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Published in:
Science of the Total Environment

Link to article, DOI:
[10.1016/j.scitotenv.2018.01.092](https://doi.org/10.1016/j.scitotenv.2018.01.092)

Publication date:
2018

Document Version
Peer reviewed version

[Link back to DTU Orbit](#)

Citation (APA):
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>

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1 A critical perspective on early communication concerning
2 human health aspects of microplastics

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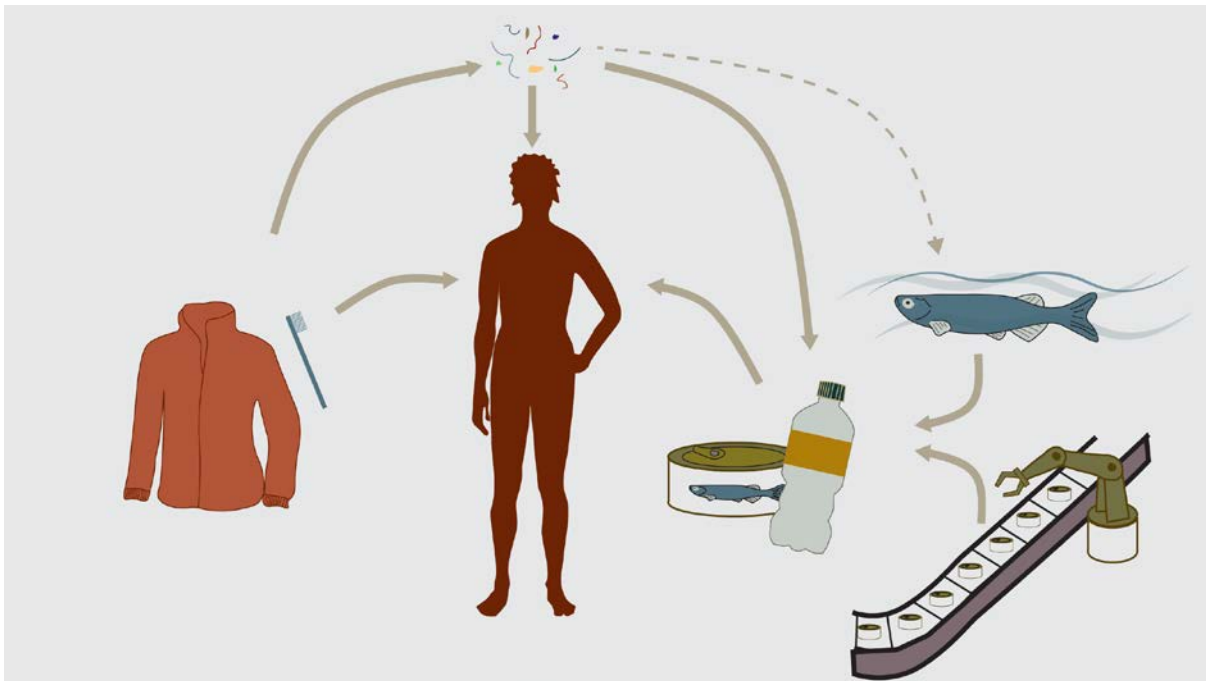
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11

12 **Abstract**

13 Microplastic research in recent years has shown that small plastic particles are found almost
14 everywhere we look. Besides aquatic and terrestrial environments, this also includes aquatic
15 species intended for human consumption and several studies have reported their prevalence in
16 other food products and beverages. The scientific as well as public debate has therefore
17 increasingly focused on human health implications of microplastic exposure. However, there
18 is a big discrepancy between the magnitude of this debate and actual scientific findings, which
19 have merely shown the presence of microplastics in certain products. While plastics can
20 undoubtedly be hazardous to human health due to toxicity of associated chemicals or as a
21 consequence of particle toxicity, the extent to which microplastics in individual food products
22 and beverages contribute to this is debatable. Considering the enormous use of plastic
23 materials in our everyday lives, microplastics from food products and beverages likely only
24 constitute a minor exposure pathway for plastic particles and associated chemicals to humans.
25 But as this is rarely put into perspective, the recent debate has created a skewed picture of
26 human plastic exposure. We risk pulling the focus away from the root of the problem: the way
27 in which we consume, use and dispose of plastics leading to their widespread presence in our
28 everyday life and in the environment. Therefore we urge for a more careful and balanced
29 discussion which includes these aspects.

