European Commission

Scientific Advice Mechanism (SAM)

Environmental and Health Risks of Microplastic Pollution

Group of Chief Scientific Advisors
Scientific Opinion 6/2019

Independent Expert Report

Research and Innovation

Environmental and Health Risks of Microplastic Pollution

Group of Chief Scientific Advisors

European Commission
Directorate-General for Research and Innovation
Unit RTD.DDG1.02 - Scientific Advice Mechanism

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EUROPEAN COMMISSION

Scientific Advice Mechanism (SAM)

INDEPENDENT SCIENTIFIC ADVICE FOR POLICY MAKING

Environmental and Health Risks of

Microplastic Pollution

Group of Chief Scientific Advisors

Scientific Opinion 6/2019

(Supported by SAPEA Evidence Review Report No. 4)

Brussels, 30 April 2019

2019 Directorate-General for Research and Innovation

Table of Contents

ACKNOWLEDGEMENTS 5

EXECUTIVE SUMMARY 6

1. Background and introduction 12

1.1. Background and approach to this Opinion 12

1.2. Policy-relevant principles and premises 13

1.3. Plastics, microplastics and the scale of pollution 14

1.4. Why microplastics have become a focus of attention now 15

1.5. Emergence of the issue 16

1.6. Making science part of the debate 16

1.7. The case for microplastic-pollution prevention 17

2. Recommendations 22

2.1 Broaden policy cover to prevent and reduce microplastic pollution 22

2.1.1 Microplastics in water, air and soil 22
2.1.2 Substance and context-specificity and uses posing the highest potential risks 24
2.1.3 Nanoplastics 26

2.2 Address wider socio-economic and trade-off implications of microplastic pollution policy actions 28

2.3 Promote global cooperation, high-quality scientific exchange and policy coherence 31

2.3.1 Global cooperation 31
2.3.2 Quality and pertinence of scientific studies of microplastics 33
2.3.3 International scientific standards and methodologies 34

3. References 35

LIST OF FIGURES

FIGURE 1 – IMPACTS OF NANO AND MICROPLATICS ON BIOTA REPORTED AT VARIOUS LEVELS OF BIOLOGICAL ORGANISATION (A BIOLOGICAL ENDPOINT IS A MARKER OF DISEASE PROGRESSION). MOST STUDIES HAVE BEEN AT SUB-ORGANISMAL LEVELS AND STUDIES AT A COMMUNITY OR ECOLOGICAL LEVEL ARE RELATIVELY SPARSE (SAPEA, 2019) 18

LIST OF ANNEXES

ANNEX 1 – INITIAL STATEMENT 48
ANNEX 2 – EXPERTS CONSULTED 52
ANNEX 3 – STAKEHOLDERS MEETING PARTICIPANTS 54
ANNEX 4 – ABBREVIATIONS 55
ANNEX 5 - GLOSSARY 56

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1 SAPEA brings together knowledge and expertise from more than 100 academies and learned societies in over 40 countries across Europe. Funded through the Horizon 2020 programme of the EU, the SAPEA consortium comprises Academia Europaea (AE), All European Academies (ALLEA), the European Academies Science Advisory Council (EASAC), the European Council of Academies of Applied Sciences, Technologies and Engineering (Euro-CASE) and the Federation of European Academies of Medicine (FEAM).

2 From DG RTD I. 2 - Eco-Innovation Unit

EXECUTIVE SUMMARY

Since the 1950s, plastics have been a source of innovation-driven growth due to their unique properties and they hold similar promise for the future. Today, plastics are in high demand and are central to modern living, but their use has become tainted by the unrelenting rise[3] of plastic and microplastic[4] pollution.

Human behaviour is largely responsible for plastic pollution. Sources of microplastic pollution include: textiles, tyres, general waste, products containing microplastics, and equipment/products used in fisheries, agriculture, and industry. Each year, a significant proportion of plastic waste[5] fragmenting into microplastics enters the environment together with human-made microplastics. Whilst marine microplastic pollution has attracted the attention of both the public and policy makers, recent reports of the ubiquity of microplastics across the air, soil, sediments, freshwaters, oceans, plants, animals, and parts of the human diet, have amplified concerns.

Research on microplastics and their potential threats to the ecosystems and humans is in its infancy and is complex - a lot remains uncertain. Relatively few studies record microplastics in nature at or below the 10-50 micron size range because they are below the detection limit of the most often used analysis equipment. Some experimental studies have shown increasing concentrations of microplastics with decreasing size[6] suggesting that actual concentrations in the environment could be higher than those reported to date. Furthermore, toxicity and the relative ease with which microplastics cross biological barriers are expected to increase with decreasing size. This raises further concerns about smaller microplastics, and in particular, nanoplastics.

Growing scientific evidence on the hazards of the uncontrolled, irreversible, and long-term ecological risks due to microplastics do exist for some coastal waters and sediments. Scientists predict that, if emissions to the environment continue at the current rate or increase, ecological risks could be widespread[7] within a century. Since most laboratory studies to date have been conducted for conditions that do not reflect real-world exposure, a better understanding is needed of the effects of different concentrations, compositions, sizes, and shapes of microplastic on ecosystems and humans before robust conclusions can be drawn about real risks.

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3 See Geyer et al. (2017), PlasticsEurope (2018) and Ryan (2015)

4 Microplastics are solid synthetic-polymer-containing particles less than five millimetres in their longest dimension. For the purposes of this Opinion, unless otherwise stated, the term includes nanoplastics – i.e. particles up to 100 nanometres.

5 Global mismanaged plastic waste in 2015 was estimated to be between 60 and 99 million tonnes (Lebreton & Andrady, 2019). Based on estimates (Boucher & Friot, 2017), the total annual amount of microplastics forming in or leaking into the environment could be of the order of 11 million tonnes. As plastic production and use continues, these figures will continue to increase in a business-as-usual scenario.

6 See Araujo et al. (2018), Enders et al. (2015) and Lorenz et al.(2018)

7 N.B. the overall scientific conclusion is that, at present, microplastic pollution does not constitute a widespread risk. However scientists also conclude that, if microplastic pollution is left unchecked, business-as-usual would lead to effect concentration thresholds being exceeded in the near future and the occurrence of widespread risk within a century (SAPEA, 2019: 2.8)

Although the currently-available evidence suggests that microplastic pollution at present does not pose widespread risk to humans or the environment, there are significant grounds for concern and for precautionary measures to be taken. High-quality risk assessment approaches are essential to prioritise such measures and to determine when and where to apply them.

Experts and society must come to a mutual agreement on risk levels and responses. With plastics playing such a pivotal role in modern life, changing human behaviour is essential. Values, motivations, incentives and supportive conditions all influence pro-environmental behavioural change of individuals and organisations[8]. A scientific understanding of behavioural factors can also help to better articulate the interplay between natural sciences and the planning of effective responses.

Society has not yet drawn much on scientific knowledge of microplastic pollution in reaching its conclusion and calling for action. Therefore, clear evidence-based communication of the uncertainties related to the environment, food and human health is absolutely necessary.

Recommendation 1: Broaden policy cover to prevent and reduce microplastic pollution

Microplastics in water, air and soil

The Commission should exploit current provisions in existing legal instruments to prevent and attenuate microplastics in water, air and soil. Airborne, freshwater and soil-based microplastic pollution should be addressed by policy to the same extent as for marine microplastics. New actions should be introduced where possible and feasible under existing relevant instruments. Potentially-relevant examples include the water framework directive and directives applicable to urban waste-water treatment, the application of sewage sludge as fertilizer, and air quality. Besides legislation, softer voluntary, economic or persuasive measures aimed at fostering responsible change through commercial, social or more altruistic initiatives should also be considered.

Substance- and context-specificity and uses posing the highest potential risks

Since microplastics constitute a plethora of materials, a multi-pronged approach is essential. This should include measures which are substance- and context-specific in terms of parameters such as composition, shape, origin, location, pathways, impacted medium and endpoints. Scientific evidence and science advice should help determine the best measure for each given problem, substance and context. Furthermore, high-volume, high-emission and/or high intrinsically hazardous sources of microplastics which pose the highest potential risks should be targeted. In the short term, this could include: tighter licensing conditions for plastic pellet producers under the industrial emissions directive; stringent performance standards for washing machines aimed at textile microplastics; and improved drainage-system

[8] See van Valkengoed & Steg (2019)

interceptors for tyre abrasion microplastics. In addition, more novel and sustainable preventative long-term solutions should be developed.

Nanoplastics

The Commission should take steps to enable the scientific community to fill knowledge gaps regarding the presence, concentration, and behaviour of nanoplastic pollution in different situations. As much as for microplastics overall, from a policy perspective, it is important that decision makers are also regularly informed and are equipped to be able to take preventative or risk-mitigating measures, should scientific evidence emerge concerning ecological or human health risks and harm specific to nanoplastics.

Recommendation 2: Address wider socio-economic and trade-off implications of microplastic pollution policy actions

Political and socio-economic feasibility

Preventative microplastic pollution measures should be politically and socio-economically feasible. To ensure net positive and sustainable benefit to society, quantitative analyses of broad factors, (e.g. trade-offs; substitution strategies/alternatives; life-cycle assessments; and cost-benefit calculations), should feature prominently in impact assessments of individual measures. Furthermore, the framing of such socio-economic and trade-off assessments of microplastic pollution measures should be embedded in a "reduce – reuse – recycle" circular-economy logic that strives for better environmental, economic and social outcomes of the plastics system as a whole.

A catalyst for other environment and health protection issues

The Commission should also seize the opportunity of wide public concerns about microplastic and broader plastic pollution consensus to help catalyse difficult environment and health protection actions in other more contested areas.

Recommendation 3. Promote global cooperation, high-quality scientific exchange and policy coherence

Global cooperation

Promote a global treaty aimed at reducing and tackling the roots of microplastic and other plastic pollution. Foster also international and cross-disciplinary collaboration and the early sharing of new knowledge and research findings. A first step would be to promote the establishment of a global scientific platform on plastic and microplastic pollution, enabling shared and cross-border access to standardised data.

Quality and pertinence of scientific studies of microplastics

Take measures to improve the overall quality and pertinence of microplastic research by: i) promoting advances in detection, measurement and analysis, and risk/impact assessment methodologies of microplastic pollution; ii) fostering rigorous and transparent disclosure of experimental procedures and meta data; and iii) encouraging the pursuit and publication of comprehensive dose/response and no-effect studies to generate a more balanced scientific knowledge base underpinning both science advice and policy in this area.

International scientific standards and methodologies

Initiate the development of consensual international definitions and standards for the measurement and monitoring of microplastic pollution and its impact on ecosystems and human health, enabling: i) a globally-coherent picture of the nature and threats of microplastic pollution and, ii) clear, unambiguous technical prescriptions and criteria for regulatory measures, when these are needed.

*** * ***

We hope the Opinion will help to further develop the policy response to microplastic pollution in the EU and globally.

Background and introduction

1. Background and introduction

1.1. Background and approach to this Opinion

The Opinion is based on a recent stock-take of the scientific knowledge in this nascent field (SAPEA, 2019) and other background work (SAM, 2018, 2019). Our intention is to inform an area of EU policy where a range of microplastic actions was announced in the January 2018 European Plastics Strategy (European Commission, 2018) and which are at varying stages of development. In a fast-evolving scientific and policy context, this Opinion should help on-going policy development by giving new science-based insights, as well as revisiting important assumptions and policy rationales in light of emerging scientific evidence.

We were first alerted to the marine component of microplastic pollution in 2017, when working on a previous Opinion on Food from the Ocean (SAM, 2017). Before proposing to the Commission to take up the issue, we undertook a preliminary exploration of the available science, as well as looking at the on-going public debate and policy context. In so doing, we observed how rapidly and deeply microplastic pollution has entered into the public consciousness. Powerful evocative media coverage, drawing on information from scientists, activists, citizens, public authorities and journalists feed this process.

We also found that, even though the number of scientific publications is increasing fast, the overall evidence and knowledge base is still quite thin. In spite of this, discussion with experts plus the fact that public opinion and policy development continue to move ahead quickly, convinced us that a Scientific Opinion on the topic could be a welcome and timely contribution.

The Commission endorsed the approach we proposed in our Initial Statement[9] published in July 2018.

A number of lines of work were undertaken to help set the scene for the Opinion:

1. A Background Paper "Microplastic Pollution - The Policy Context" (SAM, 2018) - Nov 2018;
2. A review of the scientific literature by SAPEA - "A Scientific Perspective on Microplastics in Nature and Society" (SAPEA, 2019) - Jan 2019;
3. An expert workshop - "Environmental and Health Impacts of Microplastic Pollution – from scientific evidence to policy advice" - Jan 2019[10];

The main input to the Opinion is the SAPEA report (SAPEA, 2019) which contains an objective and independent synthesis of relevant state-of-the-art scientific evidence and knowledge. It draws on the natural sciences and insights from social and

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9 https://ec.europa.eu/research/sam/pdf/topics/mp_statement_july-2018.pdf#view=fit&pagemode=none

10 https://ec.europa.eu/research/sam/pdf/topics/microplastic-sam_workshop-012019.pdf#view=fit&pagemode=none

behavioural sciences, on how people and stakeholders both perceive and are affected by microplastic pollution, and efforts to deal with it.

The Opinion has also benefited from bilateral cooperation with Canada's Chief Scientific Advisor and wider international discussions in an informal setting of chief science advisors or equivalents from G7 members[11] , as well as other ad hoc expert consultations and discussions. Finally, a stakeholders meeting with professional organisations, NGOs, scientific and policy organisations/agencies, was organised shortly before the Opinion was completed.

All of the above helped to characterize the complexity of the situation surrounding both the science and how society is experiencing and reacting to microplastic pollution. The messages and recommendations in this Opinion, on how the EU together with other global policy actors should respond to microplastic pollution, take this complexity into account.

1.2. Policy-relevant principles and premises

Given that the Opinion is directed to the highest level of policy making in the European Commission, it is relevant to recall key principles and elements of the EU approach to protecting health and the environment (noting that a more detailed description of the policy context is set out in (SAM, 2018) and in (SAPEA, 2019: Chapter 4).

The main public health-related Treaty provision[12] (Article 168) gives the EU limited powers. However, the Treaties also endow the EU with a unique mandate, obligation and substantially greater powers to protect health via all its other policies. Those with clear health-protection implications include environment, health and safety at work and consumer protection.

Similar to the Treaty basis for health policy, environment policy also has an "integration clause" (Article 11) requiring environmental protection to be integrated throughout policies and activities of the EU.

The rules-based approach to achieving the single market typifies the rationale underpinning legislation and policy measures in some of these areas – e.g. in relation to food safety, labelling and nutritional health claims, and the harmonization of environmental standards. In addition, the high importance accorded to substantiation by scientific evidence of concrete problems and proposed solutions in *ex ante* impact assessments of policy measures, is particularly pertinent to this Opinion.

