A look at microplastic in our food and water supply.

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Abstract

Microplastics are present in the air, water, and soil, and they infiltrate the food we eat every day. The growing level of microplastics in marine ecosystems, water, and food sources are gaining more attention and could become a threat to food security for humans, not just a threat to marine life. Since microplastic plastics are small enough to escape filtration, humans may be consuming 39,000 to 52,000 microplastic particles a year (CIEL, 2019). However, the health impacts of inadvertently consuming plastic are still largely unknown. This paper explores two questions: First, where is microplastic present in food and water supplies. Second, what studies have linked health concerns and the microplastics found in food and water supplies? By looking at these areas, the health impacts for humans are discussed.

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Introduction

A dead whale was found in the Philippines with “88 pounds of plastic bags and other disposable plastic products in its stomach” (Victor, 2019). Sperm whales have washed up on the shores of Italy and Indonesia with “drinking cups, plastic bags, plastic bottles, flip-flops and string” in their stomachs (Mezzofiore, 2019). A baby dugong[1] died with "eight pieces of waste plastic bags packed together" as well as "small plastic fragments" in her intestine, leading to gastritis and a blood infection (Lewis, 2019). The story received much attention and outcry, resulting in the Thailand Ministry of Public Health issuing a statement that it will immediately begin implementing a plan to reduce sea waste. While these stories make for public interest news, outside of choking hazards, little is known about how these macroplastics can harm humans.

Plastic production has increased significantly over the last six decades from around 0.5 million metric tons in 1950 to over 348 million metric tons in 2017 (CEIL, 2019). The environmental costs of this exponential growth of plastic are extensive. Macroplastics pollute our oceans and lakes and fill landfills. Microplastics are present in the air, water, and soil. Microbeads have been banned in many countries. Microplastic contamination in tap water has led to calls from scientists for “urgent research on the implications for health” (Bergmann, 2017; Barboza, 2018). We know macroplastics are killing marine life, but what about humans?

Research is still emerging and the health risks are still being studied, however there is no debating that plastic is in food and water since it can be observed and measured. The general consensus from the scientific community is macroplastics break down into microplastics through weathering (wave movement, wind abrasion, and ultraviolet radiation) and are either consumed by animals eventually eaten by humans or enter into the water supply when they escape filtration.

Plastics can enter our food supply directly and indirectly. In my research I will investigate two questions: First, where is plastic entering our food supply? While an emphasis is on waste management techniques of plastic, I also explore the potential for plastics to enter through direct

[1] Dugongs are related to manatees, with similar physical and social characteristics.

consumption of water and in storage. Secondly, what studies have linked health concerns and the plastics in our food supply? While there is limited research showing ingesting plastic has negative impacts on health, there are a number of studies which identify links between plastic additives and health concerns, as well as microplastic negative impacts on marine and terrestrial species. Drawing from these findings, I will discuss the potential consequences and risks of humans ingesting plastics on a daily basis.

Background

Plastics are used in a number of products that help advance medical technologies, generate renewable energy through solar panels and wind turbines, and lower fuel use through lighter transport vehicles. Many of these advancements with plastics could help in the fight against climate change. However, single-use plastic does not fight climate change, instead it simply adds pollution to our planet.

Accumulation of plastic in marine and terrestrial environments is a relatively new occurrence for the Earth, as mass plastic manufacturing began in the 1950s. An estimated 8.3 billion metric tons of plastic that has been produced since 1950, and almost 75% of it has become plastic waste (Geyer, 2017). 6.3 billion metric tons of plastic sits in our oceans and landfills and is now being found in food and water sources. Just a decade ago, the highest densities of plastics were associated with urban centers in the Northern Hemisphere and the "Great Pacific Garbage Patch" between Hawaii and California (Barnes, 2009). However, recent studies have found that plastic is now being found in the deep sea (Jamieson, et al., 2019). While there is not enough scientific data to predict how ingesting plastic is affecting overall health, the scientific community is beginning to identify health concerns in animals and humans (Barboza, 2018; Rustagi, 2011; Smith, 2018).