30 **Graphical abstract**



31

32 **Keywords**

33 contamination, food products, plastic additives, chemical toxicity, particle toxicity

34 **Highlights**

- 35 • There is data supporting possible chemical and particle toxicity effects of plastic
- 36 • The current debate on human health effects of plastics is unbalanced
- 37 • There is a disproportionate focus on microplastics in individual food products
- 38 • Exposure to additives and microplastics is mainly related to general plastic use
- 39 • We urge for a more balanced discussion on human exposure to plastics

40

41 **1. Introduction**

42 An increasing number of studies show that plastics in general, and microplastics in particular,
43 are ubiquitous in all environmental compartments, including sediments, soils, water columns
44 and surface layers in marine and freshwater systems (Li et al., 2016; van Sebille et al., 2015).
45 It seems that wherever we look we find plastics, and some of the supposed sources include
46 abrasion of plastic products and paints (Lassen et al., 2015), fragmentation of mismanaged
47 plastic waste, discarded/lost fishing equipment (Andrady, 2011), and microplastic fibers from
48 textiles (Browne et al., 2011). Plastic pollution is thus mainly a diffuse source problem.
49 However, major pathways for release into the environment have been identified and include
50 WWTP effluents and storm water drains (Lattin et al., 2004; van Wezel et al., 2015).
51 Although plastic pollution may cause adverse effects in all environmental compartments the
52 ecological effects of plastic pollution have so far mainly been studied in marine environments
53 where numerous species of birds, fish and invertebrates have been found to ingest macro- and
54 microplastics (GESAMP, 2015) and over 800 species are known to be affected by marine
55 litter (UNEP, 2016). Field measurements have also shown their presence in marine species
56 used for human consumption, like bivalves and fish (Dehaut et al., 2016; Rochman et al.,
57 2015). Furthermore, microplastics have been reported in tap water, bottled water, sugar, salt,
58 beer and honey (Karami et al., 2017; Kosuth et al., 2017; Liebezeit and Liebezeit, 2014, 2013;
59 Schymanski et al., 2017; Yang et al., 2015). The issue of microplastic contamination in food
60 products and beverages has gained increasing public interest and media attention in recent
61 years, triggering the logical question: are there implications for human health? This concern
62 likely results from a synthesis of different inputs: the easily identifiable environmental
63 pollution associated with macroplastic littering and mismanaged waste, a fear of the
64 seemingly omnipresent and invisible microplastics, and finally the well-known harmful
65 effects of some plastic additives and plasticizers such as for example phthalates. In
66 combination, this has led to numerous publications (both scientific and popular) speculating
67 about the human health consequences of microplastic exposure. There is, however, a large
68 discrepancy between the current state of scientific evidence concerning effects of
69 microplastics and the ongoing public discussion and subsequent fears, leading to a potentially
70 incorrect focus and path forward. We will explain why this is problematic.

71 Since their first commercial production in the mid-20th century plastics have revolutionized
72 society; from healthcare to food safety and transport (Andrady and Neal, 2009). In fact,
73 plastics have allowed for a technological leap in many areas directly or indirectly related to

74 human health. Conversely, plastic materials have the potential to pose or contribute to direct
75 or indirect human health risks. Plastic bags have for example been seen to provide breeding
76 habitats for mosquitoes carrying malaria (Njeru 2006) or causing flooding by blocking drains
77 as it happened in Bangladesh in 2002 (NOLAN-ITU, 2002). Plastic materials are also
78 associated with thousands of chemicals; several of which are found in human blood, urine and
79 breastmilk and some of which are known to have adverse effects on animals and potentially
80 humans (Talsness et al., 2009). There are many areas in the world that lack proper waste
81 management, which often results either in the creation of vast landfills or in a routine burning
82 of waste. When incinerated, plastic materials have long been known to release polycyclic
83 aromatic hydrocarbons (PAHs) (Li et al., 2001) and toxic gases, for example furan and dioxin
84 (Menad et al., 1998). Moreover they can leave residues of lead and cadmium (Korzun and
85 Heck, 1990), two metals known to be toxic to human health. A more recently explored aspect
86 of plastic-related human health effects concerns particles in the micro- and nano-scale, which
87 are either intentionally produced in that size or created through the fragmentation of larger
88 plastics. Potential effects of such particles have to a degree been studied in the field of
89 arthroplasty where plastic prosthesis have been shown to fragment, creating small plastic
90 particles (Hicks et al., 1996). Human health effects of particles in general have also been
91 extensively documented within the field of air pollution (Chen et al., 2016; Stone et al., 2007).