EU environment policy aims at a high level of protection taking into account the diversity of situations in the regions of the Union. It rests on the principles of **precaution**, **prevention** and **rectifying pollution at source**, and on the **polluter**

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11 Co-Chairs summary http://science.gc.ca/eic/site/063.nsf/eng/h_97763.html

12 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012E/TXT&from=EN

pays principle. These principles are embedded in horizontal strategies and are taken into account in international environmental negotiations.

The precautionary principle may be invoked when there is scientific uncertainty about a suspected risk to human health or to the environment emanating from a certain action or situation (Bourguignon, 2015; European Commission, 2017b). For instance, should doubts arise about the potentially harmful effects of a product or substance, and should — following an objective scientific evaluation — uncertainty persist, instructions may be given to stop its distribution or remove it from the market. Such measures must be **non-discriminatory** and **proportionate**, and must be reviewed once more scientific information is available.

It is also worth pointing out that, in a recent meeting of chief scientific advisors or equivalents from G7 countries on "Scientific Advice Cooperation on Microplastics", three other Principles were retained[13]:

- **Scientific integrity** - Scientific advice should be based on an objective assessment of the range of robust scientific evidence and expert knowledge available on microplastics, drawing on the breadth of reliable research sources, and across all disciplines in a balanced, transparent and accountable manner that is free from interference;
- **Scientific responsibility** - Scientific evidence should be made available in appropriate and accessible forms, and in a timely manner, so that it can effectively feed into policy development. This should consist of the body of current scientific knowledge and knowledge gaps on the occurrence, fates, impacts, hazards, ecological and health risks of the sources and types of microplastics pollution in all environmental compartments (air, soil and water);
- **Broader plastics context** - Scientific advice on microplastics needs to be considered within the broader context of plastic pollution and alongside other pollutants taking into account geographic variability in incidence and impacts.

Our Opinion is guided by all of the above.

1.3. Plastics, microplastics and the scale of pollution[14]

High demand, low cost and a range of unique properties have made plastics essential to modern living. Since the mass application of plastic began in the 1950s, not only has it constituted an alternative to other materials, its properties have brought increased versatility, cost and energy savings, functionality and amenity on which society and the economy have become dependent. Plastics have been a source of innovation-driven growth in areas such as electronics, construction,

[13] Co-Chairs summary http://science.gc.ca/eic/site/063.nsf/eng/h_97763.html

[14] Note that science and regulation normally distinguish contamination from pollution, contamination being the presence of a substance where it should not be or at concentrations above background, while pollution is contamination that results in or can result in adverse biological effects to resident communities. All pollutants are contaminants, but not all contaminants are pollutants (Chapman, 2007) – in this Opinion, we use pollution to refer to both pollution and contamination.

vehicle safety, fuel economy, energy conversion, food preservation and improved human health via many medical applications (Andrady & Neal, 2009; P. Kershaw, 2018; PlasticsEurope, 2019). Furthermore, their use instead of other materials can result in net energy and materials-saving gains (Azapagic, Emsley, & Hamerton, 2003).

Annual global production of 350 million tonnes in 2017 makes plastic the third most abundant human-made material after steel and concrete (PlasticsEurope, 2018). Since the 1950s, an average annual growth rate of 4% has given rise to a cumulative production of 8,300 million tonnes. 4,900 tonnes (60%) of this have ended up in landfills or in the environment (Geyer, Jambeck, & Law, 2017) representing a major economic, social and environmental cost. Global mismanaged plastic waste in 2015 was estimated to be between 60 and 99 million tonnes (Lebreton & Andrady, 2019). Based on estimates by (Boucher & Friot, 2017), the total annual amount of microplastics forming in, or leaking into, the environment could be of the order of 11 million tonnes.

There is as yet no consensual scientific or regulatory definition of microplastics. For the purpose of this Opinion, we follow the prevailing view in the scientific literature whereby microplastics are considered to be solid synthetic-polymer-containing particles of no more than five millimetres in their longest dimension (i.e. $\Phi \leq 5$ mm)[15] and which may contain additives or other substances. Microplastic pollution is thus the lower end of the size spectrum of all plastic litter, noting that anything with $\Phi < 0.05$ mm (50 micrometres or µm) is generally invisible to the naked eye[16]. In this Opinion, except otherwise stated (e.g. in the case of nanoplastics [Φ in the range 1 - 100 nm]), we use the term microplastics to refer to the totality of the sub-five-millimetre size class of these materials.

1.4. Why microplastics have become a focus of attention now

Microplastics have come to the attention of the general public and policy makers on the back of rising concerns about plastic pollution in the marine environment. The societal consensus on the need to solve the plastic pollution problem is driven by a combination of factors – e.g. rejection of the disamenity of plastic pollution visible in water bodies and coastal zones; concern about negative physiological (e.g. growth, reproduction, mortality) and behavioural (e.g. feeding) impacts on animals and other biota; and conflict with the moral convictions of individuals. This same consensus has been galvanized by reports of the ubiquity of microplastic pollution, including in the remotest places on earth such as the Arctic, Antarctica, the deep ocean and secluded mountainous regions, as well as in foodstuffs.

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[15] The 5 mm upper-limit is attributed to (Thompson et al., 2004) and to a 2008 National Oceanic and Atmospheric Administration (NOAA) workshop see (Arthur, Baker, & Bamford, 2009)

[16] https://www.quora.com/Vision-eyesight-What-is-the-smallest-thing-a-human-eye-can-see-and-why

1.5. Emergence of the issue

According to Ryan (2015), many environmental concerns about plastic litter were identified in the 1970s-80s including the presence and formation of small pieces of plastics in the marine environment (Carpenter & Smith Jr., 1972; Gregory, 1983; Scott, 1972). At the time, this gave rise to some progress in curbing plastic waste (Chen, 2015). However, the unrelenting increase in global plastic production and litter more than offset the gains made. After a lull in the 1990s, research took off again as a result of increasing attention to the north Pacific garbage patch (Lebreton et al., 2018; Moore, 2008; Rochman, Cook, & Koelmans, 2016; van Sebille, England, & Froyland, 2012) and the work of Thomson and co-workers (Thompson et al., 2004) who coined the term microplastics. In the past few years, attention has been amplified by developments such as: the microbead outrage (Dauvergne, 2018); the so-called blue-planet effect[17]; reports of the apparent presence of microplastics in foodstuffs (seafood, drinking water, table salt, beer) (EFSA Panel on Contaminants in the Food Chain et al., 2016; Kosuth, Mason, & Wattenberg, 2018; Toussaint et al., 2019; Smith, Love, Rochman, & Neff, 2018) and as-yet unconfirmed and non-peer reviewed reports of microplastics in vegetables[18] and human faeces (Liebmann et al., 2018)[19]. All this has cemented public anxiety and heightens political resolve to deal with plastic and microplastic pollution.

1.6. Making science part of the debate

Much of the emotion in the present debate vilifies plastic as being intrinsically bad[20] (Hartley et al., 2018), but it is important to keep a balanced perspective. As pointed out by Wolf, Baitz, & Kreissig, (2009), no material is intrinsically good or bad *per se*, or, according to a basic principle of toxicology, "it is the dose that makes the poison".

Faced with a broken and costly plastics system characterised by a twenty-fold production increase in 50 years and only 2% in closed loop recycling (Linder, 2017), the public and politicians are taking action and calling for change. However, they often do so oblivious to important scientific knowledge and uncertainties. It is therefore important that science be part of the debate. Scientists and science advisors can help to ensure more tempered policy measures and other stakeholder actions, which take full account of what is known or likely within applicable ranges of uncertainty and timescales.

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[17] https://www.theguardian.com/environment/2018/nov/13/the-plastic-backlash-whats-behind-our-sudden-rage-and-will-it-make-a-difference;https://www.britsoc.co.uk/about/latest-news/2019/march/sociological-perspectives-on-plastic-pollution/

[18] https://www.agrifoodtoday.it/ambiente-clima/plastica-veleno-cibo-contaminato.html

[19] https://www.scientificamerican.com/article/microplastics-have-been-found-in-peoples-poop-mdash-what-does-it-mean/; https://www.nationalgeographic.com/environment/2018/10/news-plastics-microplastics-human-feces/

[20] https://www.nationalgeographic.com.au/nature/we-made-plastic-we-depend-on-it-now-were-drowning-in-it.aspx

1.7. The case for microplastic-pollution prevention

The four pillars of the 2018 European Plastics Strategy (European Commission, 2018) are reuse and recycling, curbing waste, achieving full circularity through innovation and investment, and encouraging global actions. The microplastics actions in the Strategy fall under the curbing waste pillar which states that targeted pollution prevention measures should be actioned for different sources. The Strategy acknowledges that understanding of the sources and impacts of microplastic remains deficient. Chapter 4 of the SAPEA Evidence Review Report underpinning this Opinion, confirms that the scientific foundations of legislation relevant to plastic and microplastic pollution are sparse (SAPEA, 2019: Chapter 4). Hence, it is worthwhile re-examining the scientific rationale guiding current and potential future policy development aimed at microplastics in light of state-of-the-art science.

Overall, SAPEA (2019) shows that the available scientific knowledge on microplastic pollution and its impacts is a mix of consensus, contested knowledge, informed extrapolation, speculation and many unknowns. This reflects both the immaturity of the field and its intrinsic complexity.

The social and behavioural sciences literature on microplastic pollution is in its infancy. As social science research is more transferable than the natural sciences, relevant findings from other areas of study are summarised in (SAPEA, 2019: Chapter 3). The emerging literature describes public awareness[21] of microplastics (SAPEA, 2019: 3.2) and moral opposition to microplastics based on feelings of disgust and outrage, especially with regard to it entering the food chain (SAPEA, 2019: 3.3). Overall, the literature sustains consensus on the need to act, with little indication of plastic pollution deniers (SAPEA, 2019: 3.6).

The relevant natural sciences are more advanced than the social sciences, but are still not well developed. They do not yet provide an accurate picture of baseline stocks and flows of microplastics and underlying trends, let alone of their impacts, even though important findings are emerging. Reported adverse effects of acute occupational exposure to microplastics, animal experiments and what is known about potential hazards, are grounds for concern as well as a stimulus for more conclusive research to be carried out.

Some scientific studies of microplastics have focused on characterising presence, fate, as well as size-, composition- or concentration-dependent variations in their behaviour in the environment. Evidence exists of the growing scale and global reach of microplastic pollution and its long-lasting nature (Barnes et al, 2009). It has also been established that microplastics find their way into the food chain and all environmental compartments (SAPEA, 2019: Chapter 2).

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[21] Anecdotally, the choice of "microplástico" as the 2018 word of the year by Fundéu[21] (a Spanish foundation with links to the Spanish Royal Academy), and 'single-use' named as word of the year for 2018 by Collins Dictionary[21], is indicative of the level of public attention. Also, a 2017 Eurobarometer survey found that 74% of citizens were worried about the impact on their health of everyday products made of plastic, while 87% were worried about the impact of plastic products on the environment (European Commission, 2017a).

Others have studied in the laboratory how microplastics interact with biota and other substances (see Figure 1) – e.g. causing stress-response when ingested by organisms, transporting persistent organic pollutants (POPs)[22], or leaching toxic additives. Plastics are mostly considered to be biochemically inert. However, unreacted residual monomers of up to 4% can be found in synthetic polymers, since polymerisation reactions are rarely complete (Matlack, 2010). Monomer precursors as well as chemical additives used in plastic fabrication can have the highest chemical hazard ranking[23] - see Lithner, Larsson, & Dave, (2011). Other possible hazardous components of microplastics include catalysts and polymerisation solvents, and many additives (plasticisers, flame retardants, catalysts, stabilisers, pigments, etc.) which can migrate from plastics to air, water or other contact media including food (Crompton, 2007).

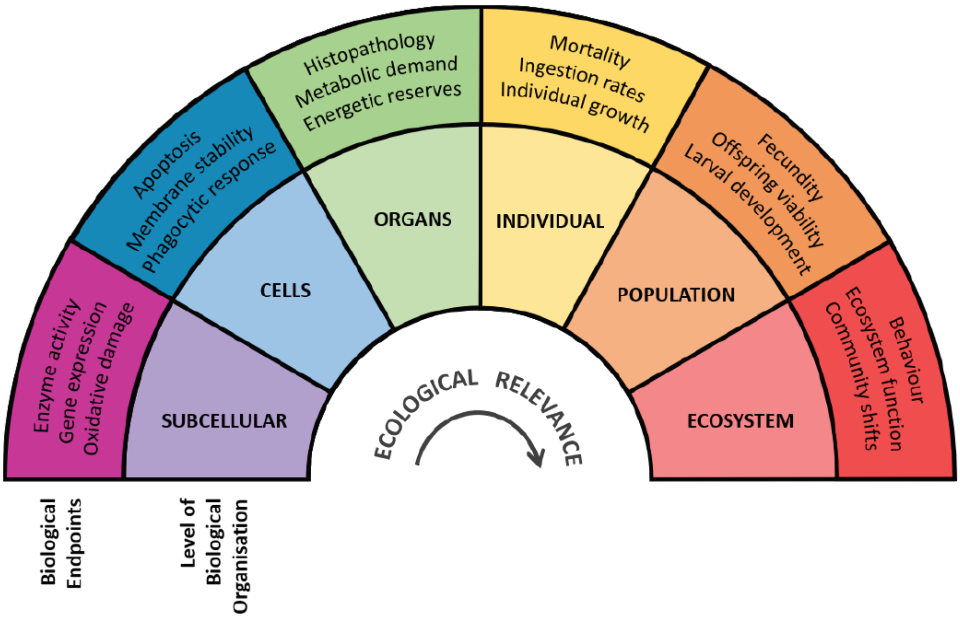

Figure 1 *– Impacts of nano and microplatics on biota reported at various levels of biological organisation (a biological endpoint is a marker of disease progression). Most studies have been at sub-organismal levels and studies at a community or ecological level are relatively sparse (SAPEA, 2019)*

It is important to shed light on the nature of such effects and whether or not any real potential exists for these effects to impact negatively on biota and ecosystems, or on human health when microplastics enter the body (via inhalation, food ingestion or through the skin). Such research, focusing on the occurrence or absence of negative effects in specific controlled circumstances and field studies, is

22 The surface chemistry of microplastics makes them a potential route for bioaccumulation and bioamplification of harmful chemicals

23 According to Annex VI in the EU classification, labelling and packaging (CLP) regulation based on the UN Globally Harmonized System (European Parliament and Council, 2008).

increasing. For example, many animal species ingest plastic mistaking it for food – from large mammals, birds and fish to tiny zooplankton, some dying as a result (de Sá, Oliveira, Ribeiro, Rocha, & Futter, 2018).

Laboratory experiments show that microplastics can give rise to a range of mechanical, chemical and biological impacts on biota causing damage, dysfunction and physiological disruptions. They provide evidence of inflammation and stress, as well as negative effects on food consumption, growth, reproduction and survival of a range of species SAPEA (2019: 2.5.1).