There are two ways plastics enter our food, primary sources and secondary sources. Primary microplastics are those materials manufactured to be their current size, these include microbeads and resin pellets created for manufacturing. Microbeads are intentionally microscopic, found in cleaning and beauty supplies, and are often small enough to escape filtration. Secondary plastics come from fragmentation due to the weathering of larger plastic, or macroplastics. When macroplastics enter the ocean in the form of a plastic bag or plastic bottle, they degrade, and yet remain in the water. The degraded plastic eventually will breakdown sufficiently to become microplastics (Cox, 2019). Small in size, these microplastic can be eaten marine animals when mistaken for food and cause health concerns from blockages in intestines.

Plastics have the potential to be ingested throughout the product lifecycle starting with the extraction and transport of the fossil fuels used to make the plastic and through the refining and manufacturing processes. However, it is not just the manufacturing of plastics that causes concern, as contact with plastic through consumer use and waste management also have potential health impacts. Figure 1 (in the appendix) displays the lifecycle of plastic and potential health impacts at each stage.

Microplastics and Microbeads

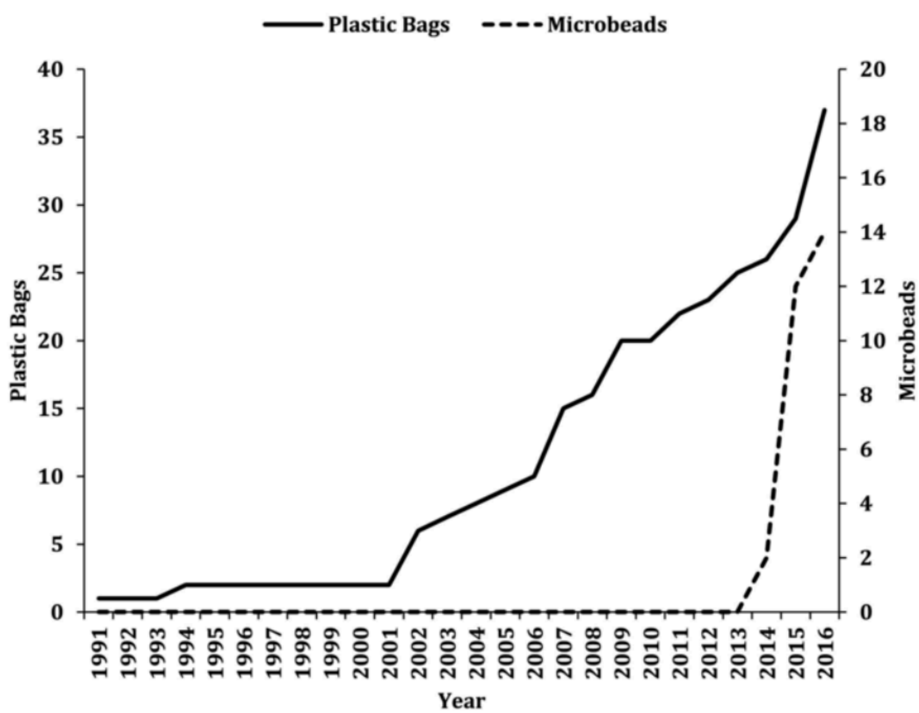
Microplastic fragments includes microbeads and small particles broken down of larger plastic containers, bottles, and trash. In the aquatic environment, marine mammals, birds, and fish cannot differentiate microplastics from real food. A microbead dimension is less than one millimeter, and as most wastewater facilities cannot filter microbeads, they have been found downstream in oceans, bays, lakes, and rivers. While 98% of microplastics are removed from most modern water treatment facilities, in one study 65 million microplastic particles from one water treatment site were still being released into waterways each day (Murphy et. al, 2016).