92 As noted above there are a number of reasons to assume that plastic materials, as we use and
93 dispose of them today, may pose risks to human health. While pollution in general is
94 recognized as a major contributor to human disease and premature death (Landrigan et al.,
95 2017), many research scientists express a mixture of skepticism and concern over the extent
96 and associated human health risks of plastic pollution as a whole (Seltenrich, 2015).
97 Nevertheless, human health effects of specifically microplastics have been the primary focus
98 of the recent public debate. These public concerns are largely linked to potential exposure to
99 microplastic contaminants in food and beverages, for example in seafood or tap water, even
100 though these are not likely to be among the major exposure pathways of microplastics and
101 associated chemicals to humans. Plastics are such an integrated part of our everyday lives that
102 the few added fibers or particles that may occur in some food products or beverages are likely
103 not even comparable to the quantity of plastic materials and chemicals that we are exposed to
104 through our usage of clothes, food contact materials, packaging, building materials and
105 kitchen appliances. In fact, it is reasonable to assume that the amount of microplastic fibers
106 that is reportedly found in tap water may be equivalent to the amount that ends up in a glass of

107 water standing on a kitchen counter as a result of settling of dust or air particulate matter
108 which consists largely of microplastic fibers from clothing. Somewhat ironically, this
109 widespread occurrence of microplastics is why researchers face such challenges in avoiding
110 sample contamination even in the cleanest lab environments. Still, the potential human health
111 risks of microplastics in food products and beverages are often exaggerated, even in the
112 scientific literature (Koelmans et al., 2017), not surprisingly leading to strong reactions in
113 public media.

114 Plastics in the environment comprise a ‘wicked problem’ (Hastings and Potts, 2013),
115 complicated by numerous stakeholders, as well as complex moral, ethical and political
116 considerations. Through focusing on the risk of microplastics in specific food items, such as
117 seafood or tap water, we risk pulling focus away from the root of the problem, namely the
118 way that we produce, use and dispose of plastic materials in modern society. While research
119 into fate, effects and consequences of microplastics is warranted, here we focus on the
120 contrast between the current debate of microplastics as a potential human health hazards and
121 known health effects of plastic materials and associated chemicals. Moreover, we want to
122 draw attention to the manner in which scientific results of this field are communicated within
123 the scientific community as well as to the general public. We urge for a more balanced and
124 careful interpretation of findings. Lastly, we want to encourage a discussion on how our
125 consumption, use and disposal of plastics may fit into the debate on human health effects.

126 **2. Potential mechanisms of plastic-related adverse effects on human health**

127 **2.1 Toxicity of chemicals in plastic products**

128 Plastic materials are made from mono- or oligomeric building blocks arranged through
129 different techniques and chemical reactions into polymeric chains. In order to create the many
130 different types of plastics with differing properties that we see on the market today, the
131 industry also makes use of a wide array of plastic additives including different types of fillers,
132 flame retardants, antioxidants, plasticizers and colorings (Halden, 2010). The produced
133 materials will contain a majority of polymeric chains, but also some residual monomers,
134 catalyzing agents used in the chemical processing, additives and potentially non-intentionally
135 added substances carried over from the raw materials (usually petroleum oil). Overall there
136 are tens of thousands of chemicals used in plastic products and an extensive review of their
137 associated risks and hazards is beyond the scope of this article. For more information there are
138 several reviews on the topic (Hahladakis et al., 2018; Halden, 2010; Hauser and Calafat,

139 2005; Sjödin et al., 2003). Here, we will, however, provide a few examples to illustrate the
140 potential health issues associated with chemicals in plastic products and discuss some known
141 exposure pathways.

142 Most polymers, for example polyethylene (PE) and polypropylene (PP), are generally
143 considered biologically inert. Some of the monomers and oligomers used in plastic products
144 have, however, been shown to leach during usage and have subsequently been found in
145 humans. Commonly mentioned examples are Bisphenol A (BPA), a monomeric building
146 block of polycarbonate (PC), but also used as an additive in other plastics, and styrene, used
147 in the production of polystyrene (PS) which is commonly used in styrofoam packaging. Both
148 of these monomers are suspected endocrine disrupting chemicals (EDCs). BPA is one of the
149 relatively few chemicals associated with plastics that have been studied extensively and it has
150 repeatedly been reported in urine, blood, breast milk and tissue samples (Halden, 2010). The
151 main exposure pathways are considered to be inhalation, dermal contact and ingestion
152 (Thompson et al., 2009) and there is a growing body of evidence that many of the additional
153 monomers, oligomers and chemicals related to plastics can adversely affect humans, with
154 exposure being correlated to e.g. reproductive abnormalities (Lang et al., 2008; Swan, 2008;
155 Swan et al., 2005).