While such effects are found for microplastic concentrations higher than those typically measured in nature, the latter may be underestimated pending better sampling and measuring techniques (SAPEA, 2019: 2.5.2). There are also many no-effect[24] studies reported in the literature e.g. (Jovanović et al., 2018; Rist, Carney Almroth, Hartmann, & Karlsson, 2018) showing that simple generalisations should not be made. SAPEA (2019: 2.5.5) also lists a range of documented human health disorders resulting from occupational exposure to acrylic, polyester, nylon and polyurethane dust, some dating from the 1970s. However, there are no population-wide studies of health effects on humans.

So, what little is known to date about ecological or health risks[25] is surrounded by considerable uncertainty. SAPEA points out that ecological risks may already exist in at least some coastal-waters and sediment locations (Bergmann et al., 2017; Fischer, Elsner, Brenke, Schwabe, & Brandt, 2015; Kanhai et al., 2019). However, the overall scientific conclusion is that, so far, microplastic pollution does not constitute a widespread risk (SAPEA, 2019). SAPEA also concludes that, if microplastic pollution is left unchecked, business-as-usual would lead to effect concentration thresholds being exceeded in the near future and the occurrence of widespread risk within a century (SAPEA, 2019: 2.8). Furthermore, scientists also agree that the evidence provides grounds for genuine concern and for precaution to be exercised.

In conclusion, growing scientific evidence on the hazards of uncontrolled microplastic pollution, combined with its long-term persistence and irreversibility, suggests that reasonable and proportional measures[26] should be taken to prevent the release of microplastics into the environment and their formation from the break-up of macroplastics. These measures should aim to: a. limit the unnecessary use of plastic; b. restrict the intentional use of microplastics; c. prevent or attenuate microplastic formation over the life-cycle of plastics and plastic-containing products; d. avoid release into the environment as near to source as possible; and e. mitigate and control at key points in pathways from source to sink.

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[24] Note that "no effect" means no significant effect on the endpoints measured. There could still be an "unseen" effect.

[25] Broadly speaking, risk is the likelihood that in given circumstances a harmful outcome will result (Iannone, 2018)

[26] In line with the EU's waste hierarchy i.e. prevention, reuse, recycling, recovery, disposal as set out in article 4(1) of the Waste Framework Directive (EU 2018/851)

Recommendations

2. Recommendations

2.1 Broaden policy cover to prevent and reduce microplastic pollution

2.1.1 Microplastics in water, air and soil

As stated above, science has not yet established reliable baseline data on the stocks, flows, pathways and time-dependent trends of microplastics in different environmental compartments. However, a number of published estimates suggest that the microplastic pollution on land in soil and freshwater systems may be more abundant than that estimated for the marine environment (Boucher & Friot, 2017; Hann et al., 2018; Horton, Walton, Spurgeon, Lahive, & Svendsen, 2017). Boucher et al., (2017) estimated that 52 % of primary microplastics remain trapped in soil. ECHA (2019) also concludes that most of the microplastics intentionally added to products ends up in the soil.

There have also been some studies of airborne microplastics in both open air and indoor environments (Dris et al., 2015; Dris, Gasperi, Saad, Mirande, & Tassin, 2016; Prata, 2018), though more as a pathway for the transport of microplastic from one location to another – e.g. airborne microplastics-containing city dust becoming atmospheric fallout over land and water bodies. However, from a human-health impact perspective, airborne microplastic has potential significance for inhalation into the body (Gasperi et al., 2018; Wright & Kelly, 2017)

Most attention by policy makers, scientists and the public to date has been paid to marine microplastic pollution. This is understandable given that the plight of the ocean has played a major role in drawing attention to the ubiquity of plastic pollution and its pernicious effects. In recommending that policy attention be broadened to other environmental compartments, this should be understood as, in addition to, and not at the expense of, current attention to the marine environment. It is important that marine microplastic pollution remains a prominent policy concern in Europe and worldwide (Gajdoš, Šperl, Kaiser, & Mentl, 2011; Raubenheimmer, Nilufer, Oral, & McIllgorm, 2017; UN Environment, 2019c).

The EU Marine Strategy Framework Directive (MSFD) for example, places obligations on member states as far as the presence of micro-litter (including microplastics) is concerned. All progress being made so far under MSFD is welcome but still more needs to be done. The fact that, according to scientists, about 99 % of the plastic which enters the ocean is unaccounted for underlines this. Scientific modelling suggests that this "missing plastic" lies in remote coastal areas, deep in the water column and in sediments where concentrations can be four to five orders of magnitude higher than in the water column (Koelmans, Kooi, Law, & van Sebille, 2017; Worm, Lotze, Jubinville, Wilcox, & Jambeck, 2017). Note that such high concentrations in sediments do not necessarily imply that the risk effect threshold for adverse ecological effects (as discussed in SAPEA, 2019:2.6) have been surpassed as the relative sensitivities of the exposed species also have to be taken into account.

There has been a recent upsurge in scientific attention to microplastics in freshwater systems (Wagner & Lambert, 2018). This is much less the case for soil where very little is known about the fate and pathways of microplastics, though there are some published studies (Hurley & Nizzetto, 2018; Rillig, 2012).

In light of the evidence, we wish to flag a number of potentially-relevant areas which, in the light of further study, could lead to concrete policy measures or adjustments to existing ones:

- The Water Framework Directive, as distinct from the Marine Strategy Framework Directive, does not oblige member states to take measures against litter in surface waters. In the context of the detailed review of the Water Framework Directive, and any potential follow-up of this review, the Commission could give consideration to bringing the Directive into line with how litter and micro-litter is treated under the Marine Strategy Framework Directive.
- A significant source of microplastic soil pollution occurs via the agricultural use of sewage sludge containing high concentrations of microplastics filtered out of waste waters. This points to a potential conflict between, on one hand, removing more microplastics from the aquatic environment (e.g. through better filtering which could be mandated under the Urban Waste Water Treatment Directive, if deemed appropriate, following the on-going review due for completion in 2019) and, on the other hand, the liklihood of such microplastics finding their way into the soil if they are not removed from the sludge. This could also have implications for the 1986 directive regulating agricultural use of sewage sludge (Directive 86/278/EEC)[27] which, we understand, has been under consideration for revision in recent years[28] – see also (European Court of Auditors, 2015).
- The EU's outdoor Ambient Air Quality Directives contain detailed prescriptions for airborne particulate matter at two different size thresholds (i.e. aerodynamic diameter[29]) - PM10 (10 microns or less) and PM2.5 (2.5 microns or less). As no material type or composition is specified, any airborne microplastics in these size classes are automatically covered. However, from the few available studies of airborne microplastic fibre fallout (Cai et al., 2017; Dris et al., 2017), concentration levels of sub 50 μm fibre lengths are unknown. Published size distributions for lengths from 50 μm up to the millimetre scale suggest higher concentrations for sub 50 μm fibres. This issue plus the fact that indoor exposure is not covered, might be worth revisiting in conjunction with the on-going fitness check of these directives.
- Legislation tends to be seen as the definitive way to bring about the changes required. However, considerations of human and organisational behaviour

27 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31986L0278

28 http://ec.europa.eu/environment/waste/sludge/index.htm

29 See Chapter 1 in (World Health Organisation, 1999)

may mean that legislation is not always the best or only solution. Beyond regulations, fees, bans, etc., microplastic-pollution-mitigating measures can include voluntary agreements and softer awareness-raising, communication and education actions (SAPEA, 2017: 3.4). SAPEA points out that behaviour can change quickly in response to new circumstances or media messages. Changes resulting from legislation may take a long time due to: slow decision-making processes; response inertia by those targeted; and enforcement difficulties. Behaviour change research suggests it is best to combine a variety of different interventions and approaches, tackling a range of behavioural determinants, both psychological and situational (e.g. social norms, attitudes, values). People and organisations are likely to change their behaviour, if there is sufficient motivation, feasible alternatives or supportive conditions and incentives (Brennholt, Heß, & Reifferscheid, 2018; Eriksen, Thiel, Prindiville, & Kiessling, 2018; SAPEA, 2019; van Valkengoed & Steg, 2019).

The Commission should exploit current provisions in existing legal instruments to prevent and attenuate microplastics in air, soil and water. Airborne, freshwater and soil-based microplastic pollution should be addressed by policy to the same extent as for marine microplastics. New actions should be introduced where possible and feasible under existing relevant instruments. Potentially relevant examples include the water framework directive and directives applicable to urban waste-water treatment, the application of sewage sludge as fertilizer, and air quality. Scientific evidence and science advice should help determine the best measure for each given problem, substance, and context. Besides legislation, softer voluntary, economic or persuasive measures aimed at fostering responsible change through commercial, social or more altruistic initiatives should also be considered.

2.1.2 Substance and context-specificity and uses posing the highest potential risks

As microplastics range in size over six orders of magnitude with a vast range of shapes and compositions, they may constitute too broad a class of substance to address by regulatory or other verifiable measures of containment, restriction or elimination (Rochman et al., 2019). Pending a more precise and verifiable approach or paradigm for describing microplastics collectively, a differentiated substance- and context-specific[30] approach is needed in which it is clear what precise material and situation is addressed by each specific measure. In its proposed restriction on intentionally added microplastics under REACH, the European Chemical Agency (ECHA, 2019), citing Hartmann et al. (2019), illustrates the level of precision and differentiation which is required for regulatory purposes, describing 14 different product groups containing such microplastics and proposing restriction measures on them ranging from bans to labelling and reporting requirements with various derogations and transition regimes. The proposed restrictions are based on a multi-

[30] E.g. determined by a combination of parameters such as composition, shape, origin, location, pathways, impacted medium, endpoint, etc.

pronged risk assessment which concluded that risks arising from the release of these microplastics into the environment are not adequately controlled. This may lead to a legally binding restriction by 2021 (ECHA, 2019; Kentin, 2018).

Notwithstanding the proposed REACH restriction, science suggests that preventive measures should prioritise plastics posing the highest potential risks – i.e. those of high-volume use (packaging, single-use plastics, etc.), high-emission profiles and/ or high intrinsic hazardous properties (SAPEA, 2019: 4.4.2). As over two-thirds (by weight) of microplastic pollution comes from the break-up of large pieces of plastic litter (Boucher & Friot, 2017), the European strategy for plastics is, in its totality, directly relevant to microplastic pollution[31]. The other third enters the environment already as microplastic, either intentionally produced (e.g. plastic pellets, microplastics added to products), or as a result of wear and tear during the normal life-cycle of plastic-containing products (e.g. synthetic textile fibres, tyre abrasion, automotive brakes, artificial turf, etc.). Estimates of overall emissions from each of these sources vary but, by and large tyre abrasion and synthetic textile fibres represent two of the biggest proportions. City dust and plastic pellets also account for sizeable proportions, though with higher ranges of uncertainty. The estimated annual release of microplastics intentionally added to products is 36,000 tonnes (ECHA, 2019) – similar to the estimated loss of plastic pellets (41,000 tonnes (Hann et al., 2018)).

From a scientific point of view, if the risk assessment conclusion of ECHA on intentionally-added microplastics is up-held, the same restriction logic should apply to other components of microplastic pollution. However, with the exception of pre-production pellets, it is difficult to conceive of an enforceable restriction for sources like tyres or textiles due to the diffuse nature of responsibility. The plastics strategy announced work on the identification of policy options to reduce such releases. It cites approaches upstream from use such as labelling, improved material and product design, etc. – more in line with innovation and changing the production/ consumption paradigm.

In the short term, experts suggest that significant reductions in some emissions could be achieved by actionable end-of-pipe type solutions without the need for new legislation (SAM, 2019). This should not compromise efforts to achieve more sustainable up-stream solutions in the long term. No quantitative scientific cost-benefit, socio-economic, or other analyses similar to those in ECHA's restriction proposal are available on which we could make strong recommendations for practical short-term measures. However, we consider the following to be sufficiently pertinent to bring to the attention of the Commission:

- Textile fibre emission could be significantly reduced by mandated performance standards for domestic washing machines, industrial laundries and similar, attainable via incremental technical improvements;

[31] Of note in this regard is the emphasis on banning single-use plastics, oxo-degradables and the discarding of fishing gear, as well as the aim to recycle all plastic packaging (i.e. 40% of all plastics produced) by 2030.

- Microplastic pollution from tyre abrasion and rubber crumb on synthetic playing fields could be reduced by modifications to hydrocarbon interceptors for road networks and dedicated drainage systems[32];
- Spillage of pre-production pellets could be curbed by introducing a condition in integrated pollution and control licences under the industrial emissions directive, aimed in a first instance at the biggest risks/ biggest polluters.

Since microplastics constitute a plethora of materials a multi-pronged approach is essential. This should include measures which are substance- and context-specific in terms of parameters such as composition, shape, origin, location, pathways, impacted medium and endpoints. Scientific evidence and science advice should help determine the best measure for each given problem, substance and context. Furthermore, high-volume, high-emission and/or high intrinsically hazardous sources of microplastics which pose the highest potential risks should be targeted. In the short term, this could include: tighter licensing conditions for plastic pellet producers under the industrial emissions directive; stringent performance standards for washing machines aimed at textile microplastics; and improved drainage-system interceptors for tyre abrasion microplastics. In addition, more novel and sustainable preventative long term solutions should be developed.

2.1.3 Nanoplastics

Limitations of scientific equipment constrain in-field detection, monitoring and measurement of microplastics, particularly for small sizes and locations which are difficult to access. One of the consequences of this is the relative scarcity of field studies sampling the lower range of particle sizes and the absence of any for nanoplastics – i.e. for the fraction of plastic pollution with $\Phi \leq 100$ nm (Bäuerlein et al., 2018; GESAMP, 2016; Lehner, Weder, Petri-Fink, & Rothen-Rutishauser, 2019; SAPEA, 2019). Another potential complication in measurement and analysis relates to the ability to discriminate between different types of anthropogenic and naturally-occurring nanoparticles – see (Nowack & Bucheli, 2007).

In fact, most studies of environmental microplastics sample and analyse particles of $\Phi \geq 100$ µm. However, as expected from the progressive fragmentation of larger particles, some studies show that the number of particles detected rises significantly when it is possible to sample smaller sizes down to the 1 to 10 µm range, albeit with higher associated error bars (Araujo, Nolasco, Ribeiro, & Ribeiro-Claro, 2018; Enders, Lenz, Stedmon, & Nielsen, 2015; Lorenz, Roscher, Meyer, Primpke, & Gerdts, 2018). An implication is that the actual concentrations of environmental microplastics – in terms of numbers of particles per unit of volume – may be underestimated (Adam, Yang, & Nowack, 2019; Conkle, Báez Del Valle, & Turner, 2018). This is important for a number of reasons:

[32] https://www.waterbriefing.org/home/water-issues/item/15892-tyre-abrasion-%E2%80%93-the-dark-side-of-microplastics-pollution

Firstly, toxicity is expected to increase with decreasing plastic particle size (Jeong et al., 2016) (Jeong et al., 2018) because of the increase in surface-to-volume ratio, in terms of releasing toxic additives from the plastic matrix and potential adsorption (Velzeboer, Kwadijk, & Koelmans, 2014) and concentration of toxic substances from the surrounding environment (Rios Mendoza, Karapanagioti, & Álvarez, 2018).