Microbeads are manufactured and placed in products with the intention of being washed away after being used. However, this means that they are "so small most wastewater treatment plant technology is not capable of removing" 100% of them from the waste stream (Murphy et. al., 2016). Since most microbeads do not biodegrade, they are discharged into nearby waters. (Barboza, 2018). Concerns with microbeads include the toxicity level of the particles and that other toxins in water "such as polychlorinated biphenyls, are attracted to microbeads" (Copeland, 2015).

Microbeads bans are gaining ground across the world, with a "rapid proliferation in policies to reduce the use of microbeads" (Xanthos, and Walker, 2016, Figure 2). In 2015, Austria, Belgium, Sweden, Netherlands, and Luxembourg, through the Council of the European Union

(EU), requested a ban of microbeads within the EU (Kentin and Kaarto, 2018). Canada became the first country to list microbeads as a "toxic substance" (Treasury Board of Canada Secretariat, 2019). In 2017, the Microbead-Free Waters Act of 2015, signed by President Barack Obama, went into effect in the United States banning microbeads in rinse-off cosmetics. (McDevitt et. al., 2017).

Figure 2: Timing and Number of Plastic Bag and Microbeads Bans, Internationally.
From Xanthos and Walker, 2017



Marine Animals and Plastic Waste

The Center for International Law (2019) study mentioned earlier in this paper identified impacts of plastics throughout the plastic lifecycle: manufacturing (wellhead to refinery), storage and consumption, and waste management. Plastic cluttering the ocean is one of the more visible aspects of plastic pollution., and causing significant concern for aquatic life. Plastic ingested by blue crabs (Callinectes sapidus) impacts respiratory function, inflammation, and immune system concerns (Johnson, et al, 2011). The Japanese medaka (Oryzias latipes) developed inflammation of the liver (hepatic stress) from eating microplastics (Rochman, 2013). Seabirds have been found with intestinal blockage and toxins in their livers caused by microplastic (Wilcox, 2015).

Although the number of studies have been increasing, the health concerns with marine birds is not new: in 1987, Azzarello and Van Vleet found plastic also caused reproductive failure in seabirds. Smith et. al. (2017) lists numerous other studies which have found links between ingesting microplastics and plastic additives on animal health. Microplastic health concerns are not just for larger animals and seabirds. Zooplankton, which are often food for larger marine animals, have been found with plastic in their digestive systems (Cole, 2013). Not only was microplastic found in the zooplankton, when microscopic amounts of microplastic, just 7.3 µm (nanometers), was present in algae the zooplankton's feeding patterns changed.

Food Storage and Food Waste Leaching Plastic Additives

Plastic in our food and water supply comes from microplastic broken down from macroplastics, however plastic additives have often been the seen as the greatest link to human health concerns. Plastic can take hundreds of years before decaying, however additives are often not chemically-bound to plastic which can cause quicker leakage into the waste management environments (landfills or water). Table 1 provides a partial list of additives in plastics that directly touch food through packaging and their known health impacts. A compressive review of the links between plastic feedstock to cancers, birth defects, developmental issues, and reproductive effects was completed by Rustagi et. al. (2011).

Table 1: From CEIL, 2019: Partial list of plastic additives and their health impact.

Chemical Additive Health	Products in Which They Can Be Found	Health Impact
Acrylonitrile	Drinking cups	Carcinogen

Bisphenol A	Polycarbonate plastics, plastic tableware, lids of glass containers, linings of aluminum cans.	Breast cancer, prostate cancer, endometriosis, heart disease, obesity, diabetes, altered immune system, and effects on reproduction, changes in brain development and behavior in children.
Phthalates	Detergents and food packaging	Harm the reproductive and nervous systems, especially in children before and after birth, asthma or other respiratory conditions.
Styrene (also known as Vinyl Benzene)	“Styrofoam”; Food packaging including cups, plates and sandwich containers	Carcinogen