156 One group of chemicals that is commonly used as additives in plastic consumer products are
157 phthalates such as di-n-octyl phthalate (DnOP) and di(2-ethylhexyl) phthalate (DEHP)
158 (Hauser and Calafat, 2005). Phthalates are associated with a wide range of health effects in
159 animals and humans, and due to their extensive use they are often found in urine and blood
160 samples from humans (Hauser and Calafat, 2005). Phthalates have been associated with
161 developmental anomalies; it has for instance been shown to affect pubertal development, male
162 and female reproductive health, pregnancy outcomes and respiratory health (reviewed in
163 Hauser and Calafat, 2005). Moreover, the additives used as flame retardants in plastic
164 products, including polybrominated diphenyl ethers (PBDE) and tetrabromobisphenol A
165 (TBBPA), can be toxic. PBDE and TBBPA have both been shown to disrupt thyroid hormone
166 homeostasis while PBDEs also exhibit anti-androgen action (Sjödin et al., 2003).

167 **2.2 Particle toxicity of micro- and nanoplastics**

168 Compared to chemicals used as plastic additives, less is known regarding the particulate
169 toxicity effects of plastic fragments. A detailed review on potential exposure pathways,
170 particle uptake/translocation and potential effects in humans has recently been provided by

171 Wright & Kelly (2017). As the main exposure pathways are ingestion and inhalation, particle
172 uptake and translocation may occur in the gastrointestinal tract (GIT) and/or in the lungs. The
173 common mechanism is thereby endocytosis; however, in the GIT persorption (the
174 translocation of particles into the circulatory system of the GIT through gaps in the epithelium
175 of the villus tips) is expected to constitute the major uptake route. Uptake and subsequent
176 translocation to secondary target organs will depend on many factors, including
177 hydrophobicity, surface charge, surface functionalization and the associated protein corona,
178 but also particle size. The translocation of smaller particles within the GIT is likely more
179 efficient since nano-sized PS particles have been found in blood and organs (Jani et al., 1990)
180 while PS microparticles of 2 μm only showed a low degree of translocation across the gut
181 layer (Doyle-McCullough et al., 2007). One study has reported persorption of starch particles
182 with a size of up to 130 μm (Volkheimer, 2001), however, this was only rarely observed and
183 the report does not provide information on the used methods. Although it is unknown whether
184 and to what extent ingested plastic particles are translocated in a similar way, research on PE
185 and PET wear particles stemming from the abrasion of prostheses gives some indications of
186 potential pathways once plastic particles have crossed the GIT layer. PE particles of up to 50
187 μm have been found to translocate to lymph nodes and could in some cases be found in the
188 liver and spleen (Doorn et al., 1996; Urban et al., 2000). They were associated with
189 inflammatory responses in surrounding tissues, which include the immune activation of
190 macrophages and the production of cytokines (Hicks et al., 1996).

191 More research has been conducted on particle toxicity of engineered nanoparticles (ENPs)
192 and airborne particulate matter (PM), which shows that air pollution with small particulates is
193 strongly associated with respiratory and cardiovascular disease (Chen et al., 2016; Stone et al.,
194 2007). This can be related to the fact that the fraction below 2.5 μm is largely retained in the
195 lungs and can pass through respiratory barriers. The main mechanism of particle toxicity is
196 thereby generation of oxidative stress and subsequent inflammation (Feng et al., 2016).
197 Accordingly, the generation of reactive oxygen species (ROS) has been shown in two human
198 cell lines (T98G and HeLa) after exposure to PE and PS particles, which did not, however,
199 affect cell viability (Schirinzi et al., 2017). Further potential biological responses include
200 genotoxicity, apoptosis and necrosis, which could ultimately lead to tissue damage, fibrosis
201 and carcinogenesis (Wright and Kelly, 2017). However, the chemical composition and the
202 particle size are decisive factors for causing adverse effects; for instance nanoparticles have
203 been found to generate more ROS than larger particles and are more likely to be translocated

204 (Stone et al., 2007). Therefore, it can be assumed that potential health effects of microplastics
205 largely depend on the particle characteristics and that adverse effects are expected for
206 nanoplastics rather than larger micrometer-sized plastic particles. Although the fields of ENPs
207 and PMs provide interesting insights into mechanisms of particle toxicity, the knowledge on
208 adverse effects of plastic particles on humans is still very limited and there is a great need for
209 experimental data to investigate potential mechanisms.

210 **3. Microplastics in seafood and other products intended for human** 211 **consumption**

212 Plastics in seafood have made the headlines more than once and their presence is often
213 described with expressions of concern to human health in mass media, campaigns from
214 environmental NGOs and in scientific articles (Rochman et al., 2015; Romeo et al., 2015).
215 The scientific studies, however, merely show the presence of microplastics in fish and
216 bivalves and hypothesize that there may be potential adverse effects on humans. No studies
217 have, so far, either confirmed or disproved this risk.