Secondly, the ease with which plastic particles can be absorbed by biota also increases with decreasing size. For example, for mammalian bodies, 150 µm[33] marks an approximate threshold below which limited systemic absorption (≤0.3%) into the body occurs with progressive ease via inhalation and ingestion (Wright & Kelly, 2017), with the sub 1.5 µm size fraction possibly penetrating deeply into organs and those ≤ 250 nm potentially translocating across blood-brain and placental barriers (EFSA Panel on Contaminants in the Food Chain (CONTAM), 2016).

Thirdly, it may mean that effect threshold concentrations used in quantitative risk characterisation (see SAPEA, 2019: 2.6; ECHA, 2019: 1.4.4.9 and references therein) may already have been reached or surpassed in different environmental compartments, though analytical techniques are not yet available to prove or disprove this.

In spite of the fact that the field of microplastics research is relatively new, it is worrying that more detailed insights are not emerging quicker on even the presence and fate of submicron-sized plastic particles (i.e. nanoplastics), let alone on their potential health and ecological impacts. The little emerging laboratory evidence on morphological, behavioural and reproductive consequences of exposure to nanoplastics (da Costa, Santos, Duarte, & Rocha-Santos, 2016; Rios Mendoza et al., 2018) and on the ease with which they translocate across biological barriers (Al-Sid-Cheikh et al., 2018) is in any case consistent with the above concern of the heightened potential risk they may represent. A recent innovation should help to facilitate the tracking of nanoplastics in different laboratory experiments (Koelmans, 2019; Mitrano et al., 2019).

As far as any existing EU regulations relevant to nanoplastics are concerned, most pertinent are the recently revised REACH Annexes (EU) 2018/1881)[34]. These set out a series of tests which need to be carried out as part of the requirements for the registration of engineered nanomaterials. They will enter into force in 2020. However, they only apply to nanoplastics which are intentionally manufactured in a form which meets the definition. They will not apply to nanoplastics resulting from degradation processes. Nonetheless, the specific tests of physicochemical properties, toxicity and ecotoxicity which will have to be developed and carried out

[33] For microplastics Φ > 150 µm local effects on the immune system and inflammation of the gut are expected

[34] This is partly based on the recommended definition set out in (2011/696/EU) which has been used to create legal definitions for REACH and other sector-specific EU legislations such as in the Biocidal Products Regulation and Medical Devices Regulation – see also (Rauscher et al., 2019) https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1881&from=EN

for engineered nanomaterials may help advance the science and understanding for all types of nanoplastics irrespective of their origin – see also (Syberg & Hansen, 2016) and (Rist & Hartmann, 2018). A more specific example – also under REACH – is the possible restriction of intentionally-added microplastics to products. This proposed restriction is specifically aimed at certain classes of manufactured microplastics. The definition of microplastics in the proposed restriction covers particle sizes from 1 nm to 5 mm and so, de facto covers nanoplastics (in the size range 1 to 100 nm).

The Commission should take steps to enable the scientific community to fill knowledge gaps regarding the presence, concentration, and behaviour of nanoplastic pollution in different situations. As much as for microplastics overall, from a policy perspective, it is important that decision makers are also regularly informed and are equipped to be able to take preventative or risk-mitigating measures, should scientific evidence emerge concerning ecological or human health risks and harm specific to nanoplastics.

2.2 Address wider socio-economic and trade-off implications of microplastic pollution policy actions

Behind the issue of microplastics pollution is the fact that plastics have become ubiquitous in our daily lives. With this come all the attendant problems society, economic actors and policy face because of the failure to develop a sustainable plastics system from the beginning. All plastic pollution is a symptom of this failure. Attaining full circularity of plastics is thus the central leitmotif of the 2018 European plastics strategy and similar efforts elsewhere, e.g. Canada (Canadian Council of Ministers of the Environment, 2018; Pettipas, Bernier, & Walker, 2017). However, responsible policy making needs to ensure that the solutions chosen do not turn out to be worse - in human, environmental, social or economic terms - than the original problems (Bach, Lehmann, Görmer, & Finkbeiner, 2018; EEB, 2018; Peake, 2018). This conundrum underlines the need to base concrete policy measures on scientific analysis of trade-offs, substitution strategies/alternatives, life-cycle assessments, cost-benefit calculations, etc. Such quantification, which can be quite complicated[35] depending on scope and boundary conditions, lies outside the scope of this Opinion and the SAPEA scientific evidence review. It should however be an explicit part of the development and design of specific policy measures addressing microplastic pollution.

Another important broad question is the relative importance of microplastic pollution compared to the other known hazardous pollutants – e.g. pesticides, residual antibiotics, hormones, heavy metals, etc. Plastic and microplastic pollution is absent from some prominent lists of priority substances. See, for example, the World Health Organization (WHO)[36], a Lancet Commission on pollution and health

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[35] Biodegradables as alternatives to conventional plastic is a case in point – see Box 1

[36] https://www.who.int/heli/risks/en/

(Landrigan et al., 2018); and the human biomonitoring initiative[37]. In contrast, a number of UN reports do discuss the threat of plastic and microplastic pollution to varying degrees of detail. Examples include "Towards a Pollution Free Planet" (United Nations Environment Programme, 2017) "Global Chemicals Outlook" (UN Environment, 2019a), and "The sixth UN Global Environmental Outlook" (UN Environment, 2019b). WHO is presently undertaking a review of human health impacts of microplastics via food and air exposure pathways and the European Commission's SCHEER committee (SCHEER - Scientific Committee on Health Environmental and Emerging Risks, 2018) recently issued a statement listing micro- and nano-plastic in the environment as one of 14 emerging health and environmental issues. There is also a relevant debate among scientists between supporters and critics of the amount of attention paid to microplastic pollution (see Backhaus & Wagner, 2018; Burton, 2015, 2017; Kramm et al., 2018).

As Scientific Advisors, we give this question serious consideration from both a scientific and public policy perspective. It may be possible to prioritise pollutants based on an objective scientific assessment of their presence and properties. However, as the social, behavioural and political sciences show, decisions on policy measures are made on the basis of many inputs and considerations, of which scientific assessments should at least be one (SAPEA, 2019: Chapter 4). In fact, the opportunity for science advice to inform policy decision making should not be missed, even in conditions of uncertainty as politicians, stakeholders and others will often act anyway and be guided by other factors (SAPEA, 2019: Chapter 4). If the scientific understanding and uncertainties on the effects of chlorofluorocarbons (CFCs) had not been part of the debate in the 1980s, the healing of the ozone layer might not have come about (Parson, 2003; Pawson et al., 2010). Policy makers should also use the consensus on plastic and microplastic pollution as a springboard to enable more difficult environment and health protection measures in other more contested and difficult areas (Raubenheimer & McIlgorm, 2017).

Preventative microplastic pollution measures should be politically and socio-economically feasible. To ensure net positive and sustainable benefit to society, quantitative analyses of broad factors, (e.g. trade-offs; substitution strategies/alternatives; life-cycle assessments; and cost-benefit calculations), should feature prominently in impact assessments of individual measures. Furthermore, the framing of such socio-economic and trade-off assessments of microplastic pollution measures should be embedded in a "reduce – reuse – recycle" strategy that strives for better environmental, economic and social outcomes of the plastics system as a whole.

The Commission should also seize the opportunity of wide public concerns about microplastic and broader plastic pollution consensus to help catalyse difficult environment and health protection actions in other more contested areas.

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[37] https://www.hbm4eu.eu/the-project/ though it does list some substances used as additives in plastics

BOX I. Microplastics and the degradation dilemma[38]

One of the worrying features of conventional-polymer-based plastic pollution is its persistence in the environment over a very long period of time. Such durability is one of the desirable properties of plastic exploited in many applications. However, for plastic litter, it means that, in spite of weathering, embrittlement, fragmentation, etc. in conditions of high temperature, oxygen availability and exposure to ultraviolet light (e.g. the sun), further (mostly bio-) degradation mediated by microorganisms to monomers or simple molecules of methane, carbon dioxide and water is extremely slow, and may be brought to a standstill in the marine environment (P. Kershaw, 2018; Nithin & Goel, 2017). Furthermore, some plastics are virtually impossible to degrade biologically in any circumstances, including those based on aromatic polyesters, one of which is the most widely used plastic of all - PET (polyethylene terephthalate).

However, many transient high-volume applications of plastic for packaging, in agriculture and horticulture, etc. which are the source of much plastic pollution could dispense with such longevity while availing of other attractive properties of plastic. Indeed, this consideration combined with broader sustainability concerns has seen the development of different types of plastic with a higher propensity to degrade or a lower ecological footprint, including so-called oxo-degradables, biodegradables, bioplastics (made from bio-based rather than petrochemical feedstock, though these are not necessarily more biodegradable than conventional plastics) and compostables. Oxo-degradables are also no more biodegradable than conventional plastics, they just break-up quicker into microplastics and in fact worsen and accelerate microplastic pollution. For this reason oxo-degradable plastics are banned in France and Spain and soon will be in the EU under a directive on the reduction of the impact of certain plastic products on the environment (the so-called Single-Use Plastics Directive) [39]. For true biodegradables, it is of course important that they are environmentally benign and that, in decomposing, they do not end up as toxic monomers and released toxic additives (see (P. Kershaw, 2018) for a list of the hazard/ toxicity of plastics and plastic monomer/ precursors).

From a regulatory perspective, in the event that prescriptions of biodegradability or compostabilty would be given, it is important to set out clear and precise criteria on matters such as: a) which timeframe (what proportion should biodegrade within what time interval?); b) in which environments (for instance, biodegradation is easier to achieve in a warm, moist, compost than in dark, cold, high-salinity water); c) what account would be taken of other degradation processes such as photo degradation, chemical degradation, and physical degradation?; and d) against what standards or references should fulfilment of

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38 For a recent review of biodegradability and related standards, see (Harrison, Boardman, O'Callaghan, Delort, & Song, 2018)

39 http://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/ENVI/AG/2019/01-21/1174364EN.pdf

the criteria be assessed? (McDevitt et al., 2017). In the EU context, this is something which is potentially pertinent at present and in the near future to plastic used for agricultural mulches and the provisions of the fertilizers directive[40] due for adoption in 2019, according to which they may qualify to receive the CE label provided that certain strict conditions are met.

Finally, while the development of totally degradable plastics may represent a potentially attractive and environmentally-benign option for some niche applications (e.g. agriculture and food-contact materials), many obstacles still present themselves. These include:

a) Additional cost of change;
b) Conditions for complete degradation under natural conditions are very rare;
c) Anything other than the strictest standards in according and enforcing use of the "biodegradable" label can defeat the whole purpose as the public will more readily discard plastic which it believes to be biodegradable;
d) Biodegradable plastics can lead to problems when they end up in conventional plastic recycling waste streams.

2.3 Promote global cooperation, high-quality scientific exchange and policy coherence

2.3.1 Global cooperation

Microplastic pollution in the marine environment has gained the attention of the international policy community (GESAMP, 2010, 2016; Raubenheimer & McIlgorm, 2017). Several regional, national and international strategies aim at preventing and reducing plastic and microplastic pollution, but none has a level of commitment commensurate with the magnitude and rate of growth of the problem (Borrelle et al., 2017). The SAM policy context paper (SAM, 2018) summarises the international and regional policy response to protecting the oceans from microplastics pollution. There is nothing similar for other environmental compartments.

At the same time, there are large geographical differences in the causes of microplastic pollution, both on land, at sea and in the air. The existence and availability of data on microplastics pollution is also geographically unevenly distributed (Horton et al., 2017). The ability to prevent and mitigate microplastic pollution varies by nation and region. Solutions can only be effective if they are context specific and take local conditions into account (Hamid et al., 2018), as those for one jurisdiction may not be appropriate for another. For example, microplastic input to the ocean via rivers can be decreased by capturing microplastics in wastewater treatment plant filters. These are common in developed countries but absent in many developing countries (P. Kershaw, 2016).

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40 The revised Regulation was agreed by the Council of the EU (http://data.consilium.europa.eu/doc/document/ST-15103-2018-INIT/en/pdf) and was approved by the European Parliament in March 2019

We think that the time is ripe to give strong impetus to international efforts in this area. This could be by policy makers taking steps towards the negotiation of an international treaty aimed at reducing microplastic and other plastic pollution in a manner similar to the Paris climate accord targets – see (Hugo, 2018) and references therein. This should go beyond marine pollution and tackle the roots of the problem. It should take advantage of the growing appetite for coordinated international marine action and policy as clear from resolutions adopted on marine litter and microplastics at all four UN Environment Assemblies (UNEA) – see those adopted at UNEA-3 and -4 (UN Environment, 2018, 2019c). The most recent (UN Environment, 2019c) calls on UNEP Executive Director to, inter alia, convene "existing relevant science advisory initiatives" to provide concrete input to the continuing work of an ad hoc open ended expert group on the topic and to a new multi-stakeholder platform tasked to take action on long-term elimination of marine litter and microplastics. The work of these bodies can be crucial in enabling a good global agreement by identifying specific actions which should be implemented as well as ways for the developing world to be fully on board.

From a global governance perspective, the state of discussions on plastic and microplastic pollution is similar today to what it was for climate change in 1992 (Borrelle et al., 2017), when the UN Framework Convention on Climate Change (UNFCCC) recognized climate change but only encouraged voluntary and undefined support. Policy makers should learn from the slow pace of international processes aimed at climate change and other global environmental issues. In our view, it would be both smart and wise to capitalise on the current consensus to reach an international agreement on microplastic/ plastic pollution in an accelerated manner rather than waiting for international diplomacy to deliver at its normal pace.

The rapidity with which the Montreal Protocol on ozone-depleting substances was agreed may provide a model to emulate. Flexibility incorporated in the Montreal Protocol has allowed it to accommodate advances in: science and monitoring standards; data and information exchange; and recycling and reduction technologies (Raubenheimer & McIlgorm, 2017). The Montreal Protocol also provides for the sharing of research, development of public awareness and education, and exchange of information. Such features, as well as generation and access to standardised microplastic pollution data (as is the case for climate data), could be part of such an international agreement on microplastic pollution. A potential lead example in the EU is the sharing via EMODnet[41] of standardised measures of plastic on European beaches and seafloors, under the Marine Strategy Framework Directive[42] which will now be extended to microplastics.

Altogether, global efforts would benefit greatly from a scientific platform for plastic pollution. The above-mentioned actions called for in UN Environment (2019c) could help to nucleate such a platform.