Additives most frequently found in marine environments include polybrominated diphenyl ethers (PBDE), phthalates, nonylphenols (NP), and bisphenol A (BPA) (Hermabessiere, et. al. 2017). Phthalates and BPA are linked to cancer risks, developmental disorders, reproductive and nervous system health concerns, and known to alter the endocrine system (Talsness, et. al., 2009). Prior to the ban on BPA in baby bottles, Vandenberg (2007), found the levels of BPA in the US population was “orders of magnitude” greater than what would cause harm in laboratory studies on mice. Since the ban, Lehmler (2018) found that BPA alternatives including Bisphenol F, BPF and bisphenol S, are present in most of the US population.

A recent study examined the environmental impacts of three different food takeaway materials: aluminum, expanded polystyrene (EPS / Styrofoam®), and polypropylene (Gallego-Schmid, Alejandro, 2019). The finding presents a challenging dilemma: the least environmentally damaging materials to produce are also the most damaging materials for waste management and human health. EPS was found to cause the least environmental damage in its production process, however its health impacts and waste management issues greatly off-set the lower manufacturing footprint. Aluminum, while causing a greater manufacturing environmental footprint due to higher energy needs than EPS, has lower potential health impacts[2]. Aluminum is

[2] The study did emphasize greater recycling levels would lower the environmental footprint of aluminum.

highly recyclable, and while it takes more energy to produce, it produces far less permanent waste and does not break down into microplastics. Furthermore, EPS is a known carcinogen. The balance of health concerned caused by environmental damage and health impacts from ingestion are policy and lifecycle issues that need to be addressed.

Plastic Waste and Water Supplies

While the exact level of plastic toxicity that can directly cause health concerns in humans is uncertain, researchers are learning more about where plastic comes from in the food chain, and it is not just marine animals ingesting plastic: plastic is in the world's water supplies.

The majority of consumed microplastics are in water supplies, with approximately 1700 microplastic particles, between 10 micrometers and 1 millimeter in size, in one person's average weekly water supply (CEIL, 2019). Fracking, negligent disposal of manufacturing waste, or improper transport can all lead to microplastics entering the water supply. During consumer use of products like washing pods, plastic is designed to be washed down the drain during use. Poor quality microfibers wash down the drain in the laundry. At the end of the plastic lifecycle, improperly disposed of plastic pollutes waters and decomposes into harmful fragments for marine life and remains unfiltered in drinking water sources. There are ample opportunities for plastic to enter the water supply and then join the food supply after being consumed by plants and animals.

A study on water quality in the Great Lakes, a source of water for cities in the Midwest, found an average of 43,000 microplastic particles/km^2, with one area containing over 466,000 particles/km^2 (Eriksen, 2013). Many microplastic particles were suspected to be microbeads from consumer products. The study created momentum to restore the Great Lakes and eventually led to the ban on microplastics in the US.

With plastic in the water supply, any food products coming from those waters has the potential to be contaminated with plastic as well. According to the Food and Agriculture Organization of the

United Nations, of the twenty-five fish species of commercial significance, 11 were found to contain microplastics (FAO, 2016; Lusher, 2017). This accounts for 41% of fish production in the world. This number is just a fraction of the entire population of marine animals who have been found to ingest plastic in their natural habitat: 220 of 800 species of marine animals have been found to consume microplastic trash (Smith, 2018).

The potential to eat microplastics continues when eating other products from the sea and consuming products using lake and sea water. One study looked at 159 water samples and 12 sea salt samples from water sources around the globe (Kosuth et.al, 2018). Sea salt averaged 212 particles/kg. 81% of the 159 tap water samples contained microplastic particles. Tap water samples from the USA had the highest concentration of plastic, with 9.24 particles per liter on average. Table 2 shows the levels of plastic found in all the water samples.