218 When discussing the exposure to microplastics through consuming seafood, it is important to
219 consider the particle numbers that have been reported to date. For bivalves, values of 0 – 10.5
220 plastic particles per g have been reported and Van Cauwenberghe and Janssen estimated a
221 maximum exposure of 11 000 particles per year for a European shellfish consumer (Li et al.,
222 2015; Rochman et al., 2015; Van Cauwenberghe and Janssen, 2014). One study on readily
223 processed fish products in the form of canned sardines and sprats reported only a maximum of
224 3 plastic particles per can (Karami et al., 2018), which presents a very low exposure compared
225 to other pathways. Furthermore, the microplastics that are found in fish are mostly located
226 within the gut (Foekema et al., 2013; Rochman et al., 2015; Romeo et al., 2015), which is
227 rarely consumed, thus making it less likely for these particles to end up on our plates.

228 Seafood is not the only food product in which microplastics have been found in recent years.
229 They have been reported in beer (Liebezeit and Liebezeit, 2014), honey, sugar (Liebezeit and
230 Liebezeit, 2013), salt (Karami et al., 2017; Yang et al., 2015) and recently in tap water
231 (Kosuth et al., 2017) and bottled water (Schymanski et al., 2017) (for an overview see Table
232 S1). On this basis, estimated maximum consumptions per person per year were reported to be
233 4000 plastic particles from tap water (Kosuth et al., 2017) and between 37 (Karami et al.,
234 2017) and 1000 (Yang et al., 2015) from sea salt. While results of these studies have received

235 massive attention in public media, they need to be evaluated with care. The methodology that
236 was used in the studies on honey, sugar and beer by Liebezeit & Liebezeit (2013; 2014) was
237 recently questioned and results were related to background contamination and potential
238 erroneous identification of plastic particles (Lachenmeier et al., 2015). Moreover, a similar
239 study on honey did not find a significant contamination of microplastics (Mühlschlegel et al.,
240 2017). Also, the report on microplastics in tap water lacks a chemical/physical confirmation
241 of the synthetic origin of the particles (Kosuth et al., 2017). A more thorough analysis has
242 been performed in the study on bottled water, which found 14 particles/L in single-use plastic
243 bottles and 118 particles/L in returnable plastic bottles that were traced back to originating
244 from the bottles themselves (Schymanski et al., 2017). This indicates the importance of
245 investigating the production and packaging processes for plastic contamination. However, the
246 authors also report difficulties with blank samples that showed 14 particles/L on average.
247 There are thus still many methodological and analytical uncertainties and we should be
248 careful with generalizing from individual case studies. Further efforts are needed to develop
249 reliable methods for sampling and analysis to avoid artefacts.

250 **4. The relative contribution to human exposure from different exposure** 251 **pathways**

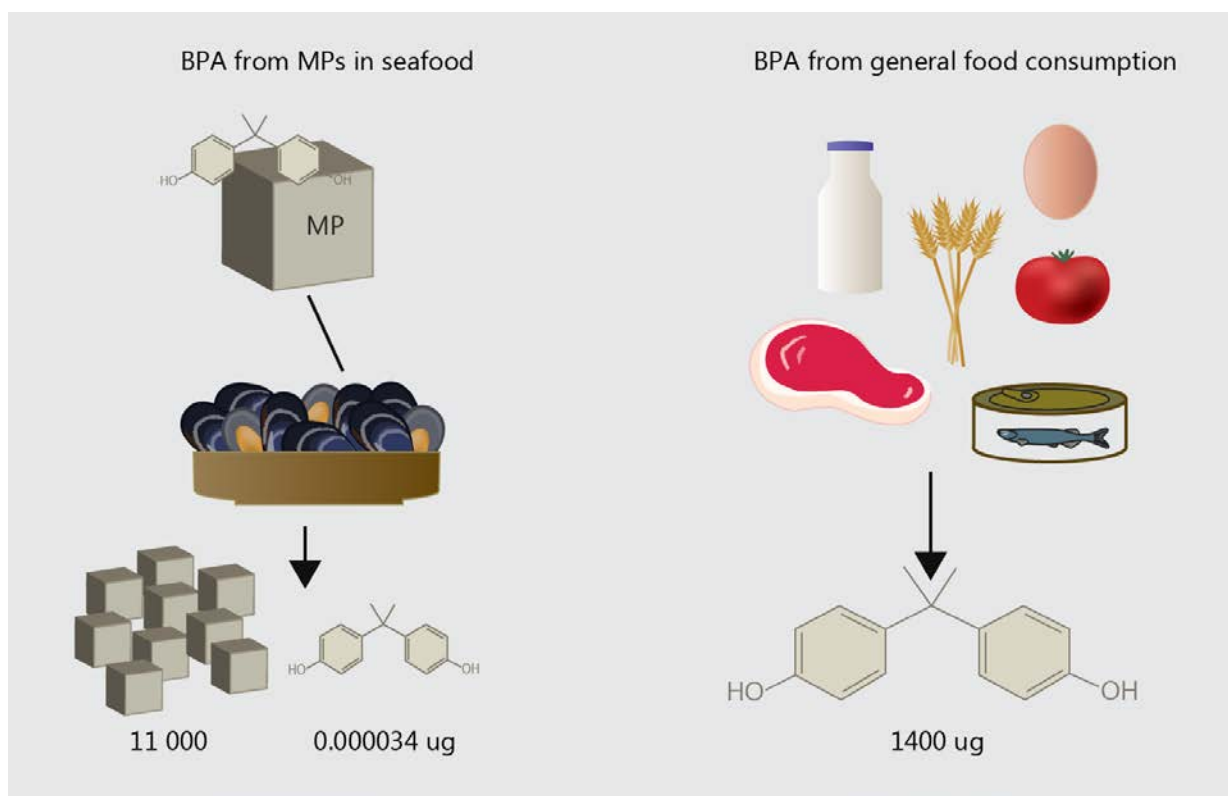
252 Based on the above described exposure pathways, we are here aiming at comparing the
253 relative contributions of microplastics and associated chemicals to human exposure.