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41 European Marine Observation and Data Network http://www.emodnet.eu/

42 Including planned data interoperability with China

Promote a global treaty aimed at reducing and tackling the roots of microplastic and other plastic pollution. Foster also international and cross-disciplinary collaboration and the early sharing of new knowledge and research findings. A first step would be to promote the establishment of a global scientific platform on plastic and microplastic pollution, enabling shared and cross-border access to standardised data.

2.3.2 Quality and pertinence of scientific studies of microplastics

SAPEA (2019) points out that the recent proliferation of microplastics studies is not accompanied by a commensurate increase in knowledge due to redundancy, marginality and questionable quality in much of what is published. For example, Koelmans et al., (2019) found only four of 50 studies of microplastics in freshwaters and drinking water to be of useful quality and reliability. Elsewhere, a review of microplastics in the food chain (Toussaint et al., 2019) excludes 60% of potentially relevant publications from its analysis because of data quality deficiencies. See also Hermsen et al, (2018) for a similar review of quality in studies of microplastics in biota.

It is also unhelpful that the field suffers somewhat from publication bias (Fanelli, 2012; Van Assen, Van Aert, Nuijten, & Wicherts, 2014) towards studies showing an effect and away from those that do not (Koelmans, Besseling, et al., 2017; de Sá, Oliveira, Ribeiro, Rocha, & Futter, 2018b; SAM, 2019)[43]. However, no-effect studies can be of high quality and value and should be published. They are necessary for a complete and balanced knowledge base on which to guide future research, policy, and practice (Frank, Engel, Matosin, Lum, & Newell, 2014). Removing bias requires cultural change on the part of both the scientific and particularly publisher communities, in terms of academic recognition incentives and editorial policies (Edwards & Roy, 2016).

Technical improvements and other innovations are also called for to overcome equipment limitations concerning in-field sampling and analysis of the concentration, composition, behaviour, etc. of microplastic pollution. This is vital baseline information for risk and impact assessment studies. Furthermore, to properly characterise potential risks and impacts, carefully designed studies are needed to measure complete dose / response curves for the types of microplastic found in real-world situations for a variety of different endpoints and a wide range of concentrations. For this, we endorse option 6 in SAPEA (2019) calling for the development of high-quality fit-for-purpose risk assessment approaches tailored to the complexity of microplastic pollution – see also ECETOC (2018) and Koelmans, Besseling, et al. (2017). Rigorous quality assurance and quality control procedures

43 Such bias characterising many areas of research has been recognized for decades and its distortion effects documented (Cook & Therrien, 2017)(Ferguson & Heene, 2012)(Dickersin, Chan, Chalmersx, Sacks, & Smith, 1987); less affected areas include climate change science (Harlos, Edgell, & Hollander, 2017), high-energy physics (https://lifeandphysics.com/2010/03/22/minimum-bias/) and some areas of applied medical research (Son, Tavakoli, & Bartanusz, 2016)

should be followed and published along with all pertinent metadata. This is vital to ensure validation, replication and ultimately the utility of the results obtained.
Scientists, reviewers and journal editors as well as public authorities in so far as risk management related science is concerned, all have roles to play in bringing the above-described quality and pertinence improvements about. Cooperation of the media in reporting and commenting on scientific findings with integrity and credibility would also be most welcome.

Take concrete measures to improve the overall quality and pertinence of microplastic research by: i) promoting advances in detection, measurement and analysis, and risk/impact assessment methodologies of microplastic pollution; ii) fostering rigorous and transparent disclosure of experimental procedures and meta data; and iii) encouraging the undertaking and publication of comprehensive dose/response and no-effect studies to generate a more balanced scientific knowledge base underpinning both science advice and policy in this area.

2.3.3 International scientific standards and methodologies

Any synthesis or meta-analysis based on the expanding corpus of scientific knowledge on microplastic pollution would be facilitated if studies followed standardised and harmonised definitions, measurement, monitoring and impact assessment techniques. However, these do not yet exist.

While top quality research can and should continue apace with or without such standards, for regulatory clarity purposes and the activities of affected businesses, they are essential. Their absence is part of a problem which applies to all plastic litter, though microplastic pollution has its own specificities. This is particularly the case for international/ global cooperation and policy coherence as standardisation and harmonisation enables international comparability and application in regulatory contexts across multiple jurisdictions. Harmonised and standards-compliant studies also facilitate a global analysis of the microplastic pollution problem such as might be undertaken by a global scientific platform on plastic and microplastic pollution.

Standardisation and harmonisation is supported by SAPEA (2019) and other credible and representative scientific and stakeholder bodies (Baztan et al., 2018; Crippa et al., 2019; ECETOC, 2018; Piha & Zampoukas, 2011).

It is our view that relevant standardisation and harmonisation should be developed and agreed internationally, building on existing momentum in various international forums such as the UN (GESAMP, 2019; UN Environment, 2019c) and G7/G20 contexts. In relation to this, we also endorse options 7 in SAPEA (2019) regarding the instigation without delay of coordinated monitoring efforts across the EU, comparable to the WATCHLIST procedure under the Water Framework Directive (Loos, Marinov, Sanseverino, Napierskaand, & Lettieri, 2018).

Initiate the development of consensual international definitions and standards for the measurement and monitoring of microplastic pollution and its impact on ecosystems and human health enabling: i) a globally-coherent picture of the nature and threats of microplastic pollution and, ii) clear, unambiguous technical prescriptions and criteria for regulatory measures, when these are needed.

3. References

Adam, V., Yang, T., & Nowack, B. (2019). Toward an ecotoxicological risk assessment of microplastics: Comparison of available hazard and exposure data in freshwaters. *Environmental Toxicology and Chemistry*, *38*(2), 436–447. https://doi.org/10.1002/etc.4323

Al-Sid-Cheikh, M., Rowland, S. J., Stevenson, K., Rouleau, C., Henry, T. B., & Thompson, R. C. (2018). Uptake, Whole-Body Distribution, and Depuration of Nanoplastics by the Scallop Pecten maximus at Environmentally Realistic Concentrations. *Environmental Science and Technology*, *52*(24), 14480–14486. research-article. https://doi.org/10.1021/acs.est.8b05266

Andrady, A. L., & Neal, M. A. (2009). Applications and societal benefits of plastics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 1977–1984. https://doi.org/10.1098/rstb.2008.0304

Araujo, C. F., Nolasco, M. M., Ribeiro, A. M. P., & Ribeiro-Claro, P. J. A. (2018). Identification of microplastics using Raman spectroscopy: Latest developments and future prospects. *Water Research*. Pergamon. https://doi.org/10.1016/j.watres.2018.05.060

Arthur, C., Baker, J., & Bamford, H. (2009). *Proceedings of the International Research. Workshop on the Occurrence, Effects and Fate of Microplastic Marine Debris. NOAA Technical Memorandum*. USA: National Oceanic and Atmospheric Administration Office of Response & Restoration. NOAA Marine Debris Division.

Azapagic, A., Emsley, A., & Hamerton, L. (2003). *Polymers, the Environment and Sustainable Development*. *Polymers, the Environment and Sustainable Development*. Chichester, UK: J. Wiley. https://doi.org/10.1002/0470865172

Bach, V., Lehmann, A., Görmer, M., & Finkbeiner, M. (2018). Product environmental footprint (PEF) pilot phase-comparability over flexibility? *Sustainability (Switzerland)*, *10*(8), 2898. https://doi.org/10.3390/su10082898

Backhaus, T., & Wagner, M. (2018). Microplastics in the environment: much ado about nothing ? A debate. *PeerJPreprints*, 0–5. https://doi.org/10.7287/peerj.preprints.26507v2

Barnes, D. K. A. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 1985–1998. https://doi.org/10.1098/rstb.2008.0205

Bäuerlein, P. S., Van Wezel, A. P., Dekker, S. C., Koelmans, A. A., Mintenig, S. M., Bäuerlein, P. S., … Van Wezel, A. P. (2018). Closing the gap between small and smaller: towards a framework to analyse nano- and microplastics in aqueous environmental samples. *Environmental Science: Nano*, *5*(7), 1640–1649. https://doi.org/10.1039/c8en00186c

Baztan, J., Bergmann, M., Carrasco, A., Fossi, C., Jorgensen, B., Miguelez, A., … Thompson, R. C. (2018). MICRO 2018 Fate and Impact of Microplastics: Knowledge, Actions and Solutions. In *Micro 2018* (pp. 1–414). Retrieved from https://micro2018.sciencesconf.org/data/pages/micro2018_proceedings_book_1.pdf

Bergmann, M., Wirzberger, V., Krumpen, T., Lorenz, C., Primpke, S., Tekman, M. B., & Gerdts, G. (2017). High Quantities of Microplastic in Arctic Deep-Sea Sediments from the HAUSGARTEN Observatory. *Environmental Science and Technology*, *51*(19), 11000–11010. https://doi.org/10.1021/acs.est.7b03331

Borrelle, S. B., Rochman, C. M., Liboiron, M., Bond, A. L., Lusher, A., Bradshaw, H., & Provencher, J. F. (2017). Opinion: Why we need an international agreement on marine plastic pollution. *Proceedings of the National Academy of Sciences*, *114*(38), 9994–9997. https://doi.org/10.1073/pnas.1714450114

Boucher, J., & Friot, D. (2017). *Primary Microplastics in the Oceans: Global Evaluation of Sources*. *InternatIonal UnIon for ConservatIon of Nature and Natural Resources*. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources. https://doi.org/dx.doi.org/10.2305/IUCN.CH.2017.01.en

Bourguignon, D. (2015). *The precautionary principle: Definitions, applications and governance*. *European Parliamentary Research Service*. https://doi.org/10.2861/821468

Brennholt, N., Heß, M., & Reifferscheid, G. (2018). Freshwater microplastics: Challenges for regulation and management. *Handbook of Environmental Chemistry*, *58*, 239–272. https://doi.org/10.1007/978-3-319-61615-5_12

Burton, G. A. (2015). Losing sight of science in the regulatory push to ban microbeads from consumer products and industrial use. *Integrated Environmental Assessment and Management*, *11*(3), 346–347. https://doi.org/10.1002/ieam.1645

Burton, G. A. (2017). Stressor Exposures Determine Risk: So, Why Do Fellow Scientists Continue to Focus on Superficial Microplastics Risk? *Environmental Science and Technology*, *51*(23), 13515–13516. https://doi.org/10.1021/acs.est.7b05463

Cai, L., Wang, J., Peng, J., Tan, Z., Zhan, Z., Tan, X., & Chen, Q. (2017). Characteristic of microplastics in the atmospheric fallout from Dongguan city, China: preliminary research and first evidence. *Environmental Science and Pollution Research*, *24*(32), 24928–24935. https://doi.org/10.1007/s11356-017-0116-x

Canadian Council of Ministers of the Environment. (2018). *Strategy on Zero Plastic Waste*.

Carpenter, E. J., & Smith Jr., K. L. (1972). Plastics on the Sargasso sea surface. *Science*, *175*(4027), 1240–1241.

Chapman, P. M. (2007). Determining when contamination is pollution - Weight of evidence determinations for sediments and effluents. *Environment International*, *33*(4), 492–501. https://doi.org/10.1016/j.envint.2006.09.001

Chen, C. L. (2015). Regulation and management of marine litter. In *Marine Anthropogenic Litter* (pp. 395–428). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_15

Conkle, J. L., Báez Del Valle, C. D., & Turner, J. W. (2018). Are We Underestimating Microplastic Contamination in Aquatic Environments? *Environmental Management*, *61*(1), 1–8. https://doi.org/10.1007/s00267-017-0947-8

Cook, B. G., & Therrien, W. J. (2017). Null effects and publication bias in special education research. *Behavioral Disorders*, *42*(4), 149–158. https://doi.org/10.1177/0198742917709473

Crippa, M., De Wilde, B., Koopmans, R., Leyssens, J., Muncke, J., Ritschkoff A-C., Van Doorsselaer, K., … Wagner, M. (2019). *A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions*. (M. De Smet & M. Linder, Eds.). Brussels, Belgium: European Commission. https://doi.org/10.2777/269031

Crompton, T. R. (2007). *Additive migration from plastics into foods: A guide for analytical chemists*. (Smithers Rapra Technology Limited, Ed.). Shrewsbury.

da Costa, J. P., Santos, P. S. M. M., Duarte, A. C., & Rocha-Santos, T. (2016). (Nano)plastics in the environment - Sources, fates and effects. *Science of The Total Environment*, *566–567*, 15–26. https://doi.org/10.1016/j.scitotenv.2016.05.041

Dauvergne, P. (2018). The power of environmental norms: marine plastic pollution and the politics of microbeads. *Environmental Politics*, *27*(4), 579–597. https://doi.org/10.1080/09644016.2018.1449090

de Sá, L. C., Oliveira, M., Ribeiro, F., Rocha, T. L., & Futter, M. N. (2018). *Studies of the effects of microplastics on aquatic organisms: What do we know and where should we focus our efforts in the future? Science of the Total Environment* (Vol. 645). Elsevier. https://doi.org/10.1016/j.scitotenv.2018.07.207

Dickersin, K., Chan, S., Chalmersx, T. C., Sacks, H. S., & Smith, H. (1987). Publication bias and clinical trials. *Controlled Clinical Trials*, *8*(4), 343–353. https://doi.org/10.1016/0197-2456(87)90155-3

Dris, R., Gasperi, J., Mirande, C., Mandin, C., Guerrouache, M., Langlois, V., & Tassin, B. (2017). A first overview of textile fibers, including microplastics, in indoor and outdoor environments. *Environmental Pollution*, *221*, 453–458. https://doi.org/10.1016/j.envpol.2016.12.013

Dris, R., Gasperi, J., Rocher, V., Saad, M., Renault, N., & Tassin, B. (2015). Microplastic contamination in an urban area: A case study in Greater Paris. *Environmental Chemistry*, *12*(5), 592–599. https://doi.org/10.1071/EN14167

Dris, R., Gasperi, J., Saad, M., Mirande, C., & Tassin, B. (2016). Synthetic fibers in atmospheric fallout: A source of microplastics in the environment? *Marine Pollution Bulletin*, *104*(1–2), 290–293. https://doi.org/10.1016/j.marpolbul.2016.01.006

ECETOC. (2018). *An evaluation of the challenges and limitations associated with aquatic toxicity and bioaccumulation studies for sparingly soluble and manufactured particulate substances EUROPEAN CENTRE FOR ECOTOXICOLOGY AND TOXICOLOGY OF CHEMICALS*. *Technical Report No. 132*. Retrieved from http://www.ecetoc.org/wp-content/uploads/2018/12/ECETOC-TF-132-Aq-tox-particulates.pdf

ECHA. (2019). ANNEX XV RESTRICTION REPORT PROPOSAL FOR A RESTRICTION SUBSTANCE NAME: intentionally added microplastics, (January).