Table 2: Numbers of Particles per Liter of Water, from Kosuth, et. al 2018

		Particles Per Liter			
COUNTRY/SOURCE	**# of SAMPLES**	**MIN. #**	**MAX. #**	**MEAN**	**STD. DEV.**
Cuba	1	---	---	7.17	---
Ecuador	24	0	9.04	4.02	3.2
England	3	3.66	13	7.73	4.76
France	1	---	---	1.82	---
Germany	2	0	1.82	0.91	1.29
India	17	0	20	6.24	6.41
Indonesia	21	0	10.8	3.23	3.48
Ireland	1	---	---	1.83	---
Italy	1	---	---	0	---
Lebanon	16	0	23.3	6.64	6.38
Slovakia	8	0	10.9	3.83	4.47
Switzerland	2	0	5.47	2.74	3.87
Uganda	26	0	12.7	3.92	3.17
USA	33	0	60.9	9.24	11.8
Bottled Water	3	1.78	5.37	3.57	1.79

The same study also looked at microplastics in beer made from water sources from the Great Lakes. On average, the beers were found to contain four particles of plastic per liter, while the worst sample had 14 particles per liter. There was no correlation between water and beer contamination, but less plastic was found in beer than water which indicates plastic may be filtered out in the beer making process. A similar study on beer was completed using 24 German beers, which found a much greater range of plastic particle presence: between 2 to 109 fragments, granules, or fibers per liter of beer (Liebezeit and Liebezeit, 2014). The high variability in German beers and lower counts of particles in American beers may be an area for future research in identifying possible ways to eliminate microplastic particles from water sources and beverages. The average number of particles and standard deviation of microplastics found in beer and salt in the Kosuth study are presented in Figure 3 (appendix).

Microplastic and Soil Health

While most microplastic research has been limited to marine environments, microplastics in the soil is gaining attention. Microplastics in soil has the potential to not only leech into agriculture products, but also to alter the biochemistry of soil (Cat, 2019). While the health concerns for humans is unknown, there is emerging data to show plastics in the soil can impact food production. Microplastics present in soil growing spring onions created alterations to "plant biomass, tissue elemental composition, root traits, and soil microbial activities" (Machado, et. al., 2019). Organisms, like earthworms, that contribute directly and indirectly to soil microbial content also have microplastics in their digestive systems (Rillig, et al, 2017; Yuanxiang, et al., 2019). These organisms also may also be consumed at the beginning of the food chain, finding their eventual way into poultry and farmed mammals.

Similar findings to those done on marine animals are emerging as well: polystyrene microplastic caused an intestinal dysfunction in mice (Yuanxiang, 2019). Soil health and plastic contamination is just beginning to be researched, but since soil can hold more microplastics compared to water, it is highly likely that soil and terrestrial animals are consuming plastic.

Discussion on Microplastic Health Impacts in Humans

Given marine life eat microplastics, it is unavoidable that humans also consume to microplastics through seafood. While a number of studies have shown there are health concerns for marine life when plastic is ingested, and a number of studies have shown there are human health concerns related to the chemicals used to make plastics, there is little scientific knowledge to show plastics, when ingested at current amounts, cause harm.

According to the SAPEA (Science Advice for Policy by European Academies), while plastics in our food supply have the potential to harm humans, the level of toxicity needed to cause harm is not currently present in most areas of the world. Like many chemicals, the poison is in the dose. While humans ingest 5 grams of plastic a week, about the size of a US nickel, it is estimated that 90% is inert and immediately disposed of through feces (SAPEA, 2019). Since plastics are predominantly inert when moving through the digestive system quickly, plastic additives may be greatest source of human health concerns. There is no confirmation of extensive risk to human health from the current level of microplastics in the environment. However, with the continued growth of plastic use (and disposal) in our society, it is possible that increased plastic pollution could create the level of toxicity needed to cause harm to humans. While not present in the environment now, high concentrations of microplastics can "induce physical and chemical toxicity… result(ing) in physical injuries, inducing inflammation and stress, or it can result in a blockage of the gastrointestinal tract and a subsequent reduced energy intake or respiration." (SAPEA, 2019)