254 **4.1 Exposure routes for plastic-associated chemicals**

255 Several of the above mentioned chemicals have been reported in microplastics found in
256 environmental samples (Fries et al., 2013) but we question the risks they posed to human
257 health. The relatively low rate of microplastic exposure to humans, from so-far identified
258 sources, render this pathway a relatively insignificant exposure route for these chemicals
259 compared to other exposure pathways. BPA has, for example, been found in concentrations
260 between 5-284 $\mu\text{g}/\text{kg}$ microplastics (Teuten et al., 2009) and shellfish consumers have been
261 estimated to ingest up to 11 000 microplastic particles annually (Van Cauwenberghe and
262 Janssen, 2014). Using the measurements for the larger microplastics in the study, 20 μm , and
263 assuming a cubic shape each particle would have a volume of $8000 \mu\text{m}^3$ (or 0.000000008
264 cm^3). If we then assume a density of $1.38 \text{ g}/\text{cm}^3$ (based on PET), that would give a
265 weight/particle of $1.1 \times 10^{-8} \text{ g}$, giving a total weight of $1.2 \times 10^{-4} \text{ g}$ microplastics consumed per
266 year. Using the highest concentrations of additives measured in environmental microplastics
267 the theoretical annual human exposure would then be $3.4 \times 10^{-5} \mu\text{g}$ BPA from ingesting

268 microplastics in seafood. In contrast, a Swedish study estimated the mean intake per person
269 for BPA to be 3.9 $\mu\text{g}/\text{day}$ (Gyllenhammar et al., 2012) which would extrapolate to 1400 μg
270 annually - almost one hundred million times higher than the above calculated annual exposure
271 to BPA from microplastics in shellfish (Fig. 1). Although these calculations are based on
272 several assumptions and there is a variety of additives that could be considered, it does
273 indicate that the consumption of microplastics in shellfish is a comparatively small source of
274 plastic-associated chemicals. EFSA made similar calculations and came to the same
275 conclusion for BPA, PCBs and PAHs (EFSA, 2016). It is more likely that our main exposure
276 pathways to some of these chemicals are related to consumption of food contaminated by the
277 respective packaging, so called food contact materials. Accordingly, studies have shown a
278 significant reduction in the urinary levels of BPA and DEHP metabolites when the
279 participants consumed food products with limited packaging (Rudel et al., 2011). It should
280 also be noted that as these chemicals are ubiquitous in our everyday lives, there is a wide
281 array of exposure pathways related to our consumption patterns other than via food contact
282 materials. There are several indications that there is a pressing need to increase awareness
283 concerning our choices and usage of different types of plastic materials (reviewed in Halden,
284 2010). But as there is very limited labelling of plastic products aside from the voluntary usage
285 of resin identification codes, there is no real possibility for consumers to make conscious
286 choices. This puts extra weight on the governing authorities to, in the future, make responsible
287 decisions concerning which chemicals should be allowed in plastic products.

288 Furthermore, microplastics are often cited to act as potential carriers of hydrophobic
289 chemicals into water-living organisms such as fish. This statement that has recently been
290 critiqued by researchers as 1) the chemicals often bind strongly to the plastics and 2) plastic
291 particles likely constitute an insignificant exposure route in comparison to natural organic
292 material in the water as well as the water itself (Koelmans et al., 2016). Although the critique
293 rarely accounts for the potential for the material to biotransform (Watts et al., 2015) the
294 effects of degradation and weathering (Jahnke et al., 2017; Hartmann et al., 2017), or the
295 higher levels described at local hotspots (Hartmann et al., 2017), it illustrates the many
296 uncertainties that surround this issue.



298

299 **Figure 1:** Based on the estimated annual ingestion of microplastics (MPs) through consuming mussels
 300 (Van Cauwenberghe and Janssen, 2014) and using the density of polyethylene terephthalate (PET) as
 301 well as the reported concentration of bisphenol A (BPA) in environmental MPs, the theoretical
 302 exposure to BPA would be in the order of 30 picogram whereas the estimated annual exposure to BPA
 303 from general food consumption is in the order of a milligrams (Gyllenhammar et al., 2012).

304 4.2 Comparing exposure pathways of microplastics: food, beverages, air

305 From the few studies looking on microplastics in food products and beverages, estimated
 306 maximum consumptions per person per year were reported to be 37-1000 plastic particles
 307 from sea salt (Karami et al., 2017; Yang et al., 2015), 4000 from tap water (Kosuth et al.,
 308 2017) and 11 000 from shellfish (Van Cauwenberghe and Janssen, 2014). However, there are
 309 other pathways by which humans may directly be exposed to microplastics that receive less
 310 attention but are important to consider.

311 Plastic fibers have been reported to stem from atmospheric fallout with a deposition of up to
 312 355 particles/m²/day in an urban area (Dris et al., 2016). This emphasizes not only the
 313 importance of human exposure directly from the air but also the big potential for
 314 contamination of food products and beverages with microplastics in various steps of
 315 production. The products themselves, or the processing equipment, will be air-exposed at
 316 some stage, including the plates or glasses on our dinner table. Until now very little is known

317 about indoor exposure levels to airborne microplastics but at textile-processing work places
318 levels of 500 000, 800 000 and 700 000 particles/m³ have been found for nylon,
319 polyvinylchloride (PVC) and polyester, respectively (Bahners et al., 1994). Furthermore,
320 personal exposure levels to respirable inorganic and organic fibers from airborne dust have
321 been monitored with personal sampling pumps and reported values for organic fibers were up
322 to 11 000/m³ for fibers <5 μm, 19 000/m³ for fibers >5 μm and up to 2 000/m³ for fibers
323 >20μm (Schneider et al., 1996). To investigate the potential for airborne microfiber
324 deposition we conducted a small-scale test, in which a polyester shirt was taken off beside a
325 water-filled beaker that stood open for 4h (for a detailed description of the methods and
326 results see SI). The water of the air-exposed beaker as well as of a blank and tap water sample
327 were filtered and subsequently analyzed microscopically. We found a mean number of 15
328 synthetic fibers in the air-exposed treatment, in comparison to 4 in the tap water and 1.7 in the
329 blanks. Due to high variability in the air-exposed treatment group, the differences between the
330 groups were not statistically significant (p=0.06), although there was an apparent difference
331 between the air-exposed group and the other two groups (Fig. S1). Nevertheless the results
332 highlight the importance of airborne microfibers in regular indoor environments, originating
333 from the usage of synthetic materials, as an important contribution to the total microplastic
334 exposure pathway for humans. Furthermore, high numbers of non-synthetic fibers were found
335 which further emphasizes the degree of background contamination of fibers in indoor
336 environments. These numbers only provide an initial indication about airborne exposure to
337 microplastic fibers. Systematic studies on indoor exposure levels are lacking but these first
338 results demonstrate that airborne plastic fibers are likely to outnumber the plastic particles
339 found in contaminated food products. Additionally, plastic materials that are used during
340 production, transport and storage may release microplastic particles into the product as
341 indicated by plastic packaging for drinking water (Schymanski et al., 2017).

342 **5. Microplastics and human health – a question of perspective**

343 There is extensive literature supporting the case that plastic materials can affect human health,
344 with effects mainly related to toxicity of chemical additives that are used in plastic materials.
345 Furthermore, a number of studies have indicated particle toxicity of plastics in the micrometer
346 size range or smaller. Concerning the latter, the discussions on human health implications of
347 microplastics can gain a lot from other fields that are dealing with human toxicity of
348 particulate materials, like nanotoxicology, air pollution, fiber toxicity and wear debris from
349 prosthetic implants. As discussed above, many of the findings from these related fields

350 support the notion that micro- or nanometer sized plastic particles could adversely affect
351 human health.

