properties of an agent having the potential to cause adverse health effects	Selection of critical data set Modes/mechanisms of action Kinetic variability Dynamic variability Dose–response for critical effect
Exposure assessment	Evaluation of concentration or amount of a particular agent that reaches a target population	Magnitude Frequency Duration Route Extent
Risk characterization	Advice for decision-making	Probability of occurrence Severity Given population Attendant uncertainties

The steps indicated in table 3 are further described as follows: i)hazard identification consists of determining the precise identity of the chemical, which means to consider previous hazardous information. This information can be obtained from different sources like operational documents or MSDS[1] data sheet. Moreover, the identification should also contemplate other chemicals that could

[1] MSDS: Material Safety Data Sheet (MSDS) is a report which presents information regarding potential hazards of a chemical such as (health, fire, reactivity and environmental) and explains how to work safely with it. In this case MPs does not have a special MSDS data sheet.

behave different when they are alone or mixed with other ones. ii) The hazard characterization is related to the technical aspects of the compound of study. Also, it includes a quantitative and qualitative description and properties, potential risk against health, and sources of dissemination. Hazard characterization also includes toxicological guidance values. iii) The exposure assessment is useful to determine the capacity of the chemical in the study to be harmful within time, media, and quantities. This characterization is essential to understand the information available, determining short-term, medium-term, long-term exposure to create appropriate guidance for health risk. iv) Finally, the last step of the risk assessment procedure is the risk characterization which involves cancer estimation and other risk associated with an approximated exposure. The road map of this tool is explained in Figure 5.

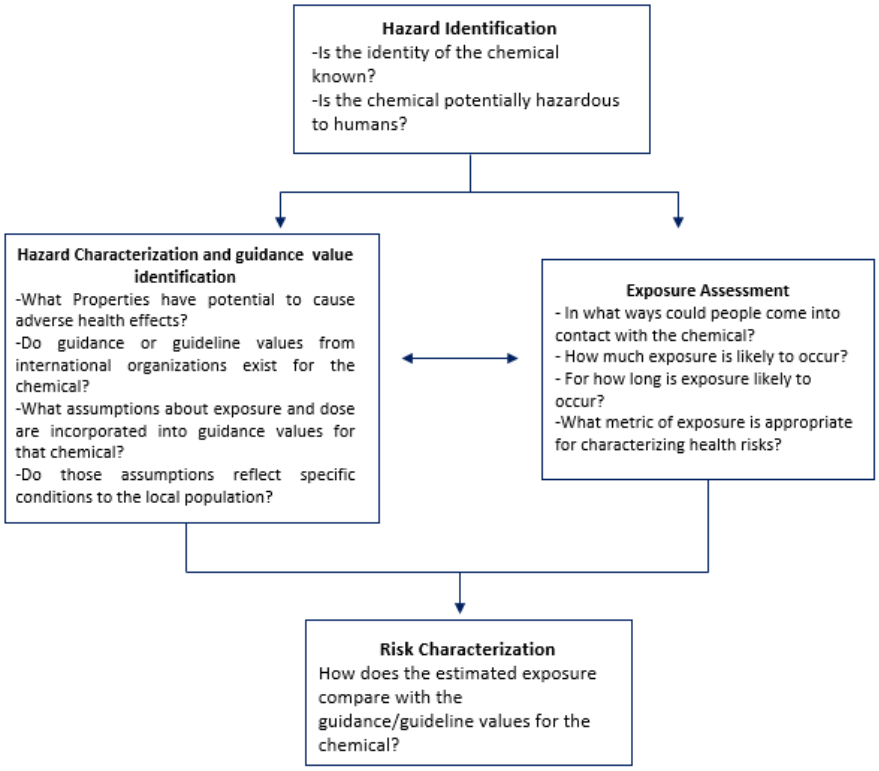

Figure 5. Risk Assessment Roadmap. Source: (World Health Organization, 2010)

The Assessment Toolkit describes several levels according to the amount of information gathered; this information can be either qualitative or quantitative (World Health Organization, 2010). Levels can go from level 1 up to level 4; these levels intend to add more information when it is available. Appendix 2 shows in detail every Level of Risk Assessment.

2.9 POLICY CONTEXT FOR MICROPLASTIC POLLUTION

This section describes several initiatives regarding policies associated with MPs pollution at the EU level. Since MP pollution is a broad topic, the most relevant measures to undertake MPs pollution are presented first at the EU level, which establishes the foundation for the policies in the Netherlands. The policy-making that confronts MPs problematic is not clear enough. At present, there is not a current policy that includes a MPs ban itself at the EU level. Table 4 summarizes all MPs policy context at the EU level, and Table 5 presents policies regarding MPS pollution in the Netherlands.

For policy makers a way to monitor plastic pollution is by using tools such as Life Cycle Assessment (LCA), which can be useful to quantify the potential environmental repercussions across the lifespan of a product. However, current LCAs do not consider plastic as a contaminant and assume that 100% of used plastics streams go to the landfill, incineration, or recycling. There is a significant lack of data to determine the impact assessment of plastics and MPs through LCA frameworks (Boucher et al., 2019).

Table 4 Policies Regarding MPs pollution at EU level

Policy	Description	Last update	Source
MPs in Cosmetics	In 2018 The European Commission decided to initiate the same procedure, the Commission asked the European Chemical Agency (ECHA) to prepare a document called "dossier" for banning MPs in cosmetic products	Evaluation stage	(Kentin & Kaarto, 2018)
REACH[2] regulation	Evaluation of the addition of MPs to REACH´s restrictive list.	Evaluation stage	(Kentin, 2018
The EU Plastics Strategy	Initiative linked to the strategy for Circular Economy (CE) within the EU called "European Strategy for Plastics in a Circular Economy," which was adopted in 2018	2018 the EP fisheries Committee called for further actions in this topic.	(SAM, 2018).
The European Food Safety Authority (EFSA)	In 2016, this organization conducted a MPs risk assessment in food. Their report concluded that there was scarce data to suggest that MPs can have potential risk for humans. The report also stated that there are several gaps in the impacts and toxicity for human health regarding MPs, and further consequences when plastic particles are immersed in cells is still unknown.	No legislation for MPs as a contaminant in food because the risk of MPs ingestion through seafood is less likely to occur.	(SAM, 2018) (EFSA CONTAM Panel, 2016)

[2] Registration, Evaluation, Authorisation and Restriction of Chemicals.

Water Framework Directive	this directive does not force Member states to undertake actions in the water bodies; they are only required to report what are the strategies to prevent pollution in water sources.	Currently, this directive does not directly state MPs pollution.	(SAM, 2018) (Brennholt et al., 2018)
Drinking Water Directive	The Commission proposed to also include MPs measures in drinking water). The amendments included an agreement among member states to promote clean water for all citizens, and this should be reflected in the water standards of every member. Also, the proposal established the maximum limits of some pollutants and the control of MPs in drinking water.	Evaluation stage.	(SAM, 2018) (European Parliament, 2020)
Air pollution Policies	Two primary directives for air pollution: a)Directive 2004/107/EC related to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in air and; (b) Directive 2008/50/EC on "Ambient air quality and cleaner air for Europe."	MPs, as such, are not addressed in any of these directives. In Airborne MPs and synthetic fibres fall into different size standards.	(SAM, 2018)

Table 5. Policies Regarding MPs pollution in the Netherlands

Policy	Requirements	Latest update	Source
Cosmetics	All cosmetics sold in the country need to comply with the EU regulation 1223/2009, which regulates security, composition, and labelling of the personal care products. All cosmetic products must follow the Commission Decision 96/335 which set the parameters for labelling ingredients in cosmetic products	These directive does not include MPs. Any changes will immediately impact Dutch policies	(RVO, 2020)
Drinking Water	All drinking water companies need to carry out tests and measurements to screen the quality and comply with the Dutch Drinking Water Decree	These standards do not include MPs.	(RIVM, 2018) (Government of The Netherlands, 2020)
Air policies	Companies in the country are required to request an environmental permit and implement a control system to monitor emissions. The specific standards are detailed in the Environmental Management Act. Concentrations are defined in the Air Quality Assessment Regulation	The air quality is based mostly on two parameters: particulate matter PM10 and nitrogen dioxide NO_2, not MPs.	(Rijkswaterstaat, 2020a)
Wastewater treatment	It is decentralized through local governments. Each municipality must follow the Urban wastewater Directive 91/271/EEC. All wastewater that is discharged needs to be treated in a plant.	No standards for MPs filtration	(Rijkswaterstaat, 2020b)
Public Health	Public health is addressed at the municipal level. The Dutch Health Care inspectorate is the instance that is in charge.	Any	(Jansen et al., 2012)

2.10 SUMMARY OF KEY ASPECTS

This section provides the key aspects from Chapter 1 and 2 to a better understanding in the following sections. Key aspects are presented as follows:

- MPs are defined as plastic particles with less than 5 mm in size and are classified in two categories: primary MPs which are engineer plastics that are manufactured with micro size shape and the so called secondary MPs which are the ones that come from degradation of plastic materials.
- MPs can be found anywhere, from air and water to food and beverages. For instance, humans are exposed to MPs by ingestion, inhalation, dermal contact. Detailed explanation is presented in section 4.2 Risk Assessment.
- At present, there is no specific regulation about MPs either in the EU or The Netherlands.

CHAPTER 3- RESEARCH DESIGN

This chapter describes the research design and the methods used to gather and analyse the information needed to address the research question of this research. The present chapter also describes the research framework, conceptual framework, research method, and research strategy.

3.1 RESEARCH FRAMEWORK

The research framework implies a *"schematic presentation of the research objective"* (Verschuren et al., 2010), which means to achieve the research objective, it is important to follow several steps to identify a clear objective and a research perspective. In this research, as presented in chapter 1, the objective is to identify possible routes and emission of MPs pollution in the Netherlands and analyse how policies can address this topic to formulate further recommendations for public health policies. Moreover, the perspective of this research is to evaluate MPs problematic in the Netherlands by using an evaluation research method: a risk assessment study. The risk assessment criteria are based on information about MPs routes of pollution, Toxicity, and Exposure from scientific literature and reports from the Dutch Ministry of Health. Then, this is interlinked with the analysis of the current policies regarding this problem in the country. To address the research objective, two sources of information are required: Desk research and interviews with experts. Desk research is used to gather technical data about MPs sources, toxicity, pathways, risks, and policies.

Furthermore, some interviews with experts also will be necessary to analyse the linkage of risk assessment and current public health policies. Hence, this research is inclined towards evaluative and descriptive forms of research. Figure 6 shows the schematics representation of the research framework.

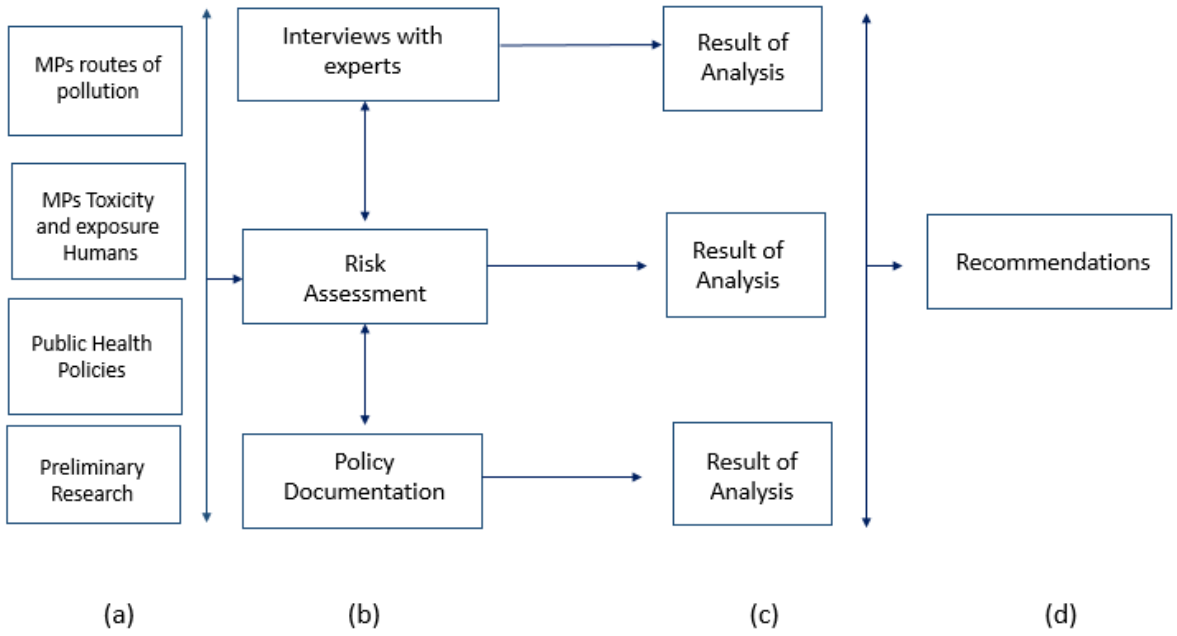

Figure 6. Figure X. Research Framework (own elaboration)

(a) Study about MPs possible routes, toxicity, and exposure in humans and analysis of current evidence on public health policies in the Netherlands.
(b) Through which the research objective is addressed.
(c) Result of the Analysis and confrontation with risk assessment as the basis for recommendation
(d) Recommendations to achieve the research objective.