Edwards, M. A., & Roy, S. (2016). Academic Research in the 21st Century: Maintaining Scientific Integrity in a Climate of Perverse Incentives and Hypercompetition. *Environmental Engineering Science*, *34*(1), 51–61. https://doi.org/10.1089/ees.2016.0223

EEB. (2018). The EU Product Environmental Footprint (PEF) Methodology What can it deliver and what not? An NGO viewpoint, (06798511314), 10.

EFSA Panel on Contaminants in the Food Chain (CONTAM). (2016). Statement on the presence of microplastics and nanoplastics in food, with particular focus on seafood. *EFSA Journal*, *14*(6), 30. https://doi.org/10.2903/j.efsa.2016.4501

Enders, K., Lenz, R., Stedmon, C. A., & Nielsen, T. G. (2015). Abundance, size and polymer composition of marine microplastics ≥10 µm in the Atlantic Ocean and their modelled vertical distribution. *Marine Pollution Bulletin*, *100*(1), 70–81. https://doi.org/10.1016/j.marpolbul.2015.09.027

Eriksen, M., Thiel, M., Prindiville, M., & Kiessling, T. (2018). Microplastic: What are the solutions? *Handbook of Environmental Chemistry*, *58*, 273–298. https://doi.org/10.1007/978-3-319-61615-5_13

European Commission. (2017a). *Special Eurobarometer 468 Report Attitudes of European citizens towards the environment*.

European Commission. (2017b). The precautionary principle : decision-making under uncertainty. *European Commission DG Environment by the Science Communication Unit*, (18), 24. https://doi.org/10.2779/709033

European Commission. (2018). A European Strategy for Plastics in a Circular Economy. https://doi.org/10.1021/acs.est.7b02368

European Court of Auditors. (2015). *EU-funding of urban waste water treatment plants in the Danube river basin: further efforts needed in helping Member States to achieve EU waste water policy objectives*. https://doi.org/10.2865/511796

Fanelli, D. (2012). Negative results are disappearing from most disciplines and countries. *Scientometrics*, *90*(3), 891–904. https://doi.org/10.1007/s11192-011-0494-7

Ferguson, C. J., & Heene, M. (2012). A Vast Graveyard of Undead Theories. *Perspectives on Psychological Science*, *7*(6), 555–561. https://doi.org/10.1177/1745691612459059

Fischer, V., Elsner, N. O., Brenke, N., Schwabe, E., & Brandt, A. (2015). Plastic pollution of the kuril-kamchatka trench area (NW pacific). *Deep-Sea Research Part II: Topical Studies in Oceanography*, *111*, 399–405. https://doi.org/10.1016/j.dsr2.2014.08.012

Frank, E., Engel, M., Matosin, N., Lum, J. S., & Newell, K. A. (2014). Negativity towards negative results: a discussion of the disconnect between scientific worth and scientific culture. *Disease Models & Mechanisms*, *7*(2), 171–173. https://doi.org/10.1242/dmm.015123

Gajdoš, L., Šperl, M., Kaiser, J., & Mentl, V. (2011). Microplastic limit of steel determined by the measurement of changes in electrical impedance. In *EAN 2011: 49th International Scientific Conference on Experimental Stress Analysis* (pp. 65–70). Brno Univ. of Technology. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84905457730&partnerID=40&md5=81e749aa5a503e674174edae3216b94e

Gasperi, J., Wright, S. L., Dris, R., Collard, F., Mandin, C., Guerrouache, M., … Tassin, B. (2018). Microplastics in air: Are we breathing it in? *Current Opinion in Environmental Science & Health*, *1*, 1–5. https://doi.org/https://doi.org/10.1016/j.coesh.2017.10.002

GESAMP. (2010). *82: Proceedings of the GESAMP International Workshop on Microplastic particles as a vector in transporting persistent, bio- accumulating and toxic sub- stances in the ocean*. (T. Bowmer & P. J. Kershaw, Eds.), *Reports and Studies GESAMP*. https://doi.org/10.1007/978-94-011-3610-5

GESAMP. (2016). *90: Sources, Fate and Effects of Microplastics in the Marine Environment: A Global Assessment*. (P. J. Kershaw, Ed.), *Reports and Studies GESAMP* (Vol. 90). UNESCO-IOC. https://doi.org/10.13140/RG.2.1.3803.7925

GESAMP. (2019). *99: Guidelines For The Monitoring and Assessment of Plastic Litter in The Ocean*. (P. J. Kershaw, A. Turra, & F. Galgani, Eds.), *Reports and Studies GESAMP*.

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, uses, and fate of all plastics ever made. *Science Advances*, *3*(7), 5.

Gregory, M. R. (1983). Virgin plastic granules on some beaches of Eastern Canada and Bermuda. *Marine Environmental Research*, *10*(2), 73–92. https://doi.org/10.1016/0141-1136(83)90011-9

Hamid, F. S., Bhatti, M. S., Anuar, N., Anuar, N., Mohan, P., & Periathamby, A. (2018). Worldwide distribution and abundance of microplastic: How dire is the situation? *Waste Management and Research*. https://doi.org/10.1177/0734242X18785730

Hann, S., Sherrington, C., Jamieson, O., Hickman, M., Kershaw, P., Bapasola, A., … Cole, G. (2018). *Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products - Final Report*. *Report fro DG ENV EC* (Vol. 62). Retrieved from http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/microplastics_final_report_v5_full.pdf

Harlos, C., Edgell, T. C., & Hollander, J. (2017). No evidence of publication bias in climate change science. *Climatic Change*, *140*(3–4), 375–385. https://doi.org/10.1007/s10584-016-1880-1

Harrison, J. P., Boardman, C., O'Callaghan, K., Delort, A. M., & Song, J. (2018). Biodegradability standards for carrier bags and plastic films in aquatic environments: A critical review. *Royal Society Open Science*. https://doi.org/10.1098/rsos.171792

Hartley, B. L., Pahl, S., Veiga, J., Vlachogianni, T., Vasconcelos, L., Maes, T., … Thompson, R. C. (2018). Exploring public views on marine litter in Europe: Perceived causes, consequences and pathways to change. In *Marine Pollution Bulletin* (p. 44). Pergamon. https://doi.org/https://doi.org/10.1016/j.marpolbul.2018.05.061

Hartmann, N., Hüffer, T., Thompson, R. C., Hassellöv, M., Verschoor, A., Daugaard, A. E., … Wagner, M. (2019). Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.8b05297

Hermsen, E., Mintenig, S. M., Besseling, E., & Koelmans, A. A. (2018). Quality Criteria for the Analysis of Microplastic in Biota Samples: A Critical Review. *Environmental Science and Technology*, *52*(18), 10230–10240. review-article. https://doi.org/10.1021/acs.est.8b01611

Horton, A. A., Walton, A., Spurgeon, D. J., Lahive, E., & Svendsen, C. (2017). Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities. *Science of The Total Environment*, *586*, 127–141. https://doi.org/https://doi.org/10.1016/j.scitotenv.2017.01.190

Hugo, T. G. (2018). *The case for a treaty on marine plastic pollution*. Retrieved from www.intlaw.no

Hurley, R. R., & Nizzetto, L. (2018). Fate and occurrence of micro(nano)plastics in soils: Knowledge gaps and possible risks. *Current Opinion in Environmental Science & Health*, *1*, 6–11. https://doi.org/https://doi.org/10.1016/j.coesh.2017.10.006

Iannone, A. P. (2018). Environmental Risk Assessment. In *Practical Environmental Ethics* (pp. 101–114). Butterworth-Heinemann. https://doi.org/10.4324/9781315127200-3

Jeong, C. B., Kang, H.-M., Lee, Y. H., Kim, M.-S., Lee, J.-S., Seo, J. S., … Lee, J.-S. (2018). Nanoplastic Ingestion Enhances Toxicity of Persistent Organic Pollutants (POPs) in the Monogonont Rotifer Brachionus koreanus via Multixenobiotic Resistance (MXR) Disruption. *Environmental Science & Technology*, *52*(19), 11411–11418. https://doi.org/10.1021/acs.est.8b03211

Jeong, C. B., Won, E.-J., Kang, H.-M. H. M., Lee, M. C. M.-C., Hwang, D.-S. D. S., Hwang, U.-K. U. K., … Lee, J.-S. J. S. (2016). Microplastic Size-Dependent Toxicity, Oxidative Stress Induction, and p-JNK and p-p38 Activation in the Monogonont Rotifer (Brachionus koreanus). *Environmental Science and Technology*, *50*(16), 8849–8857. https://doi.org/10.1021/acs.est.6b01441

Jovanović, B., Gökdağ, K., Güven, O., Emre, Y., Whitley, E. M., & Kideys, A. E. (2018). Virgin microplastics are not causing imminent harm to fish after dietary exposure. *Marine Pollution Bulletin*, *130*, 123–131. https://doi.org/10.1016/j.marpolbul.2018.03.016

Kanhai, L. D. K., Johansson, C., Frias, J. P. G. L., Gardfeldt, K., Thompson, R. C., & O'Connor, I. (2019). Deep sea sediments of the Arctic Central Basin: A potential sink for microplastics. *Deep-Sea Research Part I: Oceanographic Research Papers*, *145*(March), 137–142. https://doi.org/10.1016/j.dsr.2019.03.003

Kentin, E. (2018). Restricting microplastics in the European Union: Process and criteria under REACH. *The European Physical Journal Plus*, *133*(10). https://doi.org/10.1140/epjp/i2018-12228-2

Kershaw, P. (2016). *MARINE PLASTIC DEBRIS & MICROPLASTICS. Global lessons and research to inspire action and guide policy chance*. *UNEP*. https://doi.org/10.2173/bna.44

Kershaw, P. (2018). *Exploring the potential for adopting alternative materials to reduce marine plastic litter*. *UNEP*. Retrieved from http://wedocs.unep.org/bitstream/handle/20.500.11822/25485/plastic_alternative.pdf?sequence=1&isAllowed=y

Koelmans, A. A. (2019). Proxies for nanoplastic. *Nature Nanotechnology*, *14*(4), 307–308. https://doi.org/10.1038/s41565-019-0416-z

Koelmans, A. A., Besseling, E., Foekema, E., Kooi, M., Mintenig, S., Ossendorp, B. C., … Scheffer, M. (2017). Risks of Plastic Debris: Unravelling Fact, Opinion, Perception, and Belief. *Environmental Science and Technology*, *51*(20), 11513–11519. https://doi.org/10.1021/acs.est.7b02219

Koelmans, A. A., Kooi, M., Law, K. L., & van Sebille, E. (2017). All is not lost: deriving a top-down mass budget of plastic at sea. *Environmental Research Letters*, *12*(11). https://doi.org/10.1088/1748-9326/aa9500

Koelmans, A. A., Mohamed Nor, H. N., Hermsen, E., Kooi, M., Mintenig, S. M., & De France, J. (2019). Microplastics in Freshwaters and Drinking Water: Critical Review and Assessment of Data Quality. *Water Research*, *155*, 410–422. https://doi.org/https://doi.org/10.1016/j.watres.2019.02.054

Kosuth, M., Mason, S. A., & Wattenberg, E. V. (2018). Anthropogenic contamination of tap water, beer, and sea salt. *PLoS ONE*, *13*(4), e0194970. https://doi.org/10.1371/journal.pone.0194970

Kramm, J., Völker, C., & Wagner, M. (2018). Superficial or Substantial: Why Care about Microplastics in the Anthropocene? *Environmental Science & Technology*, *52*(6), 336–337. https://doi.org/10.1021/acs.est.8b00790

Landrigan, P. J., Fuller, R., Acosta, N. J. R. R., Adeyi, O., Arnold, R., Basu, N., … Zhong, M. (2018). The Lancet Commission on pollution and health. *The Lancet*, *391*(3rd Feb), 462–512. https://doi.org/10.1016/S0140-6736(17)32345-0

Lebreton, L., & Andrady, A. (2019). Future scenarios of global plastic waste generation and disposal. *Palgrave Communications*, *5*(1), 6. https://doi.org/10.1057/s41599-018-0212-7

Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., … Reisser, J. (2018). Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. *Scientific Reports*, *8*(1), 4666. https://doi.org/10.1038/s41598-018-22939-w

Lehner, R., Weder, C., Petri-Fink, A., & Rothen-Rutishauser, B. (2019). Emergence of nanoplastic in the environment and possible impact on human health. *Environmental Science & Technology*, acs.est.8b05512. https://doi.org/10.1021/acs.est.8b05512

Liebmann, B., Köppel, S., Königshofer, P., Bucsics, T., Reiberger, T., & Schwabl, P. (2018). ASSESSMENT OF MICROPLASTIC CONCENTRATIONS IN HUMAN STOOL - FINAL RESULTS OF A PROSPECTIVE STUDY. In *Conference on Nano and microplastics in technical and freshwater systems*. Monte Verità, Ascona, Switzerland,. https://doi.org/10.13140/RG.2.2.16638.02884

Linder, M. (2017). Ripe for disruption: Reimagining the role of green chemistry in a circular economy. *Green Chemistry Letters and Reviews*, *10*(4), 428–435. https://doi.org/10.1080/17518253.2017.1392618

Lithner, D., Larsson, A., Dave, G., Larsson, Å., & Dave, G. (2011). Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. *Science of the Total Environment*, *409*(18), 3309–3324. https://doi.org/10.1016/j.scitotenv.2011.04.038

Loos, R., Marinov, D., Sanseverino, I., Napierskaand, D., & Lettieri, T. (2018). *Review of the 1st Watch List under the Water Framework Directive and recommendations for the 2nd Watch List*. (JRC, Ed.). https://doi.org/10.2760/614367

Lorenz, C., Roscher, L., Meyer, M., Primpke, S., & Gerdts, G. (2018). *Identifying microplastics in North Sea waters – A matter of extraction and detection*. *6th International Marine Debris Conference, San Diego, 12 March 2018 - 16 March 2018*. Retrieved from hdl:10013/epic.25d1c7a5-835e-41fc-b1ae-7c96d406b4eb

Matlack, A. S. (2010). *Introduction to Green Chemistry*. (CRC Press, Ed.) (2nd ed.). Boca Raton: Taylor & Francis Group. Retrieved from https://books.google.com/books?id=gAQssnCnA48C&pgis=1

McDevitt, J. P., Criddle, C. S., Morse, M., Hale, R. C., Bott, C. B., & Rochman, C. M. (2017). Addressing the Issue of Microplastics in the Wake of the Microbead-Free Waters Act - A New Standard Can Facilitate Improved Policy. *Environmental Science and Technology*, *51*(12), 6611–6617. https://doi.org/10.1021/acs.est.6b05812

Mitrano, D. M., Beltzung, A., Frehland, S., Schmiedgruber, M., Cingolani, A., & Schmidt, F. (2019). Synthesis of metal-doped nanoplastics and their utility to investigate fate and behaviour in complex environmental systems. *Nature Nanotechnology*, *14*(4), 362–368. https://doi.org/10.1038/s41565-018-0360-3

Moore, C. J. (2008). Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research*, *108*(2), 131–139. https://doi.org/10.1016/j.envres.2008.07.025