352 Recently, the scientific discussion within the field of microplastics research as well as the
353 debate in public media has increasingly focused on the human health implications of
354 microplastics in food products and beverages. There is, however, a big discrepancy between
355 the focus and magnitude of the discussion and scientific studies. The studies that have so far
356 been published merely show the presence of plastic particles in different environments,
357 organisms and products intended for human consumption and are in most cases not aimed at
358 or designed for evaluating hazards to humans. Microplastics in seafood can be used to
359 exemplify this discrepancy: the public attention lies almost exclusively on the health
360 implications for humans who consume these organisms, while the scientific focus is mostly
361 on the effects that this may have on the organisms themselves. While the latter has a stronger
362 scientific background (Lu et al., 2016; Mattsson et al., 2015; Paul-Pont et al., 2016; Rochman
363 et al., 2013; von Moos et al., 2012; Wright et al., 2013), it has not gained the same traction. Of
364 course, it is important to address the broader implications that the presence of microplastics in
365 aquatic organisms may have, also including humans, but we need to be careful with
366 speculations that extrapolate far beyond the scientific findings. There seems to be a trend for
367 overhasty conclusions on microplastics in food products, which are quickly picked up by the
368 public media and shape a distorted picture of the issue of microplastics in comparison to the
369 scientific literature. Plastic pollution gains a lot of public attention which attenuates the need for
370 clear communication and transparency even further. Natural scientists play an important role in
371 identifying and describing problematic changes in the environment, or in terms of human health. We
372 can then convey our collective knowledge to other actors in society in order to address and mitigate
373 environmental problems. As scientists, we have a moral obligation to present the current state of
374 knowledge as correctly and accurately as possible.

375 Furthermore, there is an imbalance in the discussion on human exposure to microplastics as it
376 is rarely put into perspective via comparisons with other exposure routes. As shown above,
377 most of the exposures are likely to stem from our consumption and everyday use of plastic
378 materials and products. The current discourse seems to be a symptom of a systematic failure
379 to see the overall picture related to plastic consumption resulting in a skewed risk perception
380 where an individual may become outraged when finding out that there are plastic particles in
381 fish but not reflect on the plastic container that the fish reaches our house in. There is also a
382 palpable difference in the current debate concerning the threat of microplastics, versus the

383 hazards associated with plastic materials and associated chemicals. Plastic pollution is well
384 described and known to be associated with large socioeconomic costs and adverse
385 environmental effects. Because it is tangible and easily communicated, it has helped spark
386 several solution-based initiatives and important discussions on issues related to environmental
387 pollution. Concerning microplastics, the current knowledge on adverse effects is marginal
388 compared to the knowledgebase of chemical effects, which spans decades, generations and
389 populations. Even so, the effects of chemical pollutants are often discussed to a much lesser
390 extent in the public. And ironically, while there is widespread concern for the effects of
391 microplastics, there is comparatively little debate addressing our current large scale usage of
392 plastic materials, their impacts in the environment and for human health, and their role in
393 consumerism and economy.

394 To avoid this inconsistency, it is important that we take a more holistic viewpoint on plastics
395 and human health risks. It is possible that the fibers in the tap water may affect human health
396 and it is alarming that plastic fibers and particles are found almost everywhere, but it is
397 important to put this into the perspective relating to our own consumption. This will feed into
398 polymer research and development, and facilitate solutions and the necessary changes in
399 waste management, chemical legislation and our current overconsumption of plastic products.
400 These three important factors are incidentally also among the main root causes of plastic
401 pollution in the environment.

402 Thus, we urge for a more nuanced debate within the scientific community. In order to achieve
403 that it is important to study and evaluate potential human health effects but these studies need
404 to take exposure through our general consumption of plastic materials into account. The
405 relative importance of different exposure pathways needs to be considered and future studies
406 should also include the environmental contamination of various consumer products. The
407 interpretation of related findings however needs to maintain a broad perspective. We also
408 emphasize that it is important that the debate moving forward incorporates the bigger
409 perspectives concerning global production and usage of plastics and chemicals to a greater
410 extent.

411

412 **Acknowledgement**

413 For financial support of Therese M. Karlsson we thank the Swedish Environmental Research
414 Council Formas 2014-1146, and the Interreg project Clean Coastline. We furthermore would

415 like to thank the Technical University of Denmark for funding through the DTU-EPFL
416 collaborative PhD grant of Sinja Rist as well as the Otto Mønstedts Fond for supporting her
417 external research stay at Sven Lovén Centre for Marine Sciences. Bethanie Carney Almroth
418 was supported by the Swedish Environmental Research Council Formas 2016-00895. We
419 would also like to acknowledge the KVA grant for Internationalization and Scientific
420 Renewal at the Sven Lovén Centre for Marine Sciences for their support to Nanna B.
421 Hartmann in the project Microplastics in Marine Bivalves. The funding sources had no
422 involvement in study design, collection and interpretation of data or writing of the report.
423

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