If plastic does pose only a minimal threat to human health, the environmental damage and consequential impact to health cannot be ignored. Indirect health concerns from ingesting plastics comes from the rising use of plastics in society. First, health concerns caused by the use of fossil fuels in the plastic manufacturing process and health reactions from chemicals used to manufacture plastics is well documented. Second, if plastics have the potential to cause intestinal blockage in animals, what is it doing to the overall marine ecosystem? If zooplankton are being found with microplastic in the digestive system, what is the impact of microplastic on phytoplankton? Phytoplankton plays a vital role in the ocean's ecosystem and provides the same benefit as terrestrial plants: these single-celled organisms absorb carbon dioxide for photosynthesis and release oxygen. If phytoplankton levels decrease significantly because of plastic pollution, the ocean's carbon cycle could slow down. Even if phytoplankton populations remain stable, plastic pollution has the potential to block light from reaching organisms that rely on photosynthesis, and which are needed for the carbon cycle of the ocean.

Conclusions and Continued Research

Research on the impact of ingested plastic on human health is still in its infancy. Scientists from SAPEA do believe plastic can be harmful to health, but found that the tipping point for toxicity has not yet been reached. If future emissions of plastics continue to rise, or the breakdown of macroplastics leads to higher levels of microplastic in the environment, the health and ecological risks may become more pervasive. There is tremendous opportunity for research in the health and plastics field including looking at soil and the impact plastic has on crop productivity, toxicity levels of plastic needed to cause harm, manufacturing and filtration processes, and the emergence of nanoplastics in ecosystems.

Microplastics in our soil have not been studied to the extent of microplastics in ocean and could cause greater harm to the food supply than microplastics in oceans. Plastic additives can be leached into the soil and microplastics can alter the composition of the soil, all with the potential to reduce soil productivity and root systems. There is a large research gap for the impact plastic has on soil and agriculture. Continued research is needed to identify the levels of plastic toxicity needed to cause harm. While human health may not be of immediate concern, the potential is great. If marine life and seabirds are suffering from poor respiratory function, immune system concerns, inflammation of the liver, and intestinal blockage, is the human race immune to the same consequences? Manufacturing and filtration processes for food and water should be looked at to identify current and future technologies that can help decrease levels of microplastic. As found in the study on Great Lakes beer, if beer can have lower levels of plastic than the water it is made with, is the reduction in the manufacturing or because of saturation of other ingredients? Potential filtration processes may be duplicated for other beverages[3]. Nano-scale plastic (< 1 μm) is just beginning to be discussed and researched. Nanoplastics may have the ability to move through tissue rather than remaining outside of cells, with the potential to introduce more plastic particles into living systems. The frequency and impact of nanoplastics is ripe for investigation.

Considering the rise of plastics in the world and the continued efforts to recycle plastic, plastic pollution-related health concerns will continue to arise from all phases of the plastic lifecycle, especially from plastic waste and plastic production. While further research should identify environmentally friendly and low health risk packaging, the sheer amount of plastic on the Earth has the potential to create a toxic environment. Plastic bottles, plastic film from shopping bags, and other plastic packaging have the shortest lifespan for use, and consequently the greatest level of waste (Geyer, 2017). Future policy work and research should identify incentives and regulations that can reduce short-life, single-use plastic production. In doing so, both the amount

[3] A number of steps in the brewing process are designed to remove grain and yeast solids from the final beer, which could remove microplastic as well.

of materials used and plastic discarded could decrease enough to limit the plastic toxicity of ecosystems.

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Appendix

Figure 1: Health concerns throughout the plastic lifecycle.
From CEIL, 2019: Humans are exposed to a large variety of toxic chemicals and microplastics through inhalation, ingestion, and direct skin contact, all along the plastic lifecycle.

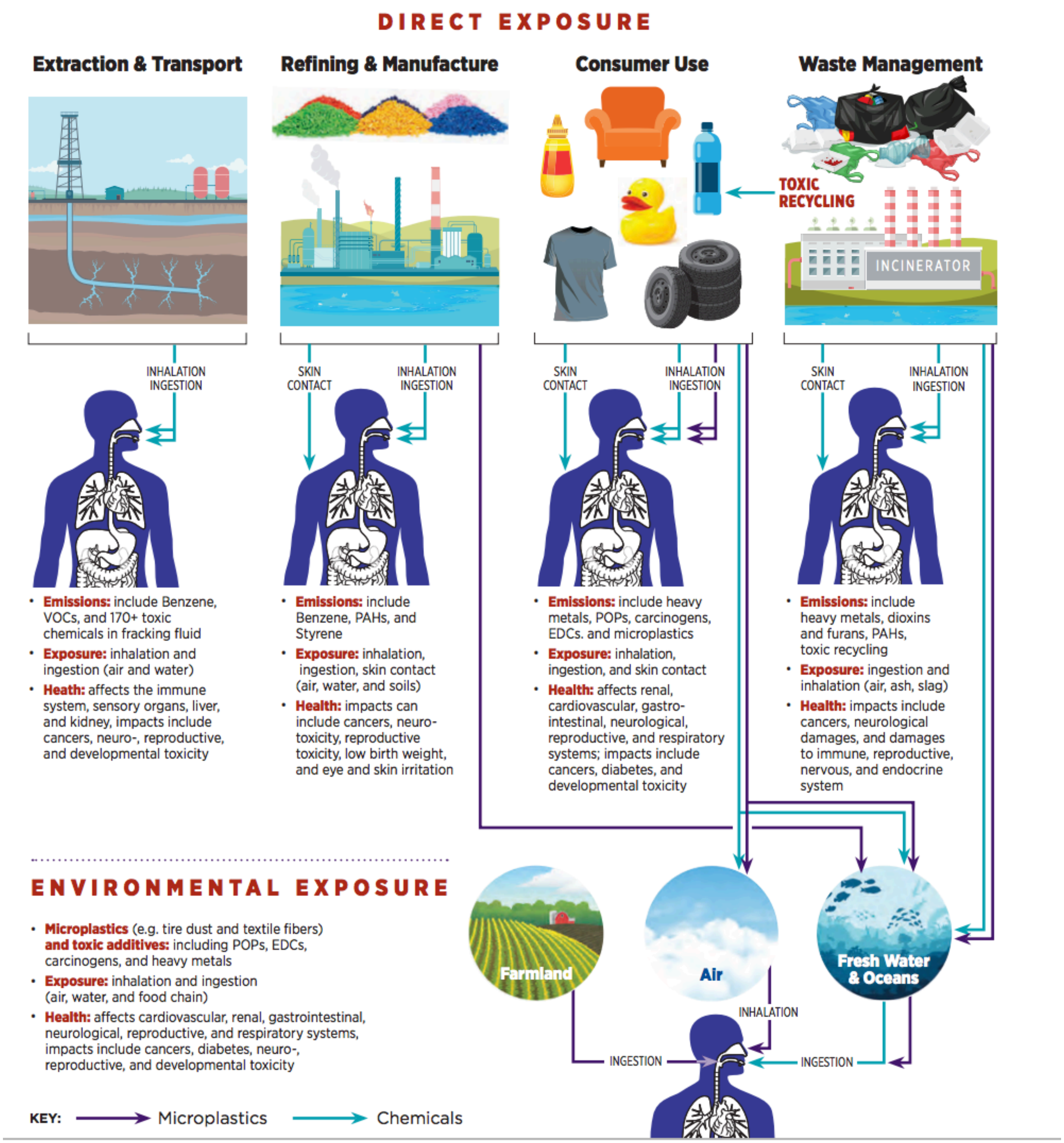

Figure 3: Water, Beer, and Sea Salt Contamination Study Average and Standard Deviations, Kosuth, et. al 2018