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The Impact of Microplastics on Health
By Ronald Smith MD

Introduction

One only has to do a casual internet search to find thousands of research articles about the negative impact of microplastics (MPs) on the environment. Indeed, a 2022 study found 6608 research articles published since 2006.[1] The science is expanding rapidly, reflecting the alarm of the scientific community about the biologic impacts that are unfolding. Still, there are huge gaps in our knowledge of the effects of MPs on our ecosystems and, indeed on our own bodies.

As a physician who practiced medicine for several decades, I am deeply concerned about the danger that microplastics pose to all forms of life, especially human. I believe that the threat of plastics including microplastics is analogous to our late and slow response to climate change, now well recognized as perhaps the most serious threat ever to exist to the health of our planet. I believe that the impact of plastics, for all the wonderful things that they do for us, may prove to be even worse.

In this brief, I will show the basic elements of what we know, and we do know a lot. However, it is a fact that our knowledge is incomplete. When we are uncertain about the safety of a practice or procedure in the field of medicine, we are *obligated* to proceed with caution. It is no different with decision making regarding Planning and Development in a County or State office; when we have science-based concerns about impacts and potential adverse outcomes of requested development, it is important and reasonable to wait until we have more answers to approve such practices.

What are Microplastics?

Microplastics (MPs) are defined as synthetic solid particles or polymeric matrices, with regular or irregular shape and with size ranging from 1 μm to 5 mm, of either primary or secondary manufacturing origin, which are insoluble in water. Nanoplastics (NPs), less than 1 μm in size

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[1] Jenkins et al., "Current State of Microplastic Pollution Research Data: Trends in Availability and Sources of Open Data."

are also coming under scrutiny.[2] MPs can be primary such as from cosmetics or contributed from clothing, but are more commonly attributed to breakdown products from plastic consumer and industrial products. By 2050 the total mass of plastic manufactured is expected to reach 33 billion tons with annual expected plastic waste to the environment reaching 67.8 million metric tons. 80% of marine microplastic is actually terrestrial in origin, but there are increasing direct uses of plastics in marine industry, especially in aquaculture. The fishing industry (including aquaculture) and coastal tourism contribute 18% of plastic marine debris (PMD). Of the types of PMD, approximately 50% is lighter in density than water, allowing it to float, the denser types sinking to the bottom.

There are several mechanisms for the breakdown of plastics into MPs and NPs.

- Fragmentation - In the marine environment, plastic fragmentation is induced by mechanical stress, e.g. due to wave action. Furthermore, fragmentation is accelerated through weathering and potential biological degradation, as these make plastics more brittle. Fragmentation leads to a change in PMD size distribution, and while fragmentation does not remove PMD from the environment, it can accelerate physicochemical and biochemical reactions at the PMD surface because the surface to volume ratio of smaller particles is higher. Progressive PMD fragmentation also leads to the formation of particle sizes <1 μm, i.e. nanoplastics, through multiple mechanisms.
- Photooxidation (i.e. exposure to sunlight) of plastics comprises free-radical reactions and chain scission initiated by (solar) UV radiation. The basic mechanisms and photochemical reactions are well known including differences in the degradation pathway of different polymers. Assuming that the residence time of PMD at the ocean surface could be in the order of years (half-life estimates of 220-380 years), and/or that PMD might oscillate in the water column and periodically re-surfaces, preliminary results show that photooxidation may indeed account for a substantial transformation of PMD into smaller chain scission products and nanoplastics. Regarding aquaculture plastics, while submerged a substantial portion of their use, these plastics are exposed during part of their use cycle, during idle storage, and when displaced in the environment, usage is planned for 20+ years.
- Plastic biodegradation entails the assimilation and mineralization of plastic-derived carbon mediated by microorganisms, leading to its eventual removal from the natural environment. As such, plastic biodegradation can proceed as a two-step process where physicochemical processes initially break down the polymer matrix into more labile daughter products that may be degraded further through microbes. Both mechanical forces, and probably more importantly, photooxidation are known to degrade polymers. It seems very likely that a reduction in particle size leads to an increase in microbial degradation velocity because of the increase in surface to volume ratio when the particle becomes smaller.[3]

Where are Microplastics found?