Nithin, B., & Goel, S. (2017). Degradation of Plastics. In *Advances in Solid and Hazardous Waste Management* (pp. 235–247). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-57076-1_11

Nowack, B., & Bucheli, T. D. (2007). Occurrence, behavior and effects of nanoparticles in the environment. *Environmental Pollution*, *150*(1), 5–22. https://doi.org/10.1016/j.envpol.2007.06.006

Parson, E. A. (2003). *Protecting the Ozone Layer: Science and Strategy*. *Protecting the Ozone Layer: Science and Strategy*. Oxford University Press. https://doi.org/10.1093/0195155491.001.0001

Pawson, S., Jackman, C. H., Newman, P. A., Stolarski, R. S., Oman, L. D., Frith, S. M., … Douglass, A. R. (2010). What would have happened to the ozone layer if chlorofluorocarbons (CFCs) had not been regulated? *Atmospheric Chemistry and Physics*, *9*(6), 2113–2128. https://doi.org/10.5194/acp-9-2113-2009

Peake, L. (2018). How not to solve plastic pollution | Inside track. Retrieved March 11, 2019, from https://greenallianceblog.org.uk/2018/09/27/how-not-to-solve-plastic-pollution/

Pettipas, S., Bernier, M., & Walker, T. R. (2017). A Canadian policy framework to mitigate plastic marine pollution. *Marine Policy*, *75*, 187. https://doi.org/10.1016/j.marpol.2016.05.002

Piha, H., & Zampoukas, N. (2011). *Review of Methodological Standards Related to the Marine Strategy Framework Directive Criteria on Good Environmental Status*. *JRC Scientific and Technical Reports*. https://doi.org/10.2788/60512

PlasticsEurope. (2018). Plastics – the Facts 2018 An analysis of European plastics production, demand and waste data. *PlasticsEurope*. https://doi.org/10.1016/j.marpolbul.2013.01.015

PlasticsEurope. (2019). PlasticsEurope. Retrieved February 28, 2019, from https://www.plasticseurope.org/en

Prata, J. C. (2018). Airborne microplastics: Consequences to human health? *Environmental Pollution*, *234*, 115–126. https://doi.org/10.1016/j.envpol.2017.11.043

Raubenheimer, K., & McIlgorm, A. (2017). Is the Montreal Protocol a model that can help solve the global marine plastic debris problem? *Marine Policy*, *81*, 322–329. https://doi.org/10.1016/j.marpol.2017.04.014

Raubenheimmer, K., Nilufer, D., Oral, A., & McIllgorm. (2017). *Combatting marine plastic litter and microplastics. An assessment of the effectiveness of relevant international, regional and subregional governance strategies and approaches.* UN Environment.

Rauscher, H., Roebben, G., Mech, A., Gibson, N., Rauscher, H., Gibson, N., … Gibson, N. (2019). *An overview of concepts and terms used in the European Commission ' s definition of nanomaterial*. Ispra. https://doi.org/10.2760/459136

Rillig, M. C. (2012). Microplastic in terrestrial ecosystems and the soil? *Environmental Science and Technology*, *46*(12), 6453–6454. https://doi.org/10.1021/es302011r

Rios Mendoza, L. M., Karapanagioti, H., & Álvarez, N. R. (2018). Micro(nanoplastics) in the marine environment: Current knowledge and gaps. *Current Opinion in Environmental Science & Health*, *1*, 47–51. https://doi.org/10.1016/j.coesh.2017.11.004

Rist, S., Carney Almroth, B., Hartmann, N. B., & Karlsson, T. M. (2018). A critical perspective on early communications concerning human health aspects of microplastics. *Science of The Total Environment*, *626*, 720–726. https://doi.org/10.1016/j.scitotenv.2018.01.092

Rist, S., & Hartmann, N. B. (2018). Aquatic ecotoxicity of microplastics and nanoplastics: Lessons learned from engineered nanomaterials. *Handbook of Environmental Chemistry*, *58*, 25–49. https://doi.org/10.1007/978-3-319-61615-5_2

Rochman, C. M., Brookson, C., Bikker, J., Djuric, N., Earn, A., Bucci, K., … Hung, C. (2019). Rethinking microplastics as a diverse contaminant suite. *Environmental Toxicology and Chemistry*, *38*(4), 703–711. https://doi.org/10.1002/etc.4371

Rochman, C. M., Cook, A.-M., & Koelmans, A. A. (2016). Plastic debris and policy: Using current scientific understanding to invoke positive change. *Environmental Toxicology and Chemistry*, *35*(7), 1617–1626. https://doi.org/10.1002/etc.3408

Rochman, C. M., Hoh, E., Kurobe, T., & Teh, S. J. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Sci Rep*, *3*(1), 3263. https://doi.org/10.1038/srep03263

Rochman, C. M., Tahir, A., Williams, S. L., Baxa, D. V., Lam, R., Miller, J. T., … Teh, S. J. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Scientific Reports*, *5*(September), 1–10. https://doi.org/10.1038/srep14340

Ryan, P. G. (2015). A brief history of marine litter research. In *Marine Anthropogenic Litter* (pp. 1–25). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_1

SAM. (2017). *Food from the Oceans*. Brussles. https://doi.org/10.2777/66235

SAM. (2018). *Microplastic Pollution: The Policy Context. Background Paper*. Brussels: The Scientific Advice Mechanism Unit of the European Commission. https://doi.org/10.2777/25898

SAM. (2019). Workshop Report - Environmental and Health Impacts of Microplastic Pollution – from scientific evidence to policy advice. Retrieved from https://ec.europa.eu/research/sam/pdf/topics/microplastic-sam_workshop-012019.pdf#view=fit&pagemode=none

SAPEA. (2019). *A Scientific Perspective on Microplastics in Nature and Society*. https://www.sapea.info/wp-content/uploads/report.pdf

SCHEER - Scientific Committee on Health Environmental and Emerging Risks. (2018). *S Statement on emerging health and environmental issues (2018)*. https://doi.org/10.2772/ND

Scott, G. (1972). Plastics packaging and coastal pollution. *International Journal of Environmental Studies*, *3*(1–4), 35–36. https://doi.org/10.1080/00207237208709489

Smith, M., Love, D. C., Rochman, C. M., & Neff, R. A. (2018). Microplastics in Seafood and the Implications for Human Health. *Current Environmental Health Reports*, *5*(3), 375–386. https://doi.org/10.1007/s40572-018-0206-z

Son, C., Tavakoli, S., & Bartanusz, V. (2016). No publication bias in industry funded clinical trials of degenerative diseases of the spine. In *Journal of Clinical Neuroscience* (Vol. 25, pp. 58–61). https://doi.org/10.1016/j.jocn.2015.05.055

Syberg, K., & Hansen, S. F. (2016). Environmental risk assessment of chemicals and nanomaterials - The best foundation for regulatory decision-making? *Science of the Total Environment*, *541*. https://doi.org/10.1016/j.scitotenv.2015.09.112

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., … Russell, A. E. (2004). Lost at Sea: Where Is All the Plastic? *Science*, *304*(5672), 838. https://doi.org/10.1126/science.1094559 %J Science

Toussaint, B., Raffael, B., Angers, A., Gilliland, D., Kestens, V., Petrillo, M., … Eede, G. Van Den. (2019). Review of micro- and nanoplastic contamination in the food chain. *Food Additives & Contaminants: Part A*, 1–61.

UN Environment. (2017). Towards a pollution-free planet Report of the Executive Director.

UN Environment. (2018). *Marine litter and microplastics (UNEA-3 Resolution UNEP/EA.3/Res.7)*. Nairobi, Kenya. Retrieved from https://papersmart.unon.org/resolution/uploads/k1800210.english.pdf

UN Environment. (2019a). *Global Chemicals Outlook II Synthesis Report (2019)*. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/27651/GCOII_synth.pdf?sequence=1&isAllowed=y

UN Environment. (2019b). *Global Environment Outlook – GEO-6: Healthy Planet, Healthy People*. Nairobi: Cambridge University Press. https://doi.org/10.1017/9781108627146

UN Environment. (2019c). *Marine plastic litter and microplastics (UNEA-4 Resolution UNEP/EA.4/L.7)*. Retrieved from https://papersmart.unon.org/resolution/uploads/k1900897.pdf

Van Assen, M. A. L. M., Van Aert, R. C. M., Nuijten, M. B., & Wicherts, J. M. (2014). Why publishing everything is more effective than selective publishing of statistically significant results. *PLoS ONE*, *9*(1), e84896. https://doi.org/10.1371/journal.pone.0084896

van Sebille, E., England, M. H., & Froyland, G. (2012). Origin, dynamics and evolution of ocean garbage patches from observed surface drifters. *Environmental Research Letters*, *7*(4), 44040. https://doi.org/10.1088/1748-9326/7/4/044040/meta

van Valkengoed, A. M., & Steg, L. (2019). Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change*, *9*(2), 158–163. https://doi.org/10.1038/s41558-018-0371-y

Velzeboer, I., Kwadijk, C. J. A. F., & Koelmans, A. A. (2014). Strong sorption of PCBs to nanoplastics, microplastics, carbon nanotubes, and fullerenes. *Environmental Science and Technology*, *48*(9), 4869–4876. https://doi.org/10.1021/es405721v

Wagner, M., & Lambert, S. (2017). Freshwater Microplastics, Emerging Environmental Contaminants? *The Handbook of Environmental Chemistry*. Springer. Retrieved from https://link.springer.com/book/10.1007%2F978-3-319-61615-5

Wolf, M.-A., Baitz, M., & Kreissig, J. (2009). Assessing the Sustainability of Polymer Products (pp. 1–53). https://doi.org/10.1007/698_2009_10

World Health Organisation. (1999). *Hazard Prevention and Control in the Work Environment: Airborne Dust Chapter 1-Dust: Definitions and Concepts*. Retrieved from https://www.who.int/occupational_health/publications/en/oehairbornedust3.pdf?ua=1

Worm, B., Lotze, H. K., Jubinville, I., Wilcox, C., & Jambeck, J. (2017). Plastic as a Persistent Marine Pollutant. *Annual Review of Environment and Resources*, *42*(1), 1–26. https://doi.org/10.1146/annurev-environ-102016-060700

Wright, S. L., & Kelly, F. J. (2017). Plastic and Human Health: A Micro Issue? *Environmental Science and Technology*, *51*(12), 6634–6647. https://doi.org/10.1021/acs.est.7b00423

Annexes

Annex 1 – Initial statement

European Commission

Initial Statement[§] by the Group of Chief Scientific Advisors

A Scientific Perspective on Microplastic Pollution and its Impacts

Starting Considerations

Concern about the presence of microplastic particles[1] in soil, air and water and their effect on biota and human health is increasing among scientists, policy makers and the public. This is due to steadily improving knowledge of the scale and impacts of pollution by plastic in general and by microplastics in particular, either intentionally produced or formed by the degradation of larger plastic items. Heightened media attention to marine and land-based plastic pollution with images of floating garbage patches, littered beaches, entangled and suffocated animals and zooplankton ingesting plastic particles is also contributing significantly to public awareness.

This concern is welcome as it creates awareness of wider environmental issues such as global climate change, and stimulates change towards dealing with plastics as part of a circular rather than a linear economy. However, action needs to be guided by scientific evidence and directed towards effective and proportionate mitigating measures.

There is a consensus that plastic pollution must be curtailed and where possible eliminated altogether. For the mostly invisible[2] microplastic component of this pollution, such a view is reinforced by multiple potential negative impacts on biota and ecosystems for which empirical evidence is slowly emerging. A consequence of this is a rise in legislative and other measures by public authorities such as the EU Plastics Strategy[3] launched in January 2018, and voluntary actions by businesses, interest groups and citizens (Dauvergne, 2018a, 2018b). Most attention has so far has focused on water-borne microplastics resulting from the break-up of discarded larger items and microbeads found in a variety of products.

As is often the case in an emerging field of science where evidence is limited, the negative impacts of microplastics are not fully understood. Very few publications to date report dose-response relations over a range of microplastic concentrations as is normally done in risk assessment studies (Lenz, Enders, & Nielsen, 2016). Moreover, most evidence of negative impacts on biota such as inflammation, disruption to growth or reproduction and other bio-toxicological responses have been found in laboratory studies at particle concentrations higher than those in the majority of habitats (e.g. Wen et al., 2018; or references cited in the following review articles by Galloway et al., 2017; Revel et al. 2018; Wright & Kelly, 2017). While increased microplastic concentrations may arise from rapidly growing plastics production (Backhaus & Wagner, 2018) it is currently unknown whether toxicologically-relevant concentrations of microplastics exist or will be reached in the future. Indeed, while the environmental concentrations of small (< 100 μm) more toxicologically-relevant microplastics are largely unknown, they are probably higher than established concentrations of larger microplastics[4].

[§] More detailed Explanatory Note and Scientific Opinion to follow
[1] In the size range from 5 mm down to the nanometre (nm) scale
[2] The smallest size visible to the naked eye is about 0.1 mm or 100 micrometres (μm or microns)

[3] A European Strategy for Plastics in a Circular Economy
[4] Current EU chemicals regulation considers that it is not possible to establish safe 'thresholds' for certain types of substances

9 July 2018

Research and Innovation

We, the Group of Chief Scientific Advisors, consider that all current scientific knowledge and present knowledge gaps on the topic should be taken into account when shaping actions and policy measures. This should entail consideration of what science says about the ecological and health risks of all sources and types of microplastic pollution and the environmental compartments (air, soil or water) where they are found - notably those that are most abundant (synthetic fibres, tyre abrasion, break-up of macroplastics, etc.). It should also consider scientific studies of how the views and actions of citizens and policy makers are influenced by a wide range of factors – scientific, economic, psychological, cultural, etc. (Sedlak, 2017), including how risks and interests are perceived (Anderson et al., 2016; Völker et al., 2017).

Based on the above considerations and a discussion with scientific experts in the field[5], we have decided to look at the health and environmental impacts of microplastic pollution. Our input to both policy and the public discussion will be driven by scientific argument and evidence (Rist et al., 2018). We intend to draw on all relevant published findings as a basis for formulating our advice.

The policy & broader context for microplastic pollution

From an efficiency and 'better regulation' perspective, it is the responsibility of the Commission to critique its policy actions with a view to maximising public good outcomes. This means taking into account in a fair and balanced way all evidence and arguments, especially in cases where public opinion and interest groups call for a specific course of action which might not be the best. It is also important to monitor and critique actions already launched to ensure that the right targets were chosen and, if not, to correct this. Evidence-based scientific advice plays an important role in this regard alongside social, economic and political considerations.

In a situation where the implementation of the Plastics Strategy looms large on the EU policy agenda, scientific advice will be of benefit to several on-going[6] or forthcoming initiatives of relevance to microplastics. The on-going reviews by the European Chemicals Agency (ECHA) of the scientific bases for, and socio-economic consequences of, introducing restrictions on deliberately added microplastics and oxo-degradable plastics are particularly pertinent. Looking beyond the Plastics Strategy, such advice may have a bearing on REFIT[7] legislation reviews (e.g. of the water framework directive which originally did not consider plastic pollution), and other regulatory initiatives such as the revised drinking water directive and others.

The relative scarcity to-date of scientific data on the toxicological hazard of microplastics is not a reason to allow their continued release into the environment – better safe now than sorry later when science may be in a position to assess the environmental risks more comprehensively. In other words, absence of evidence is not the same as evidence of the absence of harm. Still, the opportunity cost to society of implementing bans on one type of pollutant and not others should also be considered from objective evidence-based perspectives. The fact that microplastics intentionally added in products are not the largest contributor to microplastic pollution (Scudo et al., 2017) raises the question of where else (e.g. unintentionally generated microplastics (Hann et al.,

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notably for substances with effects which are difficult to predict over long time horizons or where impacts would be difficult to reverse - so-called Persistent, Bioaccumulative and Toxic (PBT) and very Persistent and very Bio-accumulative (vPvB) substances
[5]See https://ec.europa.eu/research/sam/index.cfm?pg=topics

[6]E.g. the recently-proposed EU Directive on single-use plastics and fishing gear - COM(2018)340
[7]The EC's Regulatory Fitness and Performance programme

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2018)) public policy concerns should focus and with what urgency - based on evidence and analysis of the underlying causes. It is also likely that specific restrictions, when successful, will facilitate regulatory and other voluntary actions aimed at restricting/ eliminating larger emissions.

Complexity of microplastics

The properties of microplastic particles and current knowledge gaps justify concerns with respect to toxicity, mobility, persistence, etc. (Koelmans et al., 2017). From a societal and life-cycle point of view, microplastics cannot be considered in isolation from the overall plastics pollution problem because most microplastics originate from the breakdown of macroplastic items (Kramm et al., 2018), though with some variability between soil, air and water compartments. Furthermore, the umbrella term 'microplastic' describes a very diverse category of materials in terms of the ranges of polymer types, particle sizes (ranging over six orders of magnitude), shapes (from spheres to fibres) and chemical formulations (thousands of different types), which are likely to be found in various context-specific exposure situations (Lambert at al., 2017).

Grouping together particle sizes spanning six orders of magnitude is very crude[8]. This is relevant when considering potential impacts on living organisms due to particles crossing biological barriers (e.g. cell walls, intestinal or blood-brain barriers) , which can only occur for sizes approaching or below the micron scale (Wright & Kelly, 2017). Physical and chemical phenomena such as absorption and adsorption of other pollutants may also become more acute for nano-scale plastic particles than they are for those at and above the micron scale. While much still needs to be learned about the incidence and effects of nano-scale plastic particles, it is likely that science can already provide evidence of relevance to policy, which may suggest the need to distinguish between different components of this very broad microplastics size class. It is also worth noting that larger particles progressively degrade into smaller ones over a long period of time, though certain physical, chemical and biological conditions can accelerate this process.

Other complexities relate to the presence and behaviour of microplastics in different media and their movement between compartments (soil, air, and water). Most scientific studies to date have focused on the marine environment (water column, coasts and sediments), but more and more studies are being published on soil, freshwater systems and the atmosphere. It is also likely that the scientific findings in relation to these and other dimensions of microplastics complexity will suggest the need for specific policy and regulatory responses.

Next steps

In light of the above, it will be useful to provide the Commission by the end of 2018 with an Explanatory Note which captures the different facets of the complexity of microplastics. This Explanatory Note, based on a planned evidence review report by SAPEA[9] giving a state-of-the-art synthesis of relevant published scientific evidence and findings, will be presented in a way to promote a more informed public and policy debate.

[8] to give a sense of the range note the following typical sizes: human hair thickness 0.08 mm (80 µm); animal cell 20 µm; blood cell 8 µm; bacterium 1 µm; virus 0.1 µm (100 nm); smallest smoke particles 10 nm; glucose molecule 1 nm; water molecule 0.3 nm

[9] SAPEA is key part of the Scientific Advice Mechanism https://www.sapea.info/

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The proposed components of the Explanatory Note are:

1) A rapid evidence review, map and summary of the many existing natural sciences reviews and overview reports[10] covering exposure, (eco)toxicology, environmental and human health risks and incorporating recent primary literature not covered by existing reviews
2) A digest and analysis of the social and behavioural sciences covering issues such as risk perception[11] by citizens, the behaviour of stakeholders, the political economy and psychology of the microplastic debate, public good, and opportunity cost policy considerations
3) A political and legal sciences analysis of the different national and international legislative/ regulatory/ policy frameworks of relevance – including substance-focused (REACH, drinking water,...) and ecosystem-focused (water framework directive, marine strategy framework directive, ...) measures
4) An assessment of relevant modelling approaches and of their potential to shed light on some of the more complex aspects of microplastics including future "what if?" and "under which conditions?" scenarios.

Following on from the Explanatory Note, we would aim to publish a series of recommendations in the form of a Scientific Opinion in spring 2019.

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[10]including meta analyses such as the one by Foley et al., (2018)
[11]Including how it differs from scientific notions of risk as used in risk assessment

4 | Page

References

Anderson, A. G. et al. (2016). Microplastics in personal care products: Exploring perceptions of environmentalists, beauticians and students. *Marine Pollution Bulletin*, *113*(1–2), 454–460.
Backhaus, T. & Wagner, M. (2018). Microplastics in the environment: much ado about nothing ? A debate. *PeerJPreprints*, 0–5.
Dauvergne, P. (2018a). The power of environmental norms: marine plastic pollution and the politics of microbeads. *Environmental Politics*, *0*(0), 1–19.
Dauvergne, P. (2018b). Why is the global governance of plastic failing the oceans? *Global Environmental Change*, *51*, 22–31.
Foley, C. J. et al. (2018). A meta-analysis of the effects of exposure to microplastics on fish and aquatic invertebrates. *Science of The Total Environment*, *631–632*, 550–559.
Galloway, T. S. et al. (2017). Interactions of microplastic debris throughout the marine ecosystem. *Nature Ecology and Evolution*, *1*(5), 1–8.
Hann, S. et al. (2018). *Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products Final Report*.
Koelmans, A. A. et al. (2017). Risks of Plastic Debris: Unravelling Fact, Opinion, Perception, and Belief. *Environmental Science and Technology*, *51*(20), 11513–11519.
Kramm, J. et al. (2018). Superficial or Substantial: Why Care about Microplastics in the Anthropocene? *Environmental Science & Technology*, *52*, 336–337.
Lambert, S. et al. (2017). Ecotoxicity testing of microplastics: Considering the heterogeneity of physicochemical properties. *Integrated Environmental Assessment and Management*, *13*(3), 470–475.
Lenz, R. et al. (2016). Microplastic exposure studies should be environmentally realistic. *Proceedings of the National Academy of Sciences*, *113*(29), E4121–E4122.
Revel, M. et al. (2018). Micro(nano)plastics: A threat to human health? *Current Opinion in Environmental Science & Health*, *1*, 17–23.
Rist, S. et al. (2018). A critical perspective on early communications concerning human health aspects of microplastics. *Science of The Total Environment*, *626*, 720–726.
Scudo, A. et al. (2017). *Intentionally added microplastics in products*.
Sedlak, D. (2017). Three Lessons for the Microplastics Voyage. *Environmental Science and Technology*, *51*(14), 7747–7748.
Völker, C. et al. (2017). More than a potential hazard-approaching risks from a social-ecological perspective. *Sustainability (Switzerland)*, *9*(7).
Wen, B. et al. (2018). Microplastics have a more profound impact than elevated temperatures on the predatory performance, digestion and energy metabolism of an Amazonian cichlid. *Aquatic Toxicology*, *195*, 67–76.
Wright, S. L., & Kelly, F. J. (2017). Plastic and Human Health: A Micro Issue? *Environmental Science and Technology*, *51*(12), 6634–6647.

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ETRMA - European Tyre & Rubber Manufacturers' Association	Susanne Buchholtz
EUMEPS - European Manufacturers of Expanded Polystyrene	Elisa Setien
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EurEau - European Federation of Water Services	Oliver Loebel, Bertrand Vallet
EUROCOOP - European Community of Consumer Co-operatives	Rosita Zilli
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IOGP - International Association of Oil & Gas Producers	Bernard Vanheule
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DG GROW D.1	Gert Roebben
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DG JRC - Ispra D.1	Elisabetta Balzi
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DG RTD F.2	Silvia Maltagliati
DG RTD F.5	Ivan Conesa Alcolea
DG RTD I.2	Pavel Misiga, Hans-Christian Eberl
DG SG E.2	Emilien Gasc

[44] This meeting took place in Brussels on 25 April 2019

Annex 4 – Abbreviations

CFC	Chlorofluorocarbon
ECHA	European Chemicals Agency
EFSA	European Food Safety Agency
EMODnet	European Marine Observation and Data Network
EU	European Union
MSFD	EU's Marine Strategy Framework Directive
NGO	Non-Governmental Organisation
PET	Polyethylene terephtalate
ppm	Parts per million
POP	Persistent Organic Pollutants
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SAM	Scientific Advice Mechanism
SAPEA	Science Advice for Policy by European Academies
SCHEER	Scientific Committee on Health, Environmental and Emerging Risks
SUP	Single Use Plastics
UNFCCC	United Nations Framework Convention on Climate Change
UNEA	United Nations Environment Assembly
WHO	World Health Organisation

Annex 5 - Glossary

Additive: Substance added to a plastic in order to modify its properties and to increase its performance (e.g. rigidity, flexibility, colour, durability etc.). Examples of additives include, stabilisers, colorants, fillers, plasticisers.

Adsorption: The adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface.

Anthropogenic: Originating in human activity.

Bio-based plastic: A plastic, which (partly) derived from biomass (plants). Biomass used for bioplastics stems from e.g. corn, sugarcane, or cellulose.

Biodegradation: The complete breakdown of an organic chemical compound by microorganisms in the presence of oxygen to CO_2, water and mineral salts of any other minerals present and new biomass, or in the absence of oxygen to CO_2, methane, mineral salts and new biomass.

Bioplastics: Plastics that are bio-based, biodegradable, or both.

Biota: The plant and animal life of a particular region or period.

Circular Economy: An approach whereby the value of products, materials and resources is maintained in the economy for as long as possible - when a product reaches the end of its life, it is used again to create further value and the generation of waste minimised.

Contamination: Presence of a substance where it should not be or at concentrations above normal.

Composting: A material is compostable if it undergoes biodegradation by biological processes in home or industrial composting conditions and timeframes, leaving no toxic residues.

Dose-response: The relationship between the amount of a substance to which an individual organism, population or ecosystem is exposed and the way in which it responds (e.g. in terms of toxicity).

Ecosystem: A system involving the interactions between a community of living organisms in a particular area and its non-living environment (e.g. air, water and soil).

Endpoint: In toxicological studies, a physical or chemical outcome that can be assessed by a test; for example, a change in body weight or levels of a potential toxin in the body.

Exposure: Concentration or amount of a particular substance that is taken in by an individual, population or ecosystem in a specific frequency over a certain amount of time. Exposure can occur via ingestion via the diet, but also through inhalation or dermal contact.

Fate: Destiny of a chemical or biological pollutant after release into the natural environment.

Fragmentation: The process by which plastics break into pieces over time. A plastic can fragment into microscopic pieces while not being biodegradable.

Hazard: In the context of this Opinion, the intrinsic potential of a substance to cause harm to human health or the environment. Hazard does not necessarily imply that harm will occur: this depends on the risk, which is a product of both hazard and exposure.

Litter: Regardless of the size, any persistent, manufactured or processed solid material discarded, disposed of or abandoned improperly, without consent, at an inappropriate location.

Microbead: Any solid plastic particle that is less than five mm in size and is intended to be used to exfoliate or cleanse the human body or any part thereof.

Monomer: A molecule making up the smallest repeating unit in a polymer. Monomers undergo chemical conversion to form the bonds holding them together in a polymer.

Mulch: Layer of material applied to the surface of soil for purpose of conservation of soil moisture, improving fertility and health of the soil.

No effect (Null effect/Null result): In the context of this Opinion, an experimental outcome, which shows no significant effect on the endpoints measured. There could still be an "unseen" effect.

Oxo-plastics/oxo-degradable: Plastics containing additives, which promote the oxidation of the material under certain conditions. They are used in applications such as agricultural films, rubbish and carrier bags, food packaging, and landfill covers.

Persistence: The long-term survival of plastics in the environment due to their resistance to environmental degradation through chemical, biological, and photolytic processes.

Pollution: Contamination that results in or can result in adverse biological effects to the resident communities.

Polymer: A substance consisting of molecules characterised by the sequence of one or more types of monomers.

Precautionary principle: A principle/approach designed to assist decision-makers to adopt precautionary measures when scientific evidence about an environmental or human, animal or plant health hazard is uncertain and the stakes are high.

Risk: The chance or probability that harm or the experience of an adverse effect will occur if exposed to a hazard.

Risk assessment: A scientifically-based process consisting of four steps: hazard identification, hazard characterisation, exposure assessment and risk characterisation.

Risk management: The process of weighing policy alternatives in consultation with interested parties, considering risk assessment and other legitimate factors, and, if need be, selecting appropriate prevention and control options to protect consumers, animals and the environment.

Toxicity: The state and degree to which a substance can damage a living organism, dependent on its dose.

Uncertainty: In the context of this Opinion, a lack of full knowledge about a situation or possible outcome, which is an important component of a risk assessment.

Waste: Substance or object, which the holder discards or intends to, or is required to, discard.

Sources: relevant regulations; DG-websites; EC's 'A Circular Economy for Plastics' report; SAPEA ERR; ECHA; EEA; EUNOMIA Report (Feb. 2018)

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Knowledge of ecological and health risks of microplastic pollution is surrounded by considerable uncertainty. However, if microplastic pollution continues at the present rate, these risks will increase and, in particular, widespread ecological risks are likely in the coming decades. The absence of population-wide studies means that it is not yet possible to assess risks for human health.

Ongoing and planned EU policy measures aim to reduce all plastic pollution including microplastics. But what more, if anything, should be done now as a precaution against future risks from microplastics?

This scientific opinion, informed by a SAPEA evidence review report makes recommendations to advise debate, policy and practice in this and related areas. Highlights include calls to:

- Broaden existing policy to prevent and reduce microplastic pollution in water, air, and soil; and to prioritise substance- and context-specific measures for high-volume, high-emission sources;
- Ensure benefit to society of microplastic pollution preventative measures by taking into account socio-economic cost/ benefit analyses, trade-offs and wide environmental aspects in the design of such measures; and
- Develop a co-ordinated international response consisting of research collaboration (including filling knowledge gaps on nanoplastic pollution), data sharing and standards development for measurement, monitoring and risk assessment.

Studies and reports

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