3.2 RESEARCH STRATEGY AND METHODOLOGY

The strategy of this research is considered a single case, which means that it is focused on MPs case in depth. The research methodology aims to address each question separately, predicting what would be the expected outcome of the method chosen to obtain the relevant data. Table 6 explains in detail the research methodology in this research.

Table 6. Research Methodology

Research Question	Research Method	Target Group	Expected output
RQ1. What are the most important sources of MPs in the Netherlands?	Desk research	Peer reviewed publications Reports from Ministries and organizations Official websites from NGO´s and government	Analysis of the potential risk from every MP source in the Netherlands
RQ2. What is the potential human health risk of MPs pollution in The Netherlands?	Desk research	Peer reviewed publications Documents	Elaboration of health risk assessment based on WHO toolkit, which indicates how to determine the exposure and the further implications for human health.
RQ3. How are policies addressing MPs pollution in the Netherlands?	Desk research Interviews	Policy documentation Reports from Ministries and organizations Interview with experts	Get in-depth knowledge of the current status of public health policies in the Netherlands. Analyze gaps regarding MPs in current decision-making processes.
RQ4. How can MPs pollution be strategically addressed in the Netherlands?	Desk research Interviews	Policy documentation Interview with experts	Risk Assessment determines the magnitude of the issue, resources needed, and environmental/health risks regarding MPs. This question is also baseline to give further recommendations. This question will include the knowledge acquired from sub-questions 1 and 2.

Desk Research:

This method involves identifying and reviewing existing and reliable secondary data sources such as academic literature, peer-reviewed journal articles, reports from government and organizations. Desk research was possible and accessible through the access to databases like Web of Science, Google Scholar, science direct, and other similar scientific databases. In addition to this, official web sites from the government and NGOs presented valuable data.

In-depth Interviews with Semi-Structured Questionnaire:

The initial plan for this research was to have one-on-one discussions with experts in the MPs field who can give an insight of the problem in the Netherlands. The outcome of these interviews adds value to information to answer the research questions. However, due to the Corona Virus outbreak and the measures in place, including restrictions in using public transportation, all the interviews were only possible through skype and phone calls. Table 7 presents the experts interviewed for this research.

Table 7. Research Interviews

Name	Position	Organization	Response
Daniel Poolen	Plastic Leak Expert	--	Phone interview
Prof. Dick Vethaak	Expert and researchers Microplastics risk assessment and researcher	Deltares	Phone interview
Stefan Kools	Researcher in MPs in water	KWR – Water Research Institute	Skype meeting
Sophie Vonk	Member and research MPs and Risk Assessment	Plastic Soup Foundation	Zoom meeting
Peter Boogard	Toxicology expert	Shell	Skype Meeting

Limitations of this study

Due to time constraint and the current coronavirus emergency, several limitations were found during the research process. These limitations are:

- **Interviews:** as result of measures to prevent the spread of the virus, all the employees in companies and NGOs were working from home for over three months, which made much difficult the communication to arrange interviews. Eventually, some other member of the organization has the knowledge to answer about the topic, and the internal communication among members produced an inevitable delay for scheduling interviews. Moreover, the interview process was conducted through online platforms or phone, which made the process impersonal, and the flow of the conversation was significantly different than personal interviews.
- **MPs in the marine environment:** Microplastics pollution is a broad and complicated issue, it still is challenging to separate it from the environmental effects in the marine environment. Due to the time limit, this research is only focused on all the MPs impacts and implications in human health.

Ethics statement

Following the Ethic procedures from the University of Twente stated in the Research Ethics Policy (2019), this research explicitly respects ethical standards of this policy, which includes providing the interviewee a Consent Form for the interview approval and an Interview Form with questions which were sent in advance. The interviewee was informed about the procedure in advance and is allowed to stop the interview at any time. The outcomes of the interviews are preserved the keep confidential any other information they request to be kept so.

3.3 DATA ANALYSIS

Qualitative methods are a way to study problematics, in-depth, and detailed approach. In this research, qualitative data analysis is used. This means to create a systematic analysis of in-depth interviews and rigorous desk research. Table 8 presents Data required in this research and type analysis used.

3.4 VALIDATION OF DATA ANALYSIS

Validation of data analysis is done through triangulation. To prevent bias, triangulation with several sources of information is compared to present data with accuracy. Moreover, Figure 7 shows the schematic representation of the analytical framework of this research in which all four research questions are presented. In this schematization, the information from the literature review was analysed in questions 1,2, and 3. Data from interviews was used to analyse measures and to elaborate the MPs strategy in the Netherlands complemented with scientific literature. Recommendations are developed as a result of the analysis of four questions.

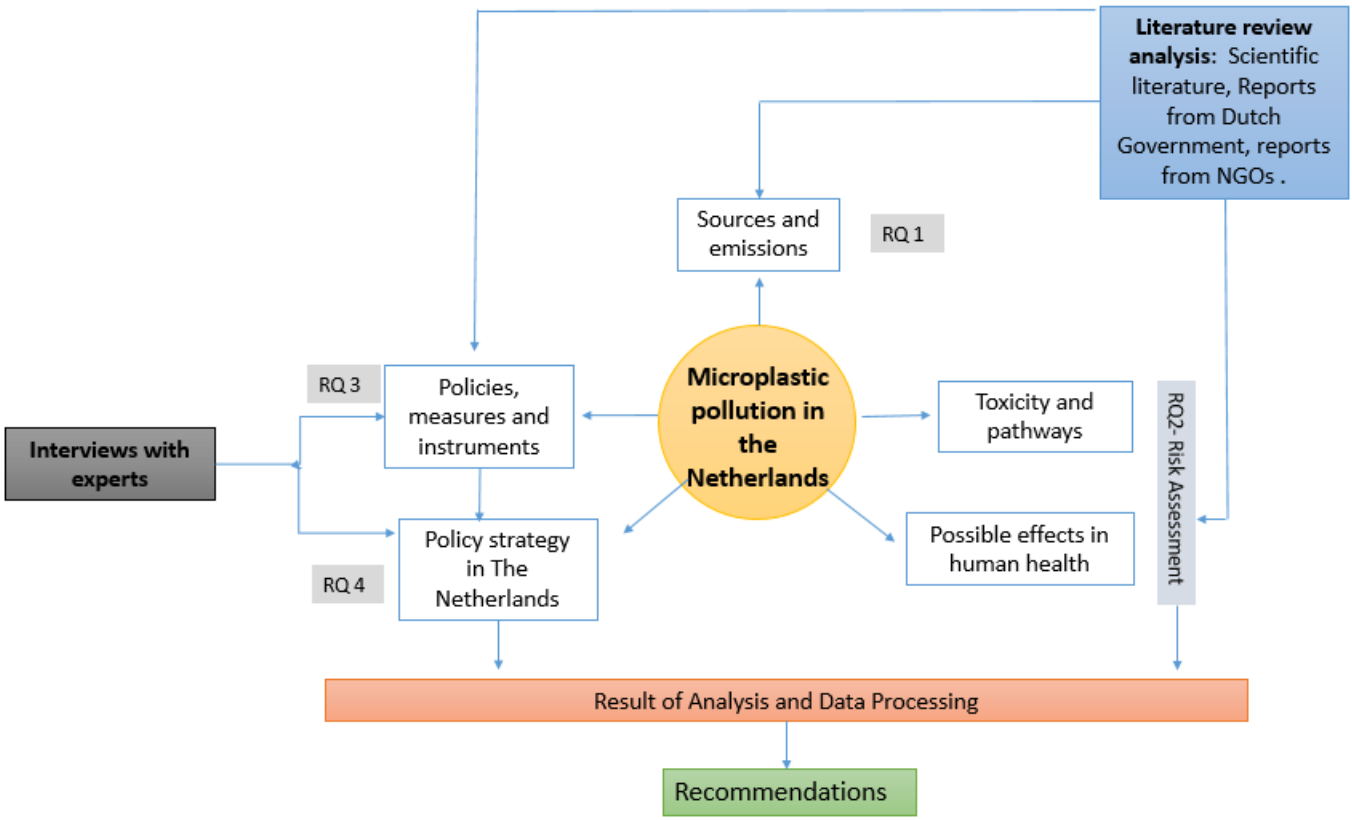

Figure 7. Analytical Framework (own elaboration)

CHAPTER 4- FINDINGS

This section presents the outcome of extensive literature scrutiny in combination with interviews with experts in MPs that aims to answer the main research question: *What initiatives can contribute to reduce the impact of MP pollution in the Netherlands?* and the sub research questions. Each subtopic addresses each research question previously defined. Every research question is addressed separately for a better understanding.

4.1 MICROPLASTICS SOURCES IN THE NETHERLANDS

To understand the most important routes of MPs in the Netherlands, I restate that MPs can pollute the environment worldwide as it was described by (Boucher & Friot, 2017) with seven primary sources: tyres, synthetic textiles, marine coating, road marking, personal care products, pellets, and city dust. However, in the Netherlands, RIVM- The National Institute for Public Health and the Environment prioritized MPs sources and emissions by establishing a prioritizing list to address MPs problem evaluating primary and secondary MPs sources in the country. The mentioned list evaluates the following sectors (RIVM, 2014):

- Waste disposal
- Agriculture
- Construction
- Nature
- Chemical industry
- Other industry
- Consumers
- Refineries
- Drinking water provision
- Sewers and water treatment plants
- Energy sector
- Traffic and transport
- Trade, services, and government
- Other sources

The full prioritizing list mentioned is presented in Appendix 4, which considers specific activity or products. According to the report, a complete assessment was carried out with literature, experts and sources from the Pollutant Release and Transfer Register to elaborate the list focused on land-based sources (RIVM, 2014)

The sources mentioned are prioritized by how should the emission and reduction be addressed. The list presents the possible sources of MPs in order of priority; the scores are based on a scale from 1 to 9, in which 9 is the highest priority. The list also indicates a separate criterion with scores from 0 to 2 (See Appendix 2 for full list). Moreover, the prioritizing list was elaborated to indicate which actor is concerned with the policy measure. This means that a particular product/service can appear several times, which suggests that several actors have different responsibilities regarding MPs in the Netherlands. The top scores of this list are packaging material (Score:9), litter in general(Score:8), cosmetics, paints, tyres, clothing fibers, runoff of paved surfaces (All Scored:7). Furthermore, RIVM considered that the distinction to weather MPs are intentionally or not added to the products is not relevant from an environmental context (RIVM, 2014). As presented in Figure 8 below, the discharge of MPs from different sectors in the Netherlands eventually reaches water sources.

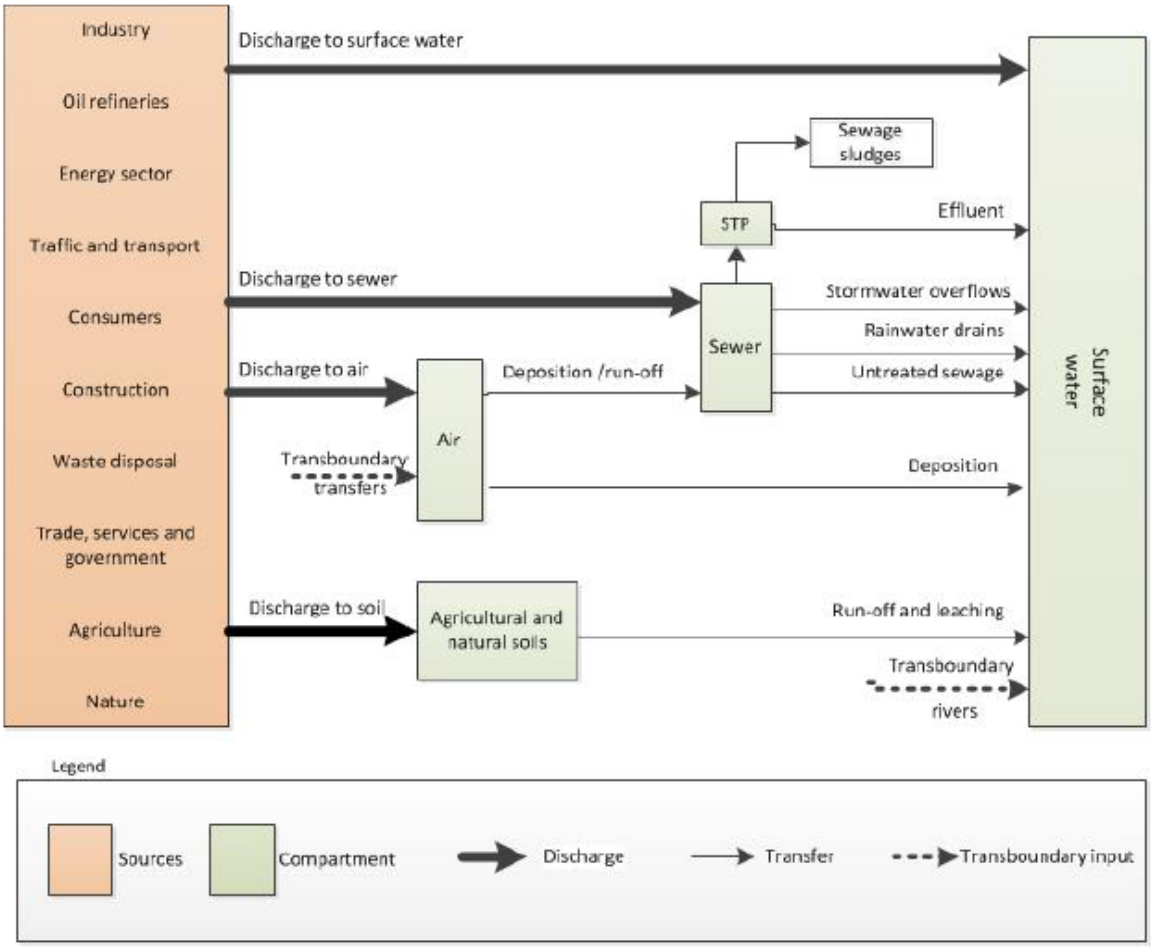

Figure 8. Transfer of MPs in the environment. Source: (RIVM, 2014).

The focus of the government to assess MPs pollution in the country is land-based activities. As it is shown in Figure 8, the left side shows land-based activities that can lead to MPs leakage, which also presents the possible contamination routes represented with arrows and sub compartments that afterward lead to MPs presence in surface waters. In this sense, RIVM acknowledges that surface water is the most affected by MPs pollution.

In the Netherlands, the discharge of water either treated or untreated need to comply with several standards that come with a license for water quality. These requirements are linked to EU regulation. Those quality requirements are mostly physical chemicals standards such as heavy metals, organic pollutants, etc., but not strictly MPs. In the country, household sewage is connected to WWTP; only a very small portion is nor connected to the technology (0.3%), and most industries are also required to treat their process wastewater. However, there is limited data regarding the efficiency to filter MPs in wastewater treatment plants in the Netherlands (RIVM, 2014)

Furthermore, some studies regarding the presence of MPs in the Netherlands date back to 2013, where was found MPs presence in Meuse and Rhine river, proving that WWTPs are not capable of filtering 100% of MPs residues in water (RIVM, 2014).In addition, a recent study conducted in 2017 by Department of Environment and Health, Vrije Universiteit Amsterdam and Deltares, it was found presence of MPS in samples of seven Dutch WWTPs, treated water from canals and marine sediments, concluding that MPs residues can reach the end pipe and be present in freshwaters sources (Leslie et al., 2017). In the mentioned study, samples from influents from WWTP also presented MPs. In 2016, RIVM presented the most important MPs emissions in the Netherlands and measures to address them, concluding that the following sources are the most urgent in the agenda: rubber tyres, paint particles and detergents. Figure 9 presents an overview of the emission from the most important sources in the Netherlands and in the following sub sections an overview of these sources.

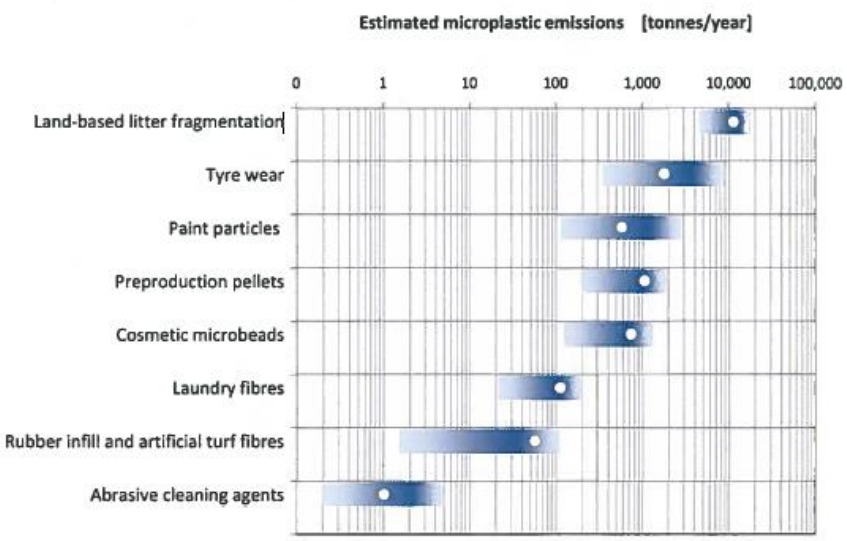

Figure 9.Estimated MPs emission in the Netherlands in tones/year. Columns show the uncertainty margins, and dots represent the average value. Source: (RIVM, 2017)

Detergents

According to RIVM, detergents can be classified into five categories: laundry detergents, dishwasher detergents, bathroom cleaners, bleaching cleaners, and surface cleaners (RIVM, 2016). Some of these products contain "abrasives" compounds whose purpose is to clean hard surfaces. To perform that cleaning function, products include particles with a size between 50 and 1000 µm; these particles are also referred to as "microbeads" and are considered to have mild abrasive action to enhance cleaning. In detergent or abrasive products, polymers are added in formulations because it has several functions such as a stabilizer, viscosity controller, soil release and anti-static agents, these polymers are also contemplated as MPs (RIVM, 2016).

In 2016, RIVM evaluated more than 400 abrasive cleaning agents of six market-leading companies in the country and found that ten products *"were suspected of containing Microplastics"* (RIVM, 2016). The institution made a rough estimation of emissions in the country base on market data concluding that the total emission of MPs from abrasive cleaning agents rises to 2.6 tonnes/year. These emissions are entirely discharged into the sewer, and surface water. MPs from this source end up in the sewage system and WWTPs (RIVM, 2016).

Paints

Paint products are widely used in several sectors in the Netherlands. In 2014, RIVM reported Dutch Paint sectors that include car repair (4%), Steel preservation (7%), Shipbuilding and maintenance (9%), Industry (8%), Do it Yourself DIY (24%) and professional building and construction (48%) (RIVM, 2016). The Ministry states that most of paint products do not have microbeads as formula ingredient. However, some special products can intentionally add microbeads to get a distinctive finish look. When the paint is applied, the solvents and water evaporate, and the binders and fillers persist in the surface, this constitutes a solid content, which part of it might be emitted as MPs (RIVM, 2016).

RIVM considers paints as MPs source not because of microbeads but due to the resin content. In this context, the Ministry has identified three crucial sub-sources of emissions related to paint usage. These sources are considered removal of old paint layers that are stripped from surfaces due to the action of the weather and also rinsing paint rollers in the sink (RIVM, 2016). The institution has calculated a total emission of 490 tonnes per year (see Table 9), which also explains the pathways of release. MPs emissions to surface water can be estimated to be 130 tonnes per year, this value also includes the shipping sector (RIVM, 2016).

Table 8. Distribution on MPs from paints application in the building sector, Do it your self-sectors within different environmental compartments. Source: (RIVM, 2016)

	Surface water		**Sludge**	**Soil**	**Total**
	Direct	*Via sewerage*			
Removal of old paint layers	7	45	36	117	**210**
Wear of paint layers	9	58	46	151	**260**
Rinsing paint rollers	0.05	7	8	0	**16**
Rounded total (tons/y)	**20**	**110**	**90**	**270**	**490**
(range)[1]	**7-37**	**22-387**	**14-343**	**113-626**	**205-1125**

[1] Ranges are the result of assuming 10% more or less paints used outdoors, and two times higher or lower emission factors for abrasion or wear, in combination with a removal efficiency in the STP of 10-90%.

Furthermore, The Ministry also acknowledges that this number has several uncertainties and assumptions, such as variation interior and exterior application of lacquer and primers. Some conjectures about the range of emission from the removal of old paints and assumptions about the rinsing of paints during its lifecycle should also be considered.

Rubber tyres

MPs can be released to the environment when tyres get eroded when they are used. These particles formed consist of polymers such as Styrene Butadiene Rubber in a mix with natural rubber and additives. MPs from tyres are described to be part of the "city dust" that is spread by wind and washed out off the road when it is raining (Boucher & Friot, 2017).

In the Netherlands, RIVM estimated in 2016 that vehicle tyres can contribute up to 1,800 tonnes of particles per year. This emission enters into surface water through asphalt road run-off, and overflows of the sewage system. RIVM also acknowledges that *"City dust in urban runoff is known as a significant source of pollution to waterways"* (RIVM, 2016). The Dutch Ministry called particles that are generated from friction in the pavement road due to rolling as Tyre and Road Wear Particles (TRWP), since these particles are produced by friction, the composition and fate is not fully known. However, RIVM considers all tyre erosion by road vehicles are MPs because the particulates partly consist of rubber polymers. (RIVM, 2016). Figure 10 presents the distribution of car tyres wear within different environmental compartments.

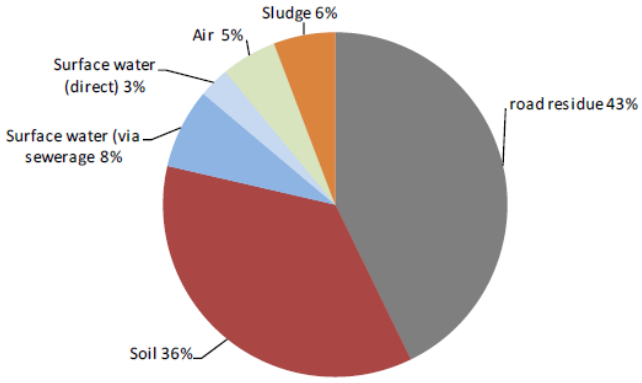

Figure 10. Distribution of tyre wear in the Netherlands within different environmental compartments Source: (RIVM, 2016)

Furthermore, table 10 below presents the estimated total amount of MPS release coming from road transport vehicle tyres in 2012 reported by RIVM, with a total were expected to contribute 1,800 tonnes of particles. Additionally, other 6,200 tonnes per year are present in the soil, 900 tonnes per year comes from tyres and those are released into the air, emissions from asphalt roads rise up to 7,400 tonnes per year (RIVM, 2016).

Table 9. MPs emissions from tyres tread per road and in different environmental compartments in the Netherlands (numbers are rounded to the nearest 100 tonnes). Source: (RIVM, 2016)

Road type	Captured road residue[1]	Air	Soil[2]	Surface water		Sludge
				Direct	Via sewerage	
Urban			1,500	0	1,300	1,000
Rural			3,800	400	0	0
Highways[1]	7,400		900	100	0	0
TOTAL	**7,400**	**900**	**6,200**	**500**	**1,300**	**1000**
range					600-1,900	300-1,600

It is important to remark that the portion that is shown as sewage sludge may vary within time since that depends on the efficiency of WWTP filters that retain MPs.

Cosmetics and Personal Care Products (PCP)

In comparison with the previous sections, this part provides the gathered information from scientific literature but not from RIVM reports, since the Ministry has not provided specific details on MPs releases from cosmetics in the country. However, this source was listed as a top priority in Prioritizing List (2014) (Appendix 4) with a score of 7, with an estimated emission of 1000 tonnes/year (Figure 9).In that scenario, I present relevant information about this MPs source.

Cosmetics are defined as any product that is designed to have contact with human skin either for beauty or for cleaning purposes. In recent years, the concern about plastic litter in oceans arose attention in the scientific community. According to the UNEP, the concerns have increased regarding plastic ingredients that are used in products worldwide, and those particles known as MPs are currently contributing to the plastic litter in oceans at present. (Leslie, 2015)

Plastics that are used as ingredients in cosmetics and PCP can consist of two categories: Thermoplastics and silicones (Leslie, 2014) mentioned in Table 1. The function of these polymers in cosmetics is diverse; some of these ingredients function as viscosity regulators, emulsifiers or film formers, exfoliates, abrasives skin conditioning (Leslie, 2014). Table 11 presents a list of polymers examples used in cosmetic industry and its function in the cosmetic formulation.

Table 10. Examples of polymers commonly used in Cosmetics and Personal Care formulations. Source: (Leslie, 2014)

Polymer name	Functions in PCCP formulations
Nylon-12 (polyamide-12)	Bulking, viscosity controlling, opacifying (e.g. wrinkle creams)
Nylon-6	Bulking agent, viscosity controlling
Poly(butylene terephthalate)	Film formation, viscosity controlling
Poly(ethylene isoterephthalate)	Bulking agent
Poly(ethylene terephthalate)	Adhesive, film formation, hair fixative; viscosity controlling, aesthetic agent, (e.g. glitters in bubble bath, makeup)
Poly(methyl methylacrylate)	Sorbent for delivery of active ingredients
Poly(pentaerythrityl terephthalate)	Film formation
Poly(propylene terephthalate)	Emulsion stabilising, skin conditioning
Polyethylene	Abrasive, film forming, viscosity controlling, binder for powders
Polypropylene	Bulking agent, viscosity increasing agent
Polystyrene	Film formation
Polytetrafluoroethylene (Teflon)	Bulking agent, slip modifier, binding agent, skin conditioner
Polyurethane	Film formation (e.g. facial masks, sunscreen, mascara)
Polyacrylate	Viscosity controlling
Acrylates copolymer	Binder, hair fixative, film formation, suspending agent
Allyl stearate/vinyl acetate copolymers	Film formation, hair fixative
Ethylene/propylene/styrene copolymer	Viscosity controlling
Ethylene/methylacrylate copolymer	Film formation
Ethylene/acrylate copolymer	Film formation in waterproof sunscreen, gellant (e.g. lipstick, stick products, hand creams)
Butylene/ethylene/styrene copolymer	Viscosity controlling
Styrene acrylates copolymer	Aesthetic, coloured microspheres (e.g. makeup)
Trimethylsiloxysilicate (silicone resin)	Film formation (e.g. colour cosmetics, skin care, suncare)

Note: some polymers may be available in various forms, as dispersions in solvents, or as partially water soluble polymer forms. International Nomenclature for Cosmetic Ingredient (INCI) names for polymers given. The functions given are examples and not an exhaustive list. Sources: EU Cosmetic Ingredient 'CosIng'

In laboratory experiments with shower gel, the results showed that there was more plastic as ingredient than the container in which was packed (Leslie, 2015). To determine an average amount of MPs releases from cosmetics and personal care products in The Netherlands is a difficult task since the % of plastic as an ingredient varies from each product type and brand. This report does not aim to calculate that emission. In the Netherlands, the report made by The NCV -Nederlandse Cosmetica Vereniging concludes that in 2019 the total cosmetic product consumption is about 2.7 billion euros and that the overall market of cosmetics has a positive development average 0.5-1.0% (NCV, 2019) More information about the exposure of this product is presented in Risk assessment section 4.2.

Fibres from clothing

In the context of worldwide MPs releases, 34% of the global MPs releases come from synthetic fibers that are washed out from clothes during laundry (Boucher & Friot, 2017). Roughly 70% of the

textiles that are manufactured globally are made from synthetic materials. The emission of MPs in the environment from synthetic clothes is originated from a mechanical and chemical reaction when clothes are being washed in laundry machines (Dalla Fontana et al., 2020).

Fibres from clothing are washed out and flushed through the sewer system after washing, and the effluent will reach the WWTP at the end pipe. As was mentioned, WWTP can achieve an efficiency of 50-90% to filter MPs. Eventually, MPs that are filtered will remain in the sewage sludge and, those fibres that aren't filtered will be released in the effluents and can reach freshwater sources(RIVM, 2019). In the Netherlands, an estimated emission of laundry fibres can have reached approximately 100 tonnes per year. (See Figure 9)

4.2 POTENTIAL HUMAN HEALTH RISKS OF MICROPLASTICS POLLUTION – RISK ASSESSMENT

This section presents the potential human health risks estimation concerning MPs pollution in the Netherlands. The entire section is based on the four steps of the Risk Assessment Toolkit from the World Health Organization presented in chapter 2. The following subsections address each step and supporting evidence of MPs regarding risks in human health.

4.2.1 Hazard identification

The first step of the risk assessment aims to identify the specific hazard and determining whether exists a potential exposure of a particular substance that can have a potential side effect for human health. The following questions are aimed to detect at first glance the potential MPs threat for humans.

- *Is the identity of the chemical known?*
- *Is the chemical potentially hazardous to humans?*

As a start point of the assessment, it is important to identify that the first risk of MPs is linked to its composition MPs are plastic particles that are made of plastic polymers. Although its composition may vary from several kinds of plastics (See Appendix 1), plastics are manufactured from polymers that contain additives to acquire specific characteristics, and those additives make PVC more flexible and stable (Lithner et al., 2011).

In the case of MPs, the identification can be based on plastic constitution according to different polymers types that are reported in the literature as MPs (Galloway, 2015; Brandsma et al., 2015). Table 11 synthesizes that information, and the same table mentions the types of polymer and hazard scores elaborated by (Lithner et al., 2011). These polymers are the most common found in

MPs. The principal author gathered information linking hazard levels of polymers from different international agencies, and the authors also calculated the hazard score for each polymer based on the classification for the monomer by those agencies. However, as a remark from the authors that the hazard score does not mean that the polymer, as such, can be harmful, but it means that it is capable of releasing hazardous substances (Galloway, 2015). It is essential to point out, that to address a proper hazard identification in plastics materials is also necessary to analyze the potential additives and their environmental fate. In the case of MPs, those topics are highly relevant, which will be addressed in section Hazard characterization.

Table 11..Polymer type found in MPs and relative hazard score. Source: (Galloway, 2015; Brandsma et al., 2015) (Lithner et al., 2011)

Polymer type	Density	Relative hazard Score (Lithner et al 2011)
Polyethylene (low, high density)	0.917-0.965	11
Polypropylene	0.9-0.91	1
Polystyrene	1.04-1.1	30
Polyamide (nylon)	1.02-1.05	63-50
Polyvinylchloride (PVC)	1.16-1.58	10,551 – 10,001
polyester	1.24-2.3	1117- 1094**
Acrylic	1.09-1.20	NO score found
polyoximethylene	1.41-1.61	1500
Polyvinyl alcohol	1.19-1.31	NO score found
polymethylacrylate	1.17-1.45	1021
Polyethylene terephthalate (PET)	1.37-1.45	4
alkyd	1.24-2.10	NO score found
polyurethane	1.2	7384

Furthermore, regarding the second question about if *the chemical is potentially hazardous to humans?* In MPs case, that question should be flexible since MPS are particles and not a single substance that can potentially affect human health. In this sense, several studies have identified MPs as a potential hazard for humans considering several properties and characteristics. For instance, some scholars have mentioned that the presence of MPs in bottled mineral water "*can represent an important risk to public health and should not be underestimated*" (Zuccarello et al., 2019). Particular properties make MPS potentially harmful to humans. The details about those properties are presented in the next section, Hazard Characterization. Finally, as part of the hazard identification, Table 13 presents a summary of the data gathering from the literature that provides scientific evidence that MPs can have adverse effects on humans.

Table 12. Summary of findings about MPs and human health

MPs source	Type of study	Pathways of MPs toxicity	Possible adverse effects in humans	Source
MPs found in Freshwater sources	Ecotoxicology In marine species	Cytotoxicity in several marine species	Not mentioned by the author	(Adam et al., 2019)
In vitro polypropylene microplastics	In vitro human cells	cytotoxicity, hypersensitivity	Direct contact of MPs particles with cells may have potential to cause health problems triggering the production of cytokines from immune cells.	(Hwang et al., 2019)
In vitro fluorescent polystyrene microspheres	Animal study	Cytotoxicity	Cellular internalization of microplastic has been described for PS in cell cultures, including macrophages, erythrocytes Cytotoxicity is a result of particle toxicity, oxidative stress and Inflammation inside the cell, MPs are not membrane bound, potentially interacting with intercellular structures	(Geiser et al., 2005) (Prata et al., 2019)
In vitro Polyethylene microspheres	In vitro human cell	Cytotoxicity	cerebral and epithelial human cells can increased reactive oxygen species to high concentrations, contributing to cytotoxicity.	(Schirinzi et al., 2017)
In vitro polystyrene particles	In vitro human lung cells	Internalization and cytotoxicity:	MPS can be able to disturb gene expression, leading to inflammatory responses, triggering apoptosis pathways. The study suggests MPs can cause definite damage and functional disturbance to human and mammalian respiratory systems.	(Xu et al., 2019)
Airborne Microplastics	Assessment of current knowledge with summary of literature review	Cytotoxicity	Can trigger bronchial reactions (asthma-like), diffuse interstitial fibrosis and granulomas with fiber inclusions (extrinsic allergic alveolitis, chronic pneumonia), chronic bronchitis.	(Prata, 2018)

			MPs may cause increase of incidence in immune and neurodegenerative diseases.	
In vitro polystyrene particles	In vitro study with mice tissues	Tissue-accumulation kinetics	Distribution and accumulation of MPs in mice tissues can trigger a significant alteration in several biomarkers which indicates potential toxicity	(Deng et al., 2017)

4.2.2 Hazard characterization and guideline value identification

The present section aims to gather qualitative or quantitative data of intrinsic properties that the substance might cause adverse effects on human health. This information pretends to answer the following questions in detail to address the possible health risk regarding MPs in different sources.

- *What properties of the chemical (or formulation) have the potential to cause adverse health effects?*
- *Do guidance or guideline values from international organizations exist for the chemical?*
- *What are assumptions about exposure and dose incorporated into guidance or guideline values for the chemical?*
- *Do those assumptions reflect conditions specific to the local situation?*

As a starting point of this section and to answer the question during data collection, several MPs characteristics that harm human health were found. Table 14 presents the most important characteristics that represent a risk for human health. The criteria to assess these characteristics as the most relevant were based on scrutiny of scientific literature.

Table 9.MPs characteristics and risk associated with human health

MPs Characteristic	Health Risk	Source
Size	-Due to the small size, MPs can be easily inhaled or ingested; this might accumulate and trigger an immune response, which leads to inflammation. -Due to the small size, MPs are easy to be swallowed by organisms, which later are consumed by humans. This can	(Wright & Kelly, 2017) (Xu et al., 2019)

	cause severe damage, disrupt biological functions, and have biological infiltration. -The diameter has been reported as a key factor to evaluate toxicological effects in lung cells -Inhalation of airborne MPS can lead to an inflammatory lesion in lung cells that can cause malignant lesions such as cancer.	(Dong et al., 2019) (Prata, 2018) (WHO, 2019)
Chemical Composition	-MPs can leach additives known as monomers, that are present in the plastic composition. Those additives have an accumulative effect; currently, there is a general concern about them. -Additives such as Bisphenol A and di-(2-ethylhexyl) phthalate (DEHP) are phthalates, and some of the brominated flame retardants, are known to be endocrine disruptors. Can be leached out to the environment from plastic debris and MPs - When Secondary MPs are formed is produced by degradation polymers when plastic debris is exposed to UV light, heat, mechanical and chemical abrasion. When those polymers break, other products are released that have potential risk for humans	(Wright & Kelly, 2017) (Hwang et al., 2019) (Halden, 2010) (Galloway, 2015) (WHO, 2019)
Microbial adherence	Plastic debris can act as a support of adherence for pathogenic micro-organisms and parasites. Pathogens can colonize in plastic surfaces when biofilms are formed	(Hwang et al., 2019) (Vethaak & Leslie, 2016)
Degradability	MPs are plastics particles known to have low degradability; they can persist in the environment for centuries.	(RIVM, 2016) (Leslie, 2014)
Physical state	Physical effects have been observed to date in human cells. Some studies show that plastic particles could cause lung and gut injury. MPs can absorb other hazardous substances like metals such as Cadmium (Cd).	(Hwang et al., 2019) (Miranda et al., 2019)

MPs can be present on the human diet and in the environment— Figure 11. MPs can enter the human body system by ingestion, inhalation, and dermal contact (Prata et al., 2019) which can accumulate and could, depending on the MP's characteristics, accumulate in human tissue then due to the characteristics. The particles can have side effects which have adverse side effects on human health (Wright & Kelly, 2017).

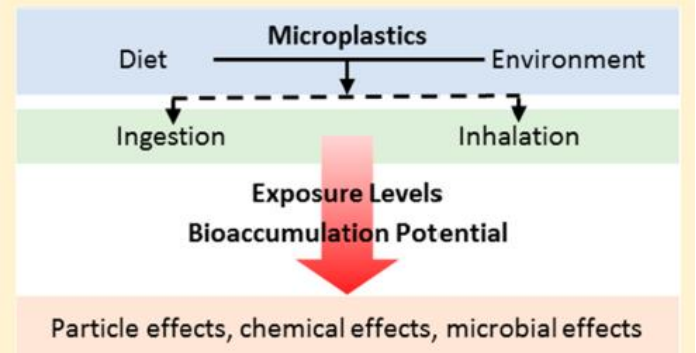

Figure 11. MPs routes of exposure. Source: (Wright & Kelly, 2017)

In addition, to address the second question about international guidelines, it is important to remark that in the context of what the toolkit was elaborated, it is expected to analyze a single substance. As mentioned in the previous section, MPs particles are not considered "chemicals" or "substances" as such. In this section, the toolkit aims to provide an inventory of all guidance from international sources available related to the substance of study. This guidance should give information about the risk of the potential "chemical". However, in some of the recognized guidance are INCHEM, International Agency for Research on Cancer (IARC), and WHO guidelines for drinking water. In all guidelines, there is a lack of data regarding MPs risks.

Moreover, regarding the last two questions about the exposure values and assumptions in a local situation, there is a lack of information regarding those topics as well, since international organizations address hazard characterization as individual chemicals, and since MPs are not a single substance they are not considered in the current databases. Furthermore, the toolkit points out that in case there is a lack of data about the exposure, it is necessary to determine the appropriate contact rate, allocation exposure, and appropriate exposure situation separately from other sources. In that context, the following section presents data for contact and exposure situations more specifically in the Netherlands.

Contact rate,

The WHO presents the four most common pathways in which potential harmful substances can enter the human system (Figure 12). The means of contacts shown in the figure below also apply for MPs situation.

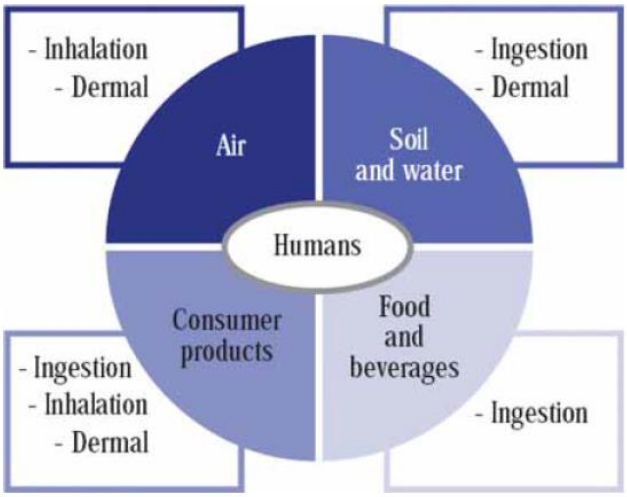

Figure 12.Possible exposure media and corresponding means of contact. Source: (World Health Organization, 2010)

In the following section, detailed information about the exposure of MP to Dutch people through ingestion and inhalation is presented. Dermal means are not addressed since this pathway is less likely to occur. In general, there is a general lack of information about risks related to it; still further research is needed (Prata et al., 2019).

Exposure by Ingestion: Food and Beverages

Data gathering has shown that the population can be exposed to MPs by several pathways. The main route of exposure of MPs to humans is ingestion (Prata et al., 2019). In this sense, it is important analyze its presence in the Dutch food chain.

Firstly, MPs presence in food has been widely investigated in the last years. It was found evidence of the presence of MPS in air, drinking water, mineral water, seafood and other food items (Zuccarello et al., 2019; Prata, 2018; Toussaint et al., 2019; Koelmans et al., 2019). However, the authors did not provide sufficient data about the amounts of MPs contained in each food category. Nevertheless, in 2019 a study published by (Cox et al., 2019) in which was analyzed 25 reviews

regarding MPS in food. This relevant data was analyzed to be used in the average Dutch food intake. In the mentioned research, food sources such as seafood, salt, honey, sugar, alcohol, bottled water, and tap water were analyzed, providing consistent data. For other food categories, there is a lack of data. Table 15 presents an estimation of MPs in food consumed by Dutch people, considering data from (Cox et al., 2019)and RIVM. MPs intake was assessed based on data published by RIVM using an average number consumed per day since MPs intake may vary among gender, age, and location.

Table 104. Estimated MPs consumption of Dutch Population. Source: combined data from Cox and RIVM.

Food type	MPs per g/L/m3 (Cox et al., 2019)*	**G consumed/ day by Dutch population RIVM****	**Estimated g of MPs ingested by Dutch population per day**
Seafood	1.48	16	17.48
Salt	0.11	7.8	7.91
Honey	0.1	0.9	1
Sugar	0.44	4.7	5.14
Alcohol	32.27	139	171.27
Bottled water	94.37	588	682.37
Tap water	4.24	- tea :225.7	954
		-Coffee: 392.5	1664.2
		- Herbal tea :88.4	374.816

*(Cox et al., 2019) gatherer data from American and the number is an average of several publications

**Source: (RIVM, 2019b)

The table above shows the sections tap water, coffee, and tea consumption since it is relevant when culturally in the Netherlands these beverages are consumed more often than other countries. It is assumed that most of them are prepared with tap water at homes or coffee machines that connected to piped water. According to (Zuccarello et al., 2019), the estimation of exposure of MPs in humans is 1,531,524 p/kg/body-weight/day corresponding to 40.1 mg/kg in a study conducted with bottled water in Italy.

Exposure by inhalation/ingestion: Soil and Water

In the Netherlands, the most significant sources of MPs reported by RIVM are from tyres, abrasion, paints, and abrasive cleaning agents (RIVM, 2016). RIVM reported in 2017 that most of these discharges end up mostly in soil and direct water sources. Also, some MPs can remain in the sewer system and later reach surface water as well (RIVM, 2017). Figure 13 presents an illustrative of the origin of MPs than Dutch population can be exposed.

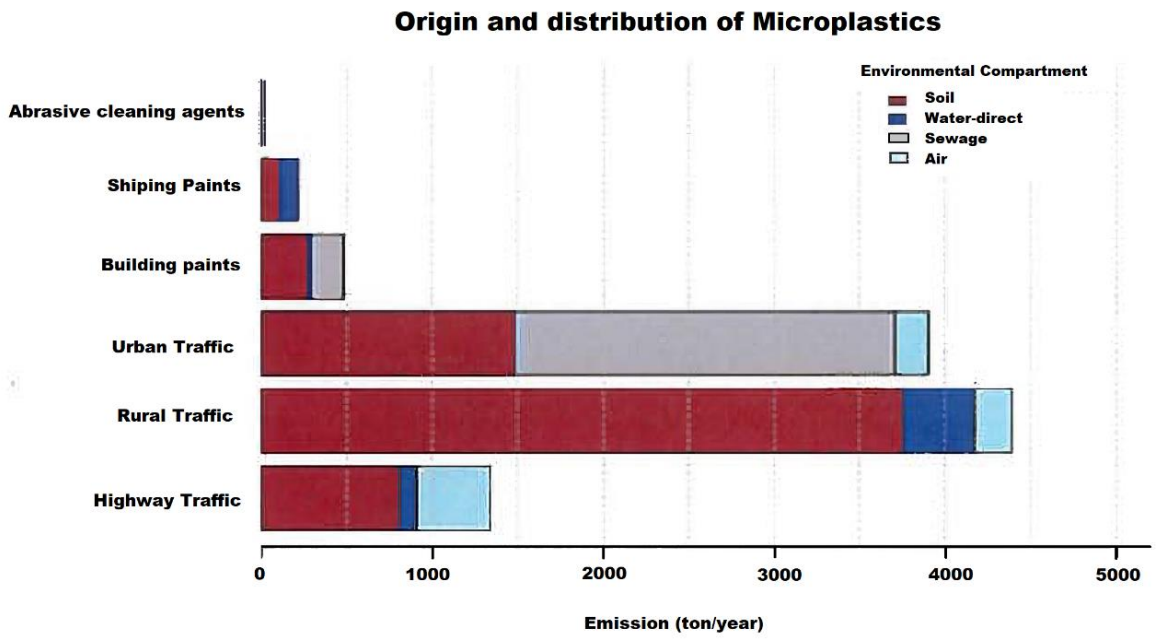

Figure 13. Origin and dispersion of MPs emission from tyres, pain and abrasive cleaning agents in the Netherlands. Source: (RIVM, 2017).

The risk related to MPs remaining in the soil, is that they can reach agriculture lands and be present in the food chain, which leads to indirect ingestion during a daily diet and direct contact with freshwater sources when diving in lakes or canals. In countries that are located upstream in the Netherlands, there is a common practice among farmers to use sewage sludge to improve crops. Even though in the Netherlands this practice is forbidden, MPs can eventually reach soil crops due to erosion and runoff through larger rivers that cross several countries (RIVM, 2019)

Regarding surface water, in the Netherlands, there is a higher exposure of MPs present in surface water sources due to particles can reach the human system. At the same time, they are ingested when people swim in those waters, a situation that is common during summer months in the country. For instance, (Leslie et al., 2017) found the presence of MPs in samples in Amsterdam Canals and other effluents from treated water. The study showed unique data about the presence of MPs in the Dutch marine and freshwater environment and wastewater treatment effluents, concluding that MPs can reach surface water.

Exposure by Ingestion: Consumer products

In the Netherlands, the population can ingest MPs indirectly from the use of certain products. Firstly, as mentioned in sources section 4.1, cosmetics and personal care products are a realistic source of MPs that can have a potential human health threat. In a study conducted by (Napper et al., 2015), MPs were found in six popular brands of facial scrubs sold in the UK. Those particles are washed out during daily shower and eventually will reach the sewers system as a direct consequence of use. In the Netherlands, the most direct source of access is ingestion either by water sources or food chain polluted with them. Several NGOs such as Plastic Soup Foundation have been working on gathering data about MPs that are present in cosmetics and personal care products. The organization found out more than 500 MPs ingredients that are broadly used in these kinds of products and, they established four categories: Red, Orange, Green, and Zero (Plastic Soup Foundation, 2020). Table 16 presents a summary of the classification with a number of ingredients that are stated in the list.

Table 115. Category of MPs contained in Cosmetics and Personal Care products, information updated to 25/03/2020 . Source: (Plastic Soup Foundation, 2020)

Category	Number of ingredients	Description
Red	539	The list includes ingredients such as Polyethylene PE, Polyacrylate, Polyethylene-glycol among others.
Orange	115	The organization considers this list as "skeptical Microplastics" ingredients, meaning that there is not enough information available.
Green	Not Available	Products in this list do not contain any MPs or "Skeptical Microplastics."
Zero	Not Available	Brands free of all known MPs ingredients

In the Netherlands, approximately 30 products from different brands contain MPs as ingredients that are listed in the red category. The full list can be found in Appendix 3.

Secondly, another product that is widely consumed worldwide is textile fibres; it is calculated that 70% of all textiles are made from synthetic materials, which are mostly MPs. In the Netherlands, the estimation is that cotton is more used, although there are no exact numbers but, it is estimated that 50- 60% of fibres used in the country are cotton and 30-40% polyester (RIVM, 2019).

The exposure of MPs released from textiles are mostly by ingestion through water sources, since fibres are washed out and end up in the sewage system, as mentioned before WWTP in the Netherlands are not capable of filtering all fibres. The density of the fibre is a distinctive characteristic of risk since a lighter one will float in the water column when a heavier fibre will sink forming sediments (RIVM, 2019). In Table 17, commercial fibres and density are presented.

Table 16. Commercial fibres and density. Source (RIVM,2019)

Textile fiber	Commercial Name	Density Kg/m^3
Polyamide or nylon	Nylon 6 or Perlon1.13 Nylon 66 or tri-nylon	1.13 1.14
Polyethyleneterephtalate (PET)		1.34-1.39
Polyester	Kodel, Vestan	1.22
Polyester	Terylene, Dacron	1.38
Viscose		1.53
Acrylic	Orlon (staple / filament)	1.14-1.17
Polyurethane	Lycra	1.15
Cotton	Raw	1.55
Pure water		1.00
Seawater		1.03

Exposure by Inhalation

As is presented in figure 13, there is a significant amount of emission coming from traffic (highway, urban and rural) that are released into the air. A small part coming from textile clothing is also emitted (RIVM, 2019). Furthermore, (Prata, 2018) expresses that textile fibers and other MPs can also be included as part of airborne contamination or such as called "city dust." The author mentioned that to understand the potential risks in humans, first it is necessary to determine the exposure to emissions indoors and outdoors. However, still, there is insufficient information about airborne MPs. In the Netherlands, due to lack of information about this “city dust” and what extent might contain MPs, the appropriate exposure cannot be determined. But it is known that some of these particles reach respiratory systems.

4.2.3 Exposure Assessment

This section aims to determine and present relevant information about the magnitude, frequency, routes, and extent. Furthermore, Risk Assessment Toolkit seeks to evaluate the concentration amounts of the agent of study that reaches a target population, which in this case, is the Dutch population.

Routes and pathways of exposure

This section explains routes of exposure to determine whether these exposures occur during occupational or non-occupational situations, indoors/outdoors exposures, and others. It aims to narrow down the information presented in previous sections on Hazard characterization and identification, to understand from which properties and from which exposure source, MPs can be a threat to human health.

Routes of exposure are defined as routes in which MPs can enter the human body, meaning: ingestion, inhalation, and dermal contact (Prata et al., 2019). All the information regarding possible MPs exposure in the Dutch population is summarized in Table 18.

Table 127. Summary Table of possible MPs exposure in the Netherlands. (own elaboration)

	Routes of exposure			Occupancy		Fate		Pathway of exposure		
Sources	**Ingestion**	**Inhalation**	**Dermal***	**Occupational**	**Non-Occupational**	**Indoors**	**Outdoors**	**Air**	**Water**	**Soil**
Food	X				X	-	-		X	X
Beverages	X				X	-	-		X	
Paints	X	X			X	X		X	X	X
Tyres	X	X			X		X	X	X	X
Cosmetics and PCP	X		X		X	X	X		X	X
Textile fibers	X	X	X	X	X	X	X	X	X	X

*Not enough information available.

Table 18 shows that the ingestion of MPs is likely to occur through food and beverages since it was presented that several food items, water sources, and seafood contain MPs. Still, in the fate category Food and beverages, the exposure is equal either indoors and outdoors. Moreover, as RIVM reported, the greatest sources of MPs are from tyres abrasion, which includes three pathways of exposure, and these can reach water sources and soil, that eventually leads to further ingestion. MPs in paints can be inhaled when small particles are released when paints get old and are released to the air. These particles also eventually reach soil and water sources that can access the food chain and enter the human body through ingestion.

Furthermore, textiles fibers are interesting to analyze since this source has evidence of occupational exposure with airborne MPs (Prata, 2018), which means that workers in that sector have more risk of having respiratory diseases related to this exposure. In addition, textile fibers also can reach all three compartments and be ingested eventually through water and soil. Finally, cosmetics and personal care products can be exposed through inhalation and dermal contact. Nevertheless, there is a general lack of information about the routes and pathways in which MPs can be absorbed through the skin; therefore, dermal contact exposure is not further discussed.

Duration of exposure:

The Risk Assessment Toolkit considers that this section is crucial in health risk assessments, a period of exposure is a crucial component that helps to design the exposure assessment. World Health Organization (2010) describes three kinds of duration exposures: short-term, medium-term, and long term.

Short term exposure is described as the one that occurs over minutes, hours or a day and have an *"immediate adverse effect in the body in certain concentrations,"* Medium-term or intermediate exposure occurs when chemicals have *"adverse effects over a period of contact that ranges from weeks to months"* and, long term exposure is related to cumulative effects that can lead to more severe diseases such as cancer (World Health Organization, 2010).

In the case of MPs, with all the information presented, it is assumed that all sources have the potential to long term exposure. MPs have the potential and characteristics that make MPs present almost everywhere from the food chain, air, water, and its consumption is constant. However, there is a consistent lack of information and further research needed about this subject. At this point, it is not possible to determine if MPs can actually produce cancer or other diseases since more concluding evidence is required.

4.2.4 Risk Characterization.

The last step in the Risk Assessment toolkit aims to make a comparison with established guidance or value from international agencies. However, as mentioned in the Hazard Characterization, there is no such value or standard. In the case of the Netherlands, RIVM is the entity that could emit those kinds of data. However, since this topic is very complex, it is not possible to limit to only one guideline. For this section there is a lack of data to evaluate further the risks required by the Risk Assessment Toolkit.

4.3 MEASURES AND INSTRUMENTS TO ADDRESS MICROPLASTICS POLLUTION IN THE NETHERLANDS

During the literature review, it was found that RIVM did extensive work by establishing measures and instruments to undertake the MPs emission such as paint, tyres, detergents, and textile fibres. Figure 14 presents the steps taken by RIVM to address MPs pollution since 2014 in which the institution started with an identification of potential MPs sources in the country and ranking the most important ones, following by several measures and evaluation of effectiveness as the last step (Step 4).

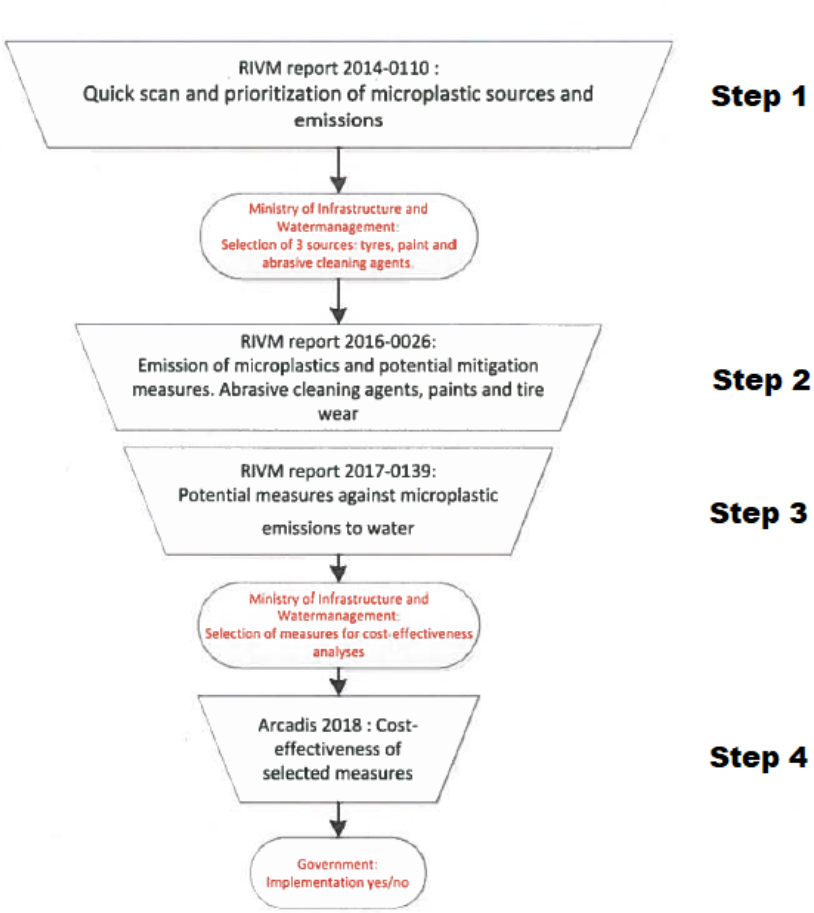

Figure 14. Roadmap of the process of research and policy making in the Netherlands regarding MPs pollution. Source: (RIVM, 2017)

In 2016 (step 2 in Figure 14), RIVM proposed a national approach that aims to comply with the demand of the Marine Strategy Framework Directive (MSFD). The Dutch government aims to reduce plastic litter and to create "Green Deals" with sectors that are compromised in shore areas such as fisheries, ports, and shipping. Moreover, creating a general awareness of plastic waste in the sea and plan to increase awareness into the circular economy to reuse plastic materials which also should be in close collaboration among stakeholders to create innovation in the market (RIVM, 2016). Furthermore, RIVM reported potential measures and instruments in 2016 to address MPs problematic in the country. These measures are focussed on three primary emissions: Tyres, Paints, and abrasive cleaning detergents. Table 19 presents a summary of those instruments and measures reported in that time to make a more straightforward understanding and comparison with further actions that are shown in later time by the same organization.

Table 138. Measures and Instruments proposed by RIVM. Source: (RIVM, 2016)

Emission	Measures	Instruments
Tyres	Improve the composition and structure of the tyres and infrastructure, Improve infrastructure and maintenance of road surfaces, Optimization of vehicle use and maintenance, Improvements of the sewerage system	Legal: Voluntary Economic or persuasive
Paints	Promote paint innovation, reduce the wear of coatings, establish limitation methods that restrict spreading of dust, reduce the amount of paint used and preventing the rinsing of brushes and rollers in the sink.	Legal, voluntary, economic or persuasive
Abrasive Cleaning Agents	Substitution of microbeads in products	-Ban on microbeads, Voluntary phase-out and Raising awareness

Table above shows the last column called Instruments. However, The Ministry did not state a precise instrument for each emission in comparison with the measures. Also, no measures or instruments involving the human health approach are stated. Furthermore, in 2017 another report regarding MPs pollution was emitted by the RIVM in which a redesign of the measures presented in 2016 was modified and added other measured they considered pertinent for the three emissions already described. Table 20 presents the amended list of measures that represent step 3 in Figure 14. This step also acknowledges that even the mentioned emissions can also be released in air and soil, water is the environmental compartment with more impact of MPs pollution.

Table19. Amended Measures to address MPs pollution in the Netherlands. Source (RIVM,2017)

MPs emission	Measures
Tyres	• Establish a legal threshold value for tyre abrasion • Introduce Tyre label with tyre abrasion indicator • Introduce a reducing abrasion factor of road surface • Create Sustainability tool for road surfaces • Create Street cleaning campaigns in urban areas • Prohibiting the use of winter tyres in summer • Implement Tyre Pressure Monitoring System in cars • Establish wheel alignment in periodic vehicle inspections • Reduce maximum speed limits • Establish a kilometre price
Paint	• Raise public awareness regarding rinsing of brushes • Establish regulations for replacing older sanding machines • Create agreements on residual emissions at shipyards • Create subsidies for research into degradation of paint • Establish Legally required guarantee period for paintwork • Facilitate reduction of residual emissions at marinas and storage facilities
Abrasive cleaning agents	European legislation banning the use of MPs in abrasive cleaning agents

Finally, RIVM recognized that other MPs sources are also relevant. This is the case of textile fibres which were addressed with specific measures in 2019. The Dutch ministry determined that to implement measures at a national level, it is important to include four stakeholders in the process

of decision making. These stakeholders are Government, Manufacturers, Consumers, and WWTPs (RIVM, 2019).

Government:

RIVM presented in the report 2019 several initiatives that compromise an investigation of the adaptation of the EU plastics strategy in which can be synthetic fibres can be included. Moreover, other regulations, such as establishing a standardization in MPs fibres, instruments such as taxation and subsidies which aims to promote the reduction of MPs emission into the sewage system. Finally, the Dutch government plans to join in the elaboration of a proposal to the European Commission in which presents the inclusion of a filter in washing machines, preventing the spread of MPs from textile fibres into the sewage and the environment (RIVM, 2019).

Manufacturers

RIVM considers that manufacturers of washing, drying machines, and detergents are key players to reduce MPs emission from textile fibres. In this context, RIVM proposed several filters that can be included when manufacturing washing machines. Also, the ministry considers that the washing cycles should be redesigned and should be combined with drying in a single device with one filter. The detergent industry should also make some changes in the labelling of products to increase consumer attention regarding MPs pollution(RIVM, 2019).

Consumers:

Measures related to reaching Dutch consumers are mostly focused on awareness about the use of synthetic fibres and to promote the use of natural fibres (RIVM, 2019). Experts in the topic also considered that targeting consumer awareness is very important to address this problem.

Wastewater Treatment Plants- WWTP:

RIVM considered that WWTP should include an extra filter and alternative purification methods that can capture MPS in the sewage system. The options to increase filtration in the treatment system comprises membrane filtration and promote research about chemicals that can flocculate and capture MPs in water. (RIVM, 2019). However, in this sense, an expert in MPs interviewed as part of this study considered that all kind of measures related to implementing new technology also must be linked to economic feasibility in the final consumer because these measures could eventually increase taxes.

Perspective from interviewees

From the perspective of the interviewees, two of the respondents commented that the Netherlands is following the right path regarding MPs pollution. The two other respondents from the KWR Water Research Institute and Plastic Soup Foundation think that measures are not being addressed adequately regarding MPs pollution. However, all interviewees mentioned that more research is still needed, and all of the interviewees remarked that awareness is a key player in this topic. Furthermore, two experts believe that it is smart first to identify which are MPs emission with the most impact in humans and then evaluate every source with a particular measure. The other two respondents mentioned that more steps should be implemented such as banning MPs in cosmetics. In addition, all experts agree that textile fibres and tyres are the most urgent sources to be addressed and the ones that can potentially have more human health risks. Two interviewees mentioned that there is evidence that smaller particles called nanoplastics[3] can potentially have more risks than MPs due to their size, and measures should start addressing this topic. Moreover, the interviewee mentioned that risks and exposure indoors are much higher than outdoors, so also measures regarding ventilation and air circulation in houses should be considered.

4.4 MICROPLASTIC STRATEGY IN THE NETHERLANDS

This section aims to answer the last research question, *"How can MPs pollution be strategically addressed in the Netherlands?", that* is associated with all the information presented and the outcome of interviews. All interview findings are presented in Appendix 5.

Firstly, to address MPs pollution in a strategic way, it is crucial to establish a standardization of measurement methods and a guideline by the Ministry or adopt/adapt one from an International Agency (such as?). As it was mentioned in the Risk Assessment section, these guidelines help to compare future data and to reduce inaccurate results. According to one interviewee, measuring the problem properly leads to understand and define its magnitude, which leads to further policy making. Moreover, most of the interviewees remarked that as long as there are no exact exposure studies of MPs in population, any measure can be enforced. Four interviewees mentioned that this lack of standardization leads not to understand the magnitude of the problem adequately and to delay in policy making.

[3] Plastic particles with size less 1µm

Secondly, experts think that a clear understanding of pathways and the potential risks in humans and, knowing to what extent MPs can harm humans, is a key factor to introduce more specific measures regarding this problem. In this context, the Dutch Government is actively promoting more research on this topic. One expert in MPs risk assessment mentioned that a significant barrier in this topic is the absence of a blood test to determine the presence and levels of MPs. Currently, there is no method to detect MPs presence in humans, he mentioned that some research is done in human faeces, but other ways of measurement such as urine, blood, breast milk, and organs are still non-existent. Without these kinds of measurements, it is impossible to determine the real human health risk in a specific population. In addition, one expert in toxicology mentioned that the fact exposure data is unknown, policy making should wait until this topic is fully understood and not to overrule.

Thirdly, an expert in plastic leakage mentioned that a useful MPs strategy would be to create a global awareness such as global warming, in which even international agreements are settled, such as the Paris Agreement. The expert thinks that at this point, a "Plastic Agreement" is needed in similarity with the Paris Agreement in which all countries make efforts to reduce emissions but, in this case, it has not been addressed due to limited awareness of the problem. Additionally, another MPs expert stated that due to the complexity of the issue, MPs measures and policy making should also be linked with the environmental problem and to enforce the precautionary principle with the plastic soup in the ocean. On the contrary, a toxicology expert thinks that the precautionary principle should be applied with a justified reason, which is not the case of MPs due to the lack of data. Furthermore, from the point of view from the Plastic Soup Foundation, it is also important worldwide collaboration to address this issue.

Fourthly, four respondents agree that MPs issue should be addressed at its origin, which means attacking plastic pollution at a first instance. In this context, The EU plastic strategy should also include MPs in its target. The Netherlands has been making several efforts to reduce plastic usage such as the implementation of the Circular Economy framework in cities and recycling. However, the recycling strategy is contradictory to the position of the interviewee from the Plastic Soup Foundation, who remarked that there is a misconception about plastic recycling. Industry and government have created the idea that plastics are easy to recycle, which is not correct; only a little amount of plastics that have been used is recyclable. The representative thinks that the only way to address plastic pollution in general, in which MPs problem is also immersed, is by taking strong actions such as banning microbeads as ingredients in products such as cosmetics, paints, and

detergents. In addition, the representative compared the plastic bags measures in which they charging 10 cents per bag in stores and supermarkets, had a positive effect in reducing the use of plastic bag among consumers. The interviewee said that similar actions have the potential to change people´s behaviour. Finally, all respondents agree that the only way to reduce MPs pollution is by increasing awareness and promoting to replace plastic products in daily life and find other alternatives to replace plastic use in general.

CHAPTER 5- DISCUSSION

5.1. MPs sources in the Netherlands

As presented in the findings sections, four MPs sources are identified by the Dutch Ministry as the most urgent; these are car tyres, pains, abrasive detergents, and textile fibers. From the perspective of most interviewees, these sources are also the most relevant to address. In 2014, the first step was to elaborate a prioritizing list (Appendix 4) with all the activities that can produce MPs emission is presented. However, later on, RIVM conducted more detailed research about three specific emissions: tyres paints, abrasive detergents, all with score 7 in the prioritizing list. The report does not mention why they decided only to address three sources when the list mentioned other several activities with the same score. In the specified list, the top score is packaging material and liter in general (rating 9 and 8 respectively), RIVM does not mention why they do not considerer to address the top sources of MPs in the Netherlands. Furthermore, RIVM does not provide any specific measures regarding MPs in cosmetics and personal care products, even this topic is already being addressed at the EU level. Unfortunately, it was not possible to arrange an interview with the RIVM so it was not possible to obtain the opinion of the Ministry regarding this topic.

5.2 Risk Assessment

During the Risk Assessment analysis, it was found that there is a significant lack of data from international agencies and Ministries. This absence does not allow us to assess a Risk Assessment fully. The section 4.3 Exposure assessment was hard to evaluate because of the absence of information about exposures of MPS; this significant absence of exposure concentrations and contact rate data was also corroborated with the opinion from experts. They expressed that the exposure data is missing, which is crucial to conduct a risk assessment framework. It was no possible to calculate an appropriate duration of exposure and exposure concentrations. In addition, the risk characterization section aims to make a comparison with international standards, however, those standards do not exist for MPs. Moreover, during interviews with experts and mentioning the Risk related with MPs, the interviewees were asked about what do they think is the most significant risk of MPs in human health, the unanimous answer was “I don´t know.” Indeed, the risks are not clear enough due to scarce information regarding the exposure, and further research is still needed.

5.3 Measures to reduce MPs pollution in The Netherlands

During the analysis of the measure, it was clear that the Dutch ministry (RIVM) determined four MPs sources as the most urgent in need of actions. These sources are Tyres, Paints, Abrasive cleaning

agents, and textile fibres. In the report's analysis, it was found that the primary purpose of reducing MPs in the Netherlands is because it is a potential harm to the environment. However, a human health approach, taking into consideration the potential risk for public health, was only mentioned in textile fibres measures. From the perspective of the interviewees, MPs pollution should be addressed as a whole, including measures to mitigate pollution in the marine environment and to prevent emission that also potentially can affect human health.

Moreover, an expert in plastic leak remarked that the cost-effectiveness in any measure should be evaluated. For instance, if the Government plans to increase the filtration potential in WWTP by adding new technology that filters MPs, that would also have repercussions in raising environmental taxes. All the interviewees mentioned that measures that are related to awareness and changing behaviour are the most effective to prevent this kind of pollution. In this sense, RIVM states that *"Detergents Regulation states that all ingredients contained in detergents must be publicly available, although this information is not always easy to find"* (RIVM, 2016). For instance, measures that address labelling in products and awareness campaigns should also take into consideration.

Furthermore, during data analysis, it was found that most measures are focused on outdoor emissions. Still, two interviewees remarked that indoor emissions are even more dangerous than outdoors since air circulation is a crucial aspect. Rules that include air ventilation in households are a way to reduce the risks of MPs in humans should be taken into consideration. Finally, three interviewees remarked that taking national approaches is the right way, but it is not enough; MPs legislations should be addressed at an EU level and even globally. In addition, an interviewee with toxicological expertise mentioned that before discussing specific measures is more relevant to study more about exposure and risk, he remarked that the EU should take the precautionary principle with a reason MPs problem should be addressed one there is significant evidence of risk.

5.4 MPs Strategy in the Netherlands

The MPs strategy presented in Chapter 4 section 4.4 is a mixture of opinions from experts and literature review, most of the interviewees agree that MPs source should be addressed by two fronts: analysing the most relevant sources and attacking general plastic pollution. The divided opinion was found among interviewees whether the Netherlands is following a right path regarding MPs pollution. Some think that in comparison to other countries, the Dutch government is taking seriously while other interviewees believe that there's still much more to do. However, all

interviewees mentioned that there is more research needed to adequate measures according to scientific findings.

CHAPTER 6- CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the research questions and findings from scientific literature and interviews with experts, several deductions were made; these are presented as follows:

Scientific literature shows that there is a potential risk of MPs in human health. However, there is no sufficient data available to elaborate a MPs risk assessment. Exposure data, concentrations, and standards from international agencies and testing techniques in human samples are missing. Extensive research is still needed on this topic.

In the Netherlands, the most relevant MPs sources are identified as car tyres, paints, abrasive detergents, and textile fibres. At present, there is no specific policy to address MPs pollution at the EU level. National measures against MPs emissions were presented, in which RIVM addresses MPs pollution by each source.

Finally, MPs pollution is a complex topic in which public health and environmental policies should join to propose adequate strategies. Due to the diversity of sources and exposure pathways of MPs to humans, it would be relevant to prioritize the attention to those MPs sources that represent higher risks. This study shows that a good way to address the problem is by treating this issue as a whole by having a start point the plastic pollution in general. Moreover, Microplastics are not a concern of a single country; global efforts should be enforced to address this problem on a worldwide scale.

6.2 Recommendations

This section presents the proposed recommendations by each stakeholder involved in MPs pollution.

For the scientific community

It is essential to carry out further research about the following topics:

- Standardization of MPs detection in water, soil, and air.
- Development of MPs detection techniques and methods in human samples such as blood, urine, and organ tissues.
- Develop epidemiological and toxicological studies regarding MPs in a specific population.
- Develop MPs Exposure studies.

For Government and policymakers

- To implement policies that aim to reduce plastic pollution in general and reduce polices about plastic recycling.
- To implement policies that restrict the use of MPs in products such as personal care, paints, and detergents.
- Implement policies that restrict single-use plastic in the industry, which is the main source of Secondary MPs.
- To implement policies that force manufacturers to label products that contain MPs.
- To support further research about MPs toxicology in large populations.
- To introduce MPs monitoring standards in treated water and drinking water as part of quality control procedures.
- Create awareness in the population about MPs pollution as part of a National Plastic Strategy that can be enforced by the municipalities.
- Regarding MPs emission of tyre abrasion, low pressure in tyres and heat increase significantly tyre wear and as consequence more MPs emissions. A recommendation for heavy transport is to stablish tyre pressure controls and restrict circulation of heavy transport in hours with peak temperatures.

For industry

- To strictly limit the use of MPs in products and to search for alternatives in product formulations.
- To implement procedures that limit the use of plastic in the whole Life Cycle of a product to limit secondary MPs emissions.
- To self-regulate by adding labels on products that contain MPs.
- The textile industry needs to reduce the use of synthetic fibres in clothing and find natural fibres alternatives.
- Washing machines can be redesigned machines in which extra filters are included to prevent fibres emissions.

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APPENDIXES

Appendix 1 : Type of plastics

Type	Description
Bio-based plastics	Plastics that are totally or partially made of renewable biological sources such as sugar cane, which is processed to manufacture ethylene or other natural source such as starch that can be transformed to produce polyactic acid (PLA).
Biodegradable plastics	Considered the degradable by microorganism in certain conditions. Due to its composition some bioplastics are made from renewable raw materials that makes easier to degrade by bacteria. Some other plastics made from petrochemicals process can also be considered as biodegradable if they contain additives that increase biodegradation.
Engineering plastics	Plastics that are manufactured precisely for engineering processes. For instance, these plastics are design to replace traditional materials like wood or metal and its properties consists in high performance and high strength.
Epoxy resins	These type of plastics is widely used in every day's life. Its characteristic is that can be transformed from low viscosity liquid to a solid state rapidly, what makes this type very versatile. This type is common found as special packaging and protection of furniture, also is widely used in pacts as a waterproof protector.
Expanded polystyrene	Also called EPS, this type of plastic is widely in several applications like bicycle helmets and insulation material. Its special characteristics is that is very versatile and low cost.
Fluoropolymers	The main characteristic of this type is the non-stick properties. For instance, this type is widely used in cookware and stain repellent for fabrics and textile industry. Within time, its use has increased in other areas such as

	communication, electronics and medical devices. The most common plastic in this category is PTFE (polytetrafluoroethylene).
Polyolefins	This type is a family of the polyethylene and polypropylene thermoplastics. These type is formed from oil sources and its characteristics make it one of the most popular plastics that people use nowadays.
Polystyrene (PE)	Considered as a synthetic polymer, it is constituted from styrene monomers, this polymer is weaken when heated and makes it very versatile for many applications and articles.
Polyurethanes (PUR)	This type is a malleable and flexible material which is used in different products. This product is often mixed with other kind of plastic materials
Polyvinyl chloride (PVC)	It is considered one of the most broadly used in the market. It is composed in majority of (57%) and oil and gas (43%) can be used in many way in every day's life.
Thermoplastics	Described as polymer that are melted and then harden again when cooling. This special characteristic made it very versatile due to is easy to reshape and mould several times. This type is easier to recycle.

Source: Plastics Europe

Appendix 2:

Levels of Risk Assessment . Source: World Health Organization,2010.

Level 1 Screening: This level indicates the analysis of the existing guidance and information available regarding the chemicals under study (in this particular case the MPs). In this level, it is not considered any changes in the current hazard characterization or other similar considerations. This level helps to have a clear view of the potential risk and the hazard information on toxicological properties from some previous studies.

Level 2 Adaptive level: In this level, the local exposure conditions should be analysed. This means, to determine local exposure conditions, it is essential to gather the actual information. This information can be obtained through routine monitoring, modelling, or any other metric available. It is important to remark that even if the evaluation is qualitative, this should include more meticulous information than Level 1.

Level 3 Modelling or field based: This level of the risk assessment includes exposure in a quantitative approach and analysis. The difference of this level with level 2 is that in this level, a field strategy that includes surveys must be done, i.e. field data. In this level new exposure information would be generated.

Level 4 De novo: This level suggests a unique risk assessment that implies the review of the original data. In this level, modelling approaches are used to determine exposure in specific and local conditions. This is applied to chemicals that have not been evaluated in the past, or when new routes of exposure are discovered. The toolkit explicitly states that this kind of assessment goes beyond the toolkit guidance.

Appendix 3:

Cosmetics and personal care products that contain MPs in the Netherlands.

Brand/Concern	Producer	Product Name	Ingredient
Albert Heijn	Koninklijke Ahold	Styling gel extra strong	Polyethylene-glycol
Clinique	Estee Lauder	Pep-start eye cream	Polyethylene PE
Dove	Uniliever	Men+Care Clean Comfort Deo	Polyacrylate
Dove	Uniliever	Original Anti-Perspeirant Anti-transpirant deodorant	Polyethylene PE
Dove	Beiersdorf	Dove invisible dry Anti-transpirant deodorant	Polyethylene PE
Etos	Koninklijke Ahold	Etos: cleansing Milk Alle Huidtypen	Polyacrylate
Guilette	Procter&Gamble	Shaving gel	Polyehtylene-glycol
Guilette	Procter&Gamble	Basis Rasiergel Normal Haut	Polyehtylene-glycol
KMS	Parfumerie Akzente GmbH	Hair Play Molding Paste	Polyvinylpolypyrrolidon
Kruidvat	A.S Watson	Keratin Hair Repair Anti-Klit Spray	Polyehtylene-glycol
L'Oréal	L´Oréal	Invisi Fix Hair Gel	Polyehtylene-glycol

Max Factor	Coty Inc.	Max Factor 2000 Calorir cur addict	Polyehtylene/acrylate copolymer
Maybelline NY	L´Oréal	SuperStay 7 days, gel nail color	Polyethylene PE; Terephthalate PET; Polyacrylate; Polyurethane
Nivea	Beiersdorf	Diamond Gloss Care- Styling Mousse	Polyehtylene-glycol
Nivea Men	Beiersdorf	Fresh Ocean Deo Roll-on	*not mentioned
Nivea Men	Beiersdorf	Sensitive Cooling Sheerschuim	Polyehtylene-glycol
O'right	O'right	Free Mind Mud 50ml	*not mentioned
Palmolive	Colgate -Palmolive	Hygene-Plus Sensitive liquid soap	Polystyrene/ acrylate copolymer
Palmolive	Colgate -Palmolive	Palmolive milde verzorging Handzeep	Polystyrene/ acrylate copolymer
Rexona	Unilever	Cotton Dry Stick	Polyethylene PE
Rituals	Rituals	Hands free hand Hygiene	Polyehtylene-glycol
Schwarkopf Gliss	Schwarkopf Gliss	Schwarkopf Gliss kur styling cream wax control & care	Polybuthylene/Ethylene/Styrene copolymer
Syoss	Schwarkopf & Henkel GmbH	Re-Style Professional Performance New Fiber Paste	*not mentioned
Taft	Schwarkopf & Henkel GmbH	Irresistible Power ger	Polyvinylpolyrrolidon
Taft	Schwarkopf & Henkel	Taft: Irresistible Power	Polyvinylpolyrrolidon Polystyrene
ULTIME	Schwarkopf & Henkel GmbH	Sea salt beach look texture spray	Polyehtylene-glycol
Uni Cura	Colgate-Palmolive	Handzeep balans	Polystyrene/ acrylate copolymer
Wella Wellaflex	Procter & Gamble	Weela Flez Hairspray extra	*not mentioned

Kruidvat	A.S Watson	Kruidvat cream soap soft& care aloe vera	Polyethylene/propylene/styrene Copolymer
Nivea	Beiersdorf	Nivea: styling spray volume care	Polystyrene/ acrylate copolymer

Source: Plastic Soup Foundation, 2020 https://www.beatthemicrobead.org/product-results/ Retrieved 20-05-2020

Appendix 4:

Priority scores for sources of MPs in the Netherlands based on five criteria. C1: Scale of emissions, C2: Indispensability, C3: Opportunities for quick wins, C4: Risk perception, C5: Alternatives for the consumer. Retrieved from RIVM , 2014

Activity/ Product	Sector	Scale	Feasibility		Urgency		Priority
		C1	C2	C3	C4	C5	
Packaging material	Consumers	2	2	2	2	1	9
Litter(general)	Various sectors	2	2	1	2	1	8
Waste collection	Waste disposal	2	0	2	2	0	7
Cosmetics	Chemical industry	1	1	2	2	1	
Cosmetics	Consumers	1	1	2	2	1	
Paint, lacquer, dyes	Consumers	2	1	1	1	1	
Fibers and clothing	Consumers	2	1	1	1	1	
Loading ,unloading, transfer	Services	2	0	1	1	2	
Runoff from paved surfaces	Traffic and transport	2	1	1	1	2	
Dust from construction sites	Construction	2	0	1	1	1	6
Abrasive cleaning agents	Industry	1	1	2	1	1	
Abrasive cleaning agents	Consumers	1	1	2	1	1	
Agricultural plastics	Agriculture	1	1	2	1	1	
Compost, sewage sludge	Agriculture	1	1	1	1	2	
Treated water	Sewage treatment plants	1	1	1	1	2	
Overflow and untreated water	Sewage treatment plants	1	1	1	1	2	
Tire wear	Traffic and transport	2	0	0	1	2	
Inflow from abroad	Other	2	0	0	1	2	
Composting installations	Waste disposal	1	0	1	1	2	5
Glues, paints	Construction	1	0	1	1	0	
Insulation	Construction	1	1	1	1	1	
Cast floors, carpeting	Construction	1	1	1	1	1	
Food	Consumers	1	1	1	1	1	
Household items	Consumers	2	0	1	1	2	

Automotive business	Services	1	1	1	0	2	
Dry cleaners	Services	1	0	2	0	2	
Cleaning of tankers	Services	1	1	1	0	2	
Sports fields	Services	1	1	0	1	2	
Foodstuffs and snacks	Consumers	0	1	1	2	1	4
Landfill sites	Waste disposal	1	0	0	1	2	
Fibers	Chemical industry	1	1	0	1	1	
Packaging	Chemical industry	1	1	0	1	1	
Granular material DIY	Chemical industry	1	1	1	0	1	
Medical resources	Consumers	2	0	1	0	0	
Toys and party items	Consumers	2	0	1	0	0	
Combustion	Waste disposal	1	0	0	0	2	3
Sandblasting	Construction	0	2	0	0	2	
Granular material	Chemical industry	1	0	0	0	2	
Foodstuffs and snacks	Chemical industry	0	1	1	1	1	
Glues and adhesives	Consumers	1	0	0	0	2	
Shipyards	Services	1	0	0	0	2	
Rotary milling	Traffic and transport	1	0	0	0	2	
Atmospheric deposition	Other	1	0	0	0	2	
Preparation of recycling	Waste disposal	1	0	1	0	0	2
Production of base chemicals	Chemical industry	0	0	0	0	2	
Paint and adhesives	Chemical industry	0	1	0	1	1	
Medical resources	Chemical industry	0	0	0	0	2	
Electronic printers	Consumers	1	0	0	0	1	
Dental surgeries	Services	1	0	0	0	1	
Corrosion of water mains	Services	0	1	0	0	1	
Extraction and distribution	Drinking water industry	0	1	0	1	1	
Cooling water	Energy	0	0	0	0	2	
Aviation	Traffic and transport	0	0	0	0	2	
Pesticides/herbicides	Chemical industry	0	0	0	0	1	1
Pesticides/herbicides	Agriculture	0	0	0	0	1	
Printing firms	Services	0	1	0	0	0	

Appendix 5:

Interview Findings

Expert 1: Plastic Leakage and materials

Question	Answer
What are the potential sources of MPs in the Netherlands	Regarding the sources, RIVM and Plastic Health Coalition are working in plastic risk related with human health. What I know briefly is that they have categories like digestion, immunology and kinetics. In the past the work was focused on identifying sources etc. but nowadays researchers are more looking into health effects and its becoming more urgent.
how are policies addressing MPs pollution in the Netherlands?	There's is the latest Circular Economy plan from the EU Commission which was recently published, in which was also addressed monitoring and identifying MPs also in fashion industry. The issue is more focused into the CE framework rather than banning MPs. The first attempt was to addressed MPs in cosmetics that are uses such as toothpaste. There had been steps to ban those MPs. The Netherlands also follows the EU line.
What do you consider is necessary (in terms of policy, consumers, etc) to reduce plastic and Microplastic pollution in the Netherlands?	When comes to Mp, now we can see how big the problem is, now the magnitude is huge so it is important to quantifying. Second it is important to determine what is MPs mechanism in life in general. These two phases will help to understand, and with that response already done will immediately lead to policy making. Meanwhile, for now it is important also to look for alternatives for plastic in industry.
What activities are the ones that produce MPs in the Netherlands and/or in Europe?	From my opinion Car Tyres and Clothing produce MPs emissions. A large part of the clothing industry uses polyester and is cheap. This product will be used more and more within time. For now, I don't find any other alternative than polyester, use of cotton maybe but there's a water issue. Looking the LCA in every step is necessary. Car tyres also are a big MPs releases but right now I don't see other alternative for rubber.

How can policies be strategically addressed MPs pollution?	There's a general debate of how to measure this pollution and what are the standards. How can human health risk should be evaluated .As I see the urgency is not the high like it is for example with Climate Change. If this comes more urgent or less urgent that will lead to further policies to address different sources or to reach a Plastic Agreement.

Expert 2: MPs risk assessment

Question	Answer
What do you considerer is the biggest risk for human heath regarding Microplastics pollution in the Netherlands?	There is no evidence yet that Mps can cause any health problem. But there is evidence from experiments in animals, mammals and also occupational exposure in textile factories that workers develop lung diseases, and there's also issues what concerns air pollutants. In general, the issue is very complex and the big knowledge gap in this issue is the MPs measurement because is too complicated. We are tying to developt method to detect MP in blood, breast milk, urine and maybe also in organs but this will take at least 5 years. We know MPs are in the air in food like beer, fish, sugar and drinking water. There is evidence that people like us can ingest MPs but that exactly does not tell you if that particle penetrates the body. The fraction that penetrates the body is very little. As long as there's no appropriate measurement methods we cannot know the real risk.
In your opinion, which Microplastic source have the biggest risk for health?	there are several particles that we re expossed to surch as from cars, fibers, also natural ones , asbestus. There are two additional hazards that this particles can bring, oxidative stress that causes cell damage and DNA damage and it causes cronic inflamation we know that is bad for the body but, also that migh be caused fro other particles. Particle toxicity and chemical toxicity are also important risk relate to this particles and they contribuite to the chemical exposure of you body. The new hazard that have been discovered related is bacteria adherence. To know the real risk, we have to know the internal concentrations in the body. There are strong indications that something is going on in human body related to MPs.

Do you consider that Microplastic pollution is being addressed adequately in the Netherlands?	I considered they are doing a good job, because you can see that the Ministry. they started making a case for MPs pollution in the environment in the country so in that sense Netherlands is pioneer in this area. Also basically due to the Plastic Soup Foundation also started a lot of campaigns about this topic. Netherlands also is enforcing reduction of use the one single use plastic. The hot spot is pretty okay compared to other countries regarding MPs pollution problem. All the sources is not easy to tackle due to is interlinkage to the environmental counterpart.
In your opinion, do you consider that Microplastics can make us sick and be a threat for public health?	Yeah there's a point of that. There's some sub particles from car tyres and dust. There's increasing evidence that there's bioaccumulation of this particles and causes inflammation that can be linked to neurodegenerative diseases etc. There are strong evidence that something like that is happening and this particles can reach circulatory system.
What do you consider is necessary (in terms of policy, consumers, etc) to reduce Microplastic pollution in the Netherlands?	I considered that every little help counts to contribute to reduce the pollution but it is a small fraction. The only solution that I think is a hole market transition with eco materials. There's a need to replace clothes for fibres eco-friendlier without MPs and without chemicals.

Expert 3: Researcher KWR

Question	Answer
What do you considerer is the biggest risk for human heath regarding Microplastics pollution in the Netherlands?	The biggest risk is still unknown, so I can speculate that a huge risk is also not taking measures to reduce plastics use.
In your opinion, do you consider that Microplastic pollution is being addressed adequately in the Netherlands?	I considered that this topic is taking seriously by the government. There are a lot of possible measures to address it and currently they are pushing to a better recollecting system, but i don't think is enough and meanwhile if there's not a current law enforcement from the government to industries there's still la lot to do but I believe there's a political willing to do it so i can considered there's a barely adequately.

What do you consider is necessary (in terms of policy, consumers, etc) to reduce plastic and Microplastic pollution in the Netherlands?	The important thing is to identify the biggest sources, and I think that transport and handling of garbage, and building projects so policies in this activities are necessary. The problem is going fast and there's not enough research done in this topic. A problem is also that measuring MPs is not a cheap method.

Expert 4. Plastic Soup Foundation

Question	Answer
What do you considerer is the biggest risk for human heath regarding Microplastics pollution in the Netherlands?	There's very little research done in MPs with human health and because of this, we know very little about the exposure, so without this is not possible to make a proper risk assessment. There are two big unknowns: one is being able to detect nanoplastics in products, tissues samples, so research have shown that nanoplastics are more potentially harmful that MPs. Also other researches shown that MPs can also pass certain barriers in our body such as lung and intestine. The extent or percentage of MPs ingested can actually pass those barriers we don´t know, if there's low exposure then the risk is not necessarily there. there are much of unknowns but is real that there's a concern due to some research that have been released.
In your opinion, Do you consider that Microplastic pollution is being addressed adequately in the Netherlands?	Not necessarily, we have been trying to get politics to adopt more policies regarding plastic pollution in general. There's an issue due to a lot of times industries and politics are trying to make it seem that plastics are very easily recyclable but that is not the case in all products. It's been shown that measures such as charging 10 cents for plastics bags actually work so that is a good start point. We are very pleased that ECHA is working on the restriction of banning MPs not only in cosmetics but a wide range of products. This will really prevent the

	release of MP pollution into the environment which automatically reduce the exposure in humans. It is not enough but is good first step.
In your opinion, which Microplastic source have the biggest risk for health?	it seems like indoors human exposure of MPs is more relevant. tearing of Rubber tyres when are used in cars are the most significant emission of MPs into the environment and of course into the air outdoors. But threes some research done and it seems like the exposure indoors is much higher because we use a lot of synthetic clothing, and synthetic products at home etc. We try to stimulate people to ventilate and to vacuum regularly due to dust also contains MPs.
What do you consider is necessary (in terms of policy, consumers, etc) to reduce Microplastic pollution in the Netherlands?	one good step is banning MPs use in products, and to promote the use of other alternatives. There's a convention about international trade of waste, in which developed countries cannot "export" waste to developing countries anymore without previous agreement among countries. The ultimate goal is to limit the use of plastic, plastic is not bad the thing is why use it when there are other better alternatives for the environment. We want to move forward a system when plastic is reduced, but is very difficult, due to we are living a convenient society when we are not aware all the much waste we are creating. So this is also a big focus to provide alternatives and to create more awareness.
In your opinion, do you consider that Microplastics in a long term (20 years from now) can make us sick and be a threat for public health?	Right now we don't know, but there's some research done in textile factories and we can see that they are more exposed to fibres -plastic fibres- in nylon factories, these research shown that these worked developed a lot of lung diseases. it is still being investigated whether if these fibres get stacked in the lungs and the immune cell attack them and they cannot biodegrade them, because it is a synthetic material, so this cause a lot of inflammation reactions, which shows that there's a potential treat of MPs to human health. But it all comes down to the exposure, and to stop plastic production if this continues plastics and MPs pollution will continue to increase. if we don't reduce plastics production and MPs, exposure level will continue to rise and if this concentration is high enough this can lead to human health effects. All depends to the extent of the exposure.

Expert 5: Toxicology expert

Question	Answer
In general, What do you considerer is the biggest risk for human heath regarding Microplastics pollution in the Netherlands?	There's little evidence from actual research about the hazard, it is not clear. So if there's no hazard there's no risk associated. we are exposed to many particles, which all are particles that we are taking up, how we can relate MPs to the other particles that we can ingest, we don't know if is a big portion or a small portion.
in which cases do you use MPs as ingredients in products?	We only use MPs when is strictly necessary, in some other brands industries use them only to get paints chine better, or to a better label but in our case no. For my perspective MPs use for that is unnecessary.
In your opinion, do you consider that Microplastic pollution is being addressed adequately in the Netherlands?	AS long as there is no evidence related to hazard and exposure, there's no sense to make regulations about it. That is the precautionary principle which is being used for MPs. Industry is dealing with precautionary principle from day to day basis, but I think we should not follow that principle for MPs because we first need to know what is the real issue about hazard and then exposure. Banning plastics would not solve the problem, education and create awareness in disposal is more important.
What do you consider is necessary (in terms of policy, consumers, etc) to reduce Microplastic pollution in the Netherlands?	it is necessary to crate methods for sampling and quantifying MPs. Intentionally added MPs should not be used in industry, MPs only should be used in industry when is strictly necessary. EU is hazard based regulated and not risk based regulated which means that at the very end they do something with risks, the only exposure metric they use is the volume of production which from the scientific point of view that is very weak. Anything that is low concentration can be no toxic and everything in high concentrations is potentially toxic. There a lot of chemicals that are in market that can be more toxic. In my opinion Precautionary principle should be used with a reason.