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[2] Frias and Nash, "Microplastics: Finding a Consensus on the Definition."

[3] Wayman and Niemann, "The Fate of Plastic in the Ocean Environment – a Minireview."

It is well accepted fact that MPs are universally distributed throughout our planet including to the furthest extent of our oceans, and that they contaminate virtually all living things, from the small organisms such as the planktonic crustacean, *Daphnia*[4], to the gargantuan grey whale[5]. Benthopelagic species, that is those found in the banks of rivers and estuaries are among the most heavily contaminated by MPs[6]. Even more significant is the effect of MPs on the basic substrates on which the smallest organisms survive, the sedimentary microbial ecosystem. Research has shown that MPs in the form of polyvinyl chloride (PVC), polyethylene (PE), polyurethane foam (PUF), and polylactic acid (PLA) adversely alter sedimental microbial community composition and nitrogen cycling processes.[7] MPs and NPs are absorbed into the basic elements of the food chain including animal and plant material with documented negative effects on growth.[8]

Subsequently, these bits of plastic debris make their way into the tissues of the earth's organisms and are concentrated by mechanisms of bioaccumulation and biomagnification. Other mechanism of absorption into humans and animals include inhalation and direct absorption through the skin. As the focus of this enquiry is aquaculture, emphasis is given to the presence of MPs in seafood with ingestion as the expected mechanism of entry.

Involvement of seafood by microplastics

Experts conclude that humans are at risk from contamination of seafood by MPs:

"As a result of widespread contamination, microplastics are ingested by many species of wildlife including fish and shellfish. Because microplastics are associated with chemicals from manufacturing and that sorb from the surrounding environment, there is concern regarding physical and chemical toxicity. Evidence regarding microplastic toxicity and epidemiology is emerging."[9]

"Fifty studies were included in the systematic review and 19 in the meta-analysis. Evidence was available on four phyla: mollusks, crustaceans, fish, and echinodermata. The majority of studies identified MP contamination in seafood. This is the first systematic review, to our knowledge, to assess and quantify MP contamination of seafood and human uptake from its consumption,

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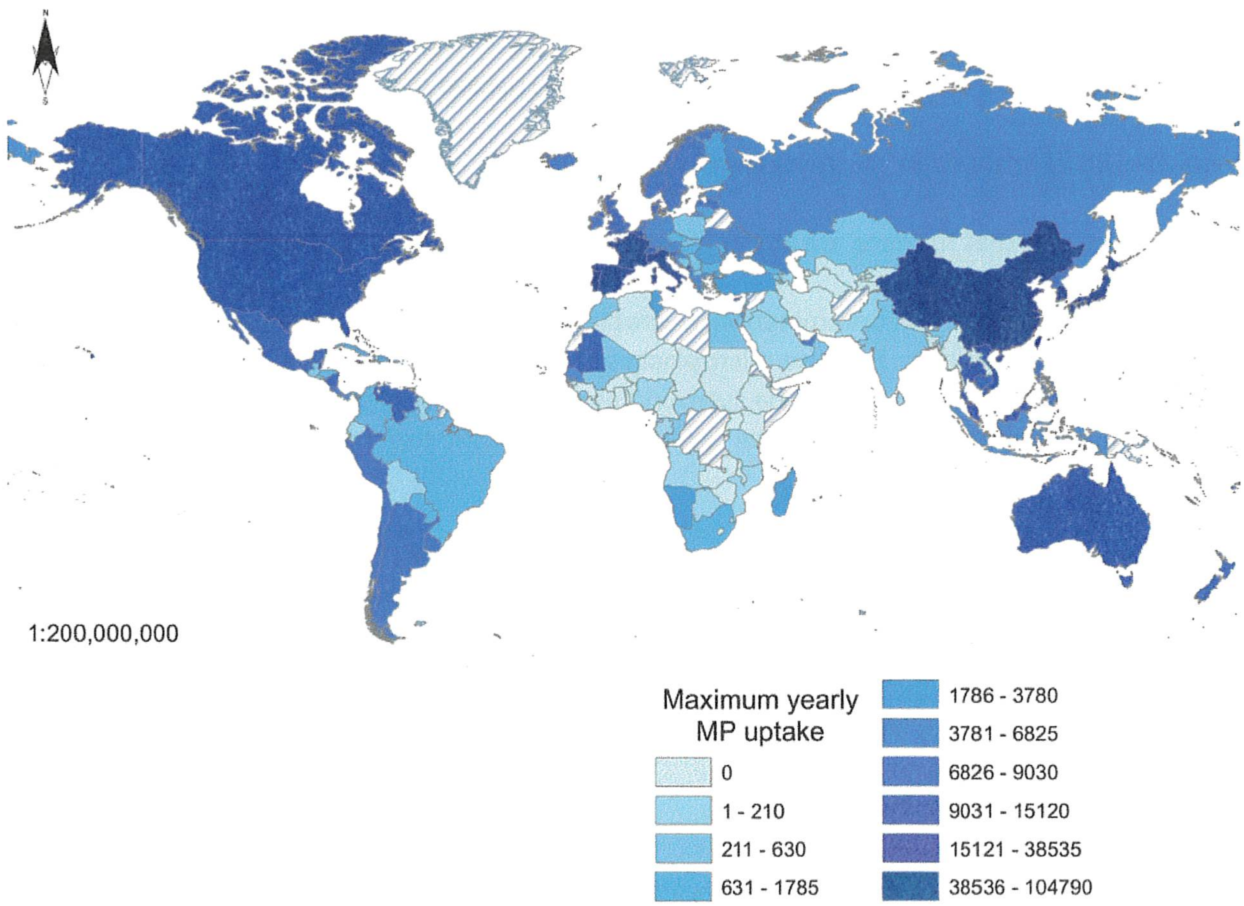
[4] Mattsson et al., "Brain Damage and Behavioural Disorders in Fish Induced by Plastic Nanoparticles Delivered through the Food Chain."
[5] Torres et al., "Zoop to Poop: Assessment of Microparticle Loads in Gray Whale Zooplankton Prey and Fecal Matter Reveal High Daily Consumption Rates."
[6] Haque et al., "Assessment of Microplastics Pollution in Aquatic Species (Fish, Crab, and Snail), Water, and Sediment from the Buriganga River, Bangladesh: An Ecological Risk Appraisals."
[7] Seeley et al., "Microplastics Affect Sedimentary Microbial Communities and Nitrogen Cycling."
[8] Esterhuizen and Kim, "Effects of Polypropylene, Polyvinyl Chloride, Polyethylene Terephthalate, Polyurethane, High-Density Polyethylene, and Polystyrene Microplastic on Nelumbo Nucifera (Lotus) in Water and Sediment."
[9] Smith et al., "Microplastics in Seafood and the Implications for Human Health."

suggesting that action must be considered in order to reduce human exposure via such consumption."[10]

"This research compared numbers of microplastics in three species of farmed and wild shellfish collected near Vancouver Island, BC. Species included were blue mussel (Mytilus edulis), Manila clam (Venerupis philippinarum), and Pacific oyster (Crassostrea gigas). This research indicates microplastics are present in three commonly consumed shellfish species near Vancouver Island and presents a possible vector for contaminant transfer to humans." Farmed species of mussels and oysters contained higher levels of MPs than wild stocks.[11]

There is great concern worldwide about plastic contamination of mollusks used as food sources by humans. In a recent meta-analysis the most microplastic (MP) contaminated areas in the world were Asia and ***North America***. The map below shows ingestion levels of MPs in humans from consumption of mollusks.



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[10] Danopoulos et al., "Microplastic Contamination of Seafood Intended for Human Consumption."

[11] Murphy, "A Comparison of Microplastics in Farmed and Wild Shellfish near Vancouver Island and Potential Implications for Contaminant Transfer to Humans."

So, it well established that MPs are found throughout our environment and in our food, including that which comes from our oceans, and that commercially grown foodstuffs generally have a higher likelihood of containing MPs.

Does science tell us that humans incorporate MPs into our tissues?

Although research into human involvement by plastics contamination is early, MPs have been demonstrated in a wide range of human tissues by scientific studies:

- "researchers collaborated with Diego Mastroeni, Ph.D., to obtain samples from a large repository of brain and body tissues that was established to study neurodegenerative diseases, such as Alzheimer's. The 47 samples were taken from **lungs, liver, spleen and kidneys** — four organs likely to be exposed to, filter or collect microplastics. The method allows the researchers to detect dozens of types of plastic components within human tissues, including polycarbonate (PC), polyethylene terephthalate (PET) and polyethylene (PE). When paired with a previously developed mass spectrometry assay, plastic contamination was detected in every sample. Bisphenol A (BPA), still used in many food containers despite health concerns, was found in all 47 human samples."[12]
- "human **breastmilk** samples collected from 34 women were analysed by Raman Microspectroscopy, and, for the first time, MP contamination was found in 26 out of 34 samples. The detected microparticles were classified according to their shape, colour, dimensions, and chemical composition. The most abundant MPs were composed of polyethylene, polyvinyl chloride, and polypropylene, with sizes ranging from 2 to 12 µm.[13]
- "For the first time, by means of Raman Microspectroscopy, 12 MP fragments were isolated in four human **placentas**. Potentially, MPs, and in general microparticles, may alter several cellular regulating pathways in placenta, such as immunity mechanisms during pregnancy, growth-factor signalling during and after implantation, functions of atypical chemokine receptors governing maternal-foetal communication, signalling between the embryo and the uterus, and trafficking of uterine dendritic cells, natural killer cells, T cells and macrophages during normal pregnancy. All these effects may lead to adverse pregnancy outcomes including preeclampsia and fetal growth restriction."[14]
- "Airborne microplastics (MPs) have been sampled globally, and their concentration is known to increase in areas of high human population and activity, especially indoors. This study analyzed digested human **lung** tissue samples (n = 13) using µFTIR spectroscopy (size limitation of 3 µm) to detect and characterise any MPs present. The MP levels within tissue samples were significantly higher than those identified within combined procedural/laboratory blanks (n = 9 MPs, with a mean ± SD of 0.53 ± 1.07, p = 0.001). Of the MPs detected, 12 polymer types were identified with polypropylene PP

[12] "Microplastics Found in Every Human Tissue Studied."
[13] Ragusa et al., "Raman Microspectroscopy Detection and Characterisation of Microplastics in Human Breastmilk."
[14] Ragusa et al., "Plasticenta: First Evidence of Microplastics in Human Placenta."

(23%), polyethylene terephthalate, PET (18%) and resin (15%) the most abundant. These results support inhalation as a route of exposure for environmental MPs."[15]

- "Four high production volume polymers applied in plastic were identified and quantified for the first time in **blood**. Polyethylene terephthalate, polyethylene and polymers of styrene (a sum parameter of polystyrene, expanded polystyrene, acetonitrile butadiene styrene etc.) were the most widely encountered, followed by poly(methyl methacrylate)."[16]
- "The results showed that MPs were detected in both **testis and semen**, with an average abundance of 0.23 ± 0.45 particles/mL in semen and 11.60 ± 15.52 particles/g in testis. Microplastics in the testis were composed of polystyrene (PS) with 67.7 %, while polyethylene (PE) and polyvinyl chloride (PVC) were the predominant polymers in semen."[17]
- Animal studies in mice demonstrate that MPs can cross the barrier between the blood and **brain**[18], penetrating neural tissues, and, in chickens, that NPs in neural tissues cause extensive **congenital malformations.**[19] This raises concern that similar outcomes such as birth defects could occur in humans and warrants further research.
- Studies of human stools have shown presence of MPs with average of 20 particles per 10 grams of stool from inadvertent ingestion. 9 plastic types were detected, with polypropylene and polyethylene terephthalate being the most abundant.[20]

What components of plastics are of concern to scientists?

To understand the health effects on plants and animals, including humans, one must first understand the chemical and physical make-up of plastics. What are they made of and what has to be added to them to make them functional in our practical world? Why do they negatively impact living things?

We live in an age so defined by plastics that some experts have started calling our time the "Plasticene Era". The growth of plastics over the last 70 years has resulted in them being prevalent throughout our world, highlighting the very practical nature of the material. One of the reasons that plastic is so useful is because of the many different forms and consistencies that have been developed for its varied use. Plastic is modified by additives that affect its rigidity, surface qualities, color, and resiliency.

These intentionally added chemicals include inert or reinforcing fillers, plasticizers, antioxidants, UV stabilizers, lubricants, dyes and flame-retardants.

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[15] Jenner et al., "Detection of Microplastics in Human Lung Tissue Using MFTIR Spectroscopy."
[16] Leslie et al., "Discovery and Quantification of Plastic Particle Pollution in Human Blood."
[17] Zhao et al., "Detection and Characterization of Microplastics in the Human Testis and Semen."
[18] Kopatz et al., "Micro- and Nanoplastics Breach the Blood–Brain Barrier (BBB): Biomolecular Corona's Role Revealed."
[19] Wang et al., "Nanoplastics Causes Extensive Congenital Malformations during Embryonic Development by Passively Targeting Neural Crest Cells."
[20] Schwabl et al., "Detection of Various Microplastics in Human Stool."

- Fillers include clays, silica, glass, chalk, talc, asbestos, alumina, rutile, carbon black, and carbon nanotubes.
- Plasticizers are complex chemical products that increase their mobility, workability or distensibility.
- Stabilizers have the function of preventing the thermal decomposition during the processing, as well as the oxidation and the consequent breaking of the polymeric chains (using phenols and aromatic amines). They mainly consist of organic or inorganic cadmium, barium, or lead salts.
- Soluble or insoluble dyes are organic or inorganic substances in the form of fine powders that give the polymer the desired color; the soluble dyes maintain the transparency of the plastic, while the insoluble ones (pigments) cover it to make it opaque. Many inorganic pigments contain heavy metals, while organic pigments include various chromophoric families like azo pigments, phthalocyanine pigments, anthraquinone chromophores, and various other chromophores.
- Lubricants and anti-adhesives are substances that facilitate the processing of plastic materials, improving their flow characteristics. They consist of calcium or magnesium stearates.
- Flame retardants have the function of cooling or protecting a material in the event of a fire by preventing the oxidation of flammable gases or by forming a layer of ash. They are products that contain, for example, chlorine and bromine, which release by the action of the flame; phosphorus, which favours the transformation into coal; and aluminium hydroxide.

Many of these chemicals are classified as dangerous by governments, but are generally allowed in the manufacture of plastics. The toxicity of a substance is its ability to cause harmful effects. These effects can strike a single cell, a group of cells, an organ system, or the entire body. Chemicals that are considered most harmful are those that cause cancer, mutations to DNA, have toxic reproductive effects, are recalcitrant into the environment, are capable of building up in the food chain or bodies, and other harmful properties, such as disrupting hormones.

Of major concern among these additives is what are termed Endocrine-disrupting chemicals (EDCs)., These are substances that are exogenous to the human or animal organism, have hormonal activity that alters the homeostasis of the endocrine system. These compounds interfere with the development of the endocrine system and affect the functioning of organs that respond to hormonal signals. The endocrinal and reproductive effects of endocrine disruptors may be a consequence of their ability to: (a) mimic natural hormones, (b) antagonize their action, (c) alter their pattern of synthesis and metabolism, or (d) modify the expressions of specific receptors.

Bisphenol A (BPA), phthalates, as well as some of the brominated flame retardants, that are used to make household products and food packaging, have been proven to be endocrine disruptors that can damage human health if ingested or inhaled.

Additional details about EDCs:

- BPA-based polycarbonate plastics are robust and stable because they can endure exposure to high temperatures and sustain high-impact collisions. These characteristics make them valuable as components of safety equipment and food packaging as they withstand heating in microwave ovens. Lack of bonding of BPA within plastic products facilitates leaching, thus reporting a high prevalence in aquatic environments, particularly in landfill leachates. BPA is estrogenic and, recently, the General Court of the EU confirmed that it is a 'substance of serious concern' for its hormonal disrupting properties on the human body.
- Phthalates are compounds that are produced in high quantities; they are the largest class of synthetic chemicals when considering production volume. Their primary use is as plasticizers that are added to basic plastic material to impart specific qualities such as flexibility, pliability, and elasticity. Many phthalates are documented endocrine disruptors, affecting the reproduction of human beings and animals, or of being carcinogenic. Among the more frequently mentioned endocrine disruptors (EDCs), phthalates are of particular concern due to their ubiquity and to the higher levels found in the environment compared to other EDCs.
- Heavy metals are primarily used as additives in polymer products (e.g., colorants, flame-retardants, fillers, and stabilizers) during the production process to improve the properties of plastics. Metals such as Zn, Pb, Cr, Co, Cd and Ti are instead used as inorganic pigment-based colorants; among these, colorants that contain cadmium and lead are used for all kinds of colored polymers, lending a coloration that goes from yellow to red. Toxicity depends on many different factors like dosage, how the subject is exposed to the element, and chemical species, as well as age, sex, genetics and the nutritional state of the exposed subject. A high concentration of heavy metals causes cellular and tissue damage, leading to a variety of adverse effects and human diseases. Though polymers were considered to be inert towards metals in the past, great attention has recently been paid to better understanding the interaction between heavy metals and microplastics. Microplastics, once spread into the environment, with their load of intrinsic (additives) and extrinsic (environmental) heavy metals, can be conveyed into the food web to reach aquatic organisms and then humans.[21] [22] [23]

An important mechanism for the transportation of chemicals and heavy metals into tissues of organisms is the "Trojan Horse" phenomenon. Because microplastics have an affinity for hydrophobic substances (those that fail to mix with water), including many of the additives to plastics as well as other organic pollutants, these substances can absorb to the surfaces of the MPs and NPs, which effectively act as a carrier for the chemical substance. It has been shown that the smaller the MP, the greater the affinity for these hydrophobic toxins to adhere to the particle. Because the toxin is merely adherent, not covalently bonded, when the MP is ingested

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[21] Eales et al., "Human Health Impacts of Exposure to Phthalate Plasticizers: An Overview of Reviews."

[22] Enyoh et al., "Microplastics Exposure Routes and Toxicity Studies to Ecosystems."

[23] Campanale et al., "A Detailed Review Study on Potential Effects of Microplastics and Additives of Concern on Human Health."

by an animal, the toxin can be transferred to the organism with subsequent negative health effects.[24]

Not only have organic pollutants been shown to be concentrated and transferred by this mechanism, more recently heavy metals have also been documented to travel in this fashion. Also demonstrated was the near complete release of heavy metals from MPs from chemicals in the digestive tract allowing absorption.[25]

Not only do MPs have an affinity for metals, it has been shown that biofilm, the organic material that rapidly develops on the surfaces of marine plastic, facilitates metal accumulation to plastics in the aquatic environment, adding to the risk of toxins adhering to those MPs.[26]

What are the health effects of MPs and NPs on animals, especially humans?

Keep in mind that mammalian systems are similar, and understand that while not yet proven within the myriad specific species in our environments, the effects on other higher mammals are very likely similar. In other words, since our biologic systems including chemical and physical pathways are similar to whales it is logical to assume that many of the diseases implicated in the human studies cited here will significantly affect whales and a host of other sea mammals. Scientific studies are increasingly pointing out impact on the health and survival of many disparate species, and ongoing studies are required to understand the extent of the problem that we face.

Diseases in mammals linked to toxins found within and transferred by MPs.

Endocrine – Endocrine-disrupting chemicals (EDCs) have already been discussed as chemical agents included in the manufacture of many plastics and subject to dispersal in the environment and ingestion by animals, with known adverse effects on the hypothalamus, pituitary, thyroid, adrenal, testes, and ovaries. These chemicals are carried by MPs and released into tissues with the smaller NPs having the ability to cross the membranes of the gastrointestinal tract to appear in the blood. They may transfer to all body organs including the liver, kidneys, brain, and lungs, as well as reach the fetus or infant by crossing the placenta and appearing in breast milk. Various EDCs contained or carried by MPs and NPs share structural similarities with specific hormone receptors; hence they interfere with normal hormone receptors, altering the hormonal action of the endocrine glands. The United States Environmental Protection Agency is specifically concerned about the effects of EDCs on the population, and have instituted an EDC Screening Program and is engaged in active, ongoing research into the effect of these chemicals on hormone producing brain tissues such as the hypothalamus, as well as potential impacts on thyroid and reproductive health.[27]

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[24] Katsumiti et al., "Polystyrene Nanoplastics and Microplastics Can Act as Trojan Horse Carriers of Benzo(a)Pyrene to Mussel Hemocytes in Vitro."
[25] Centres, "Microplastics: a trojan horse for metals."
[26] Richard et al., "Biofilm Facilitates Metal Accumulation onto Microplastics in Estuarine Waters."
[27] US EPA, "Endocrine Disruption."

- **Thyroid** - The thyroid gland is an essential endocrine gland responsible for normal brain function, growth, and neurological development of all animals. The thyroid functions under the hypothalamic axis and affects almost every organ in the body, therefore disruption in thyroid homeostasis can be detrimental and will affect the body's overall health status. Plastic additives found in MPs and pollutants such as BPA, Phthalates, and heavy metals like organotin act as thyroid-disruptive chemicals (TDCs). MPs cause thyroid dysfunction and developmental abnormalities once ingested with associated POPs and ED. Phthalate causes a reduction in thyroid weight during childhood exposure and associated with developmental abnormalities and hyperactivity of the thyroid gland. Phthalate metabolites were negatively associated with height, weight, body surface, and height gain in children of both sexes, as well as reduced serum thyroid levels in girls. TDCs are also responsible for the prevalence of subclinical thyroid disease. Thyroid hormone levels in pregnant rats and their progeny are altered by brominated flame retardant chemicals, resulting in obesity, heart illness, early puberty, and insulin resistance in their offspring. [28] [29]
- **Male reproductive system** - The development and regulation of the reproductive system depends on the HPG axis, the neuroendocrine feedback system between the hypothalamus, pituitary, and gonads. Due to the small size of MPs, they can easily enter the organism's reproductive cells, tissues, and organs altering normal morphology, histology, and physiological functions of the male reproductive system. Animal studies have shown that MPs contaminated with phthalate esters [PAEs] accumulated in the testes and altered testicular weight and sperm physiology by reducing sperm number and vitality. Additional findings were those of decreased testosterone and testicular inflammation. BPA, phthalates, and other chemicals including both Cd and Pb adversely alter the HPG axis, harming testicular tissues directly and disrupting spermatogenesis and steroidogenesis.
- **Female reproductive system** – research in animals with EDC exposure has shown adverse effects throughout the female reproductive system including decreased follicles, decreased pregnancies, increased fetal mortality, spontaneous abortion, decreased uterine blood supply, and ovarian fibrosis. Endocrine disrupting plastic additives like PBDEs, BPA, phthalates, organotins, nonylphenols, octylphenols, and biocides like TBT, mercury, arsenic, copper, cadmium, and lead can transfer from pregnant women to the fetal bloodstream through a placental barrier causing neurodevelopmental abnormalities in infants.
- **Hypothalamus** – Hypothalamus is an essential part of the endocrine system that connects the nervous system to the endocrine system and secretes both inhibiting and releasing hormones that signal the pituitary gland to release various important hormones to the whole endocrine system. There is clear evidence of mammalian hypothalamic-pituitary axes disruption caused by MPs and their composite EDCs that alter hormonal balance through feedback mechanisms. Phthalates cause hormonal

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[28] Ullah et al., "A Review of the Endocrine Disrupting Effects of Micro and Nano Plastic and Their Associated Chemicals in Mammals."

[29] Boas et al., "Childhood Exposure to Phthalates."

imbalance by interacting with nuclear receptors, hormonal receptors, signaling pathways, and modulate gene expression linked with reproduction thereby, disrupting the HPG axis that affects fertility.

- **Pituitary** - The pituitary gland is a neuroendocrine organ having an essential role in major physiological functions such as growth, sexual development, metabolism, and stress responses. It maintains a balanced homeostatic condition and is responsible for essential hormone secretion that regulates the thyroid, adrenal gland, gonads, somatic growth, and many other functions. HP axis is vulnerable to a variety of MPs composite EDCs such as BPA, PCBs, PBDEs, PBBs, dichlorodiphenyltrichloroethane [DDT], and TBT. Research into direct effects on the mammalian pituitary gland are limited, but this is within the area of interest of the EPA in their evaluation of human effects of EDCs.
- **Adrenal gland** - The adrenal gland is an essential endocrine gland located on the top of the kidneys and composed of the adrenal cortex and adrenal medulla that release hormones like cortisol, aldosterone, epinephrine, and norepinephrine. Human research is limited. Animal studies suggest associations of BPA with adrenal adenomas and elevated adrenal weight, as well as association of heavy metals with dysregulation of the HPA axis.[30]

Cancer – of special interest to researchers is breast cancer, because of the estrogen-like effect of EDCs, but there has not yet been any direct link found. However, recent studies have found laboratory evidence that MPs can stimulate growth in metastatic breast cancer by enhancing metastasis-related gene expression and cytokines in breast cancer cells, exacerbating breast cancer metastasis.[31]

Polycyclic aromatic hydrocarbons (PAH) are known cancer causing agents, found in coal, coal-tar, and gasoline related sites. From adsorption phenomenon, carcinogenic PAH compounds have been shown to combine with MPs. There is concern that these attached chemicals could transfer to fish and prawns.[32]

There is known global increase in cancer in wildlife. The possibility that MPs play a role has been raised, either through direct effect from chemicals used to manufacture plastics or by other toxins that attach themselves to MPs.[33] [34]

Gastrointestinal disorders – In a study analyzing the characteristics of MPs in the feces of patients with inflammatory bowel disease (IBD) and healthy people it was found that the fecal MP concentration in IBD patients (41.8 items/g dm) was significantly higher than that in healthy people (28.0 items/g dm). In total, 15 types of MPs were detected in feces, with poly(ethylene terephthalate) (22.3–34.0%) and polyamide (8.9–12.4%) being dominant, and their primary

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[30] Ullah et al., "A Review of the Endocrine Disrupting Effects of Micro and Nano Plastic and Their Associated Chemicals in Mammals."

[31] Park et al., "Polypropylene Microplastics Promote Metastatic Features in Human Breast Cancer."

[32] Sharma et al., "Assessment of Cancer Risk of Microplastics Enriched with Polycyclic Aromatic Hydrocarbons."

[33] Pesavento et al., "Cancer in Wildlife."

[34] "Microplastics in Seafood and Cancer Risk."

shapes were sheets and fibers, respectively. There was evidence indicating that a positive correlation exists between the concentration of fecal MPs and the severity of IBD.[35]

Infectious disease - misuse or overuse of antibiotics has been thought to be exclusively responsible for the origin of antibiotic resistance but it has been recently discovered that co-contamination of microplastics, metals and antibiotics results in development and spread of multiple drug resistant human pathogens through a co-selection mechanism. This poses a risk to human health due to the development of metal driven multiple antibiotic resistance.[36]

Plastic debris can have considerable impacts on microbial community structure and functions in marine environments, and has been associated with an enrichment of pathogenic bacteria and antimicrobial resistance (AMR) genes. Researchers have shown that plastic leachate exposure significantly enriches AMR genes that confer multidrug, aminoglycoside and peptide antibiotic resistance. In fact, that enrichment from chemical leachate was shown to occur even without the presence of plastic substrate. This a significant impact from plastic pollution with potential consequences for human and ecosystem health.[37]

In fish, and potentially other living creatures, microplastics may have a significant impact on population health when presented with another stressor, in this case inflammation from coexisting viral infection. Mortality correlated with host viral load, mild gill inflammation, immune responses, and transmission potential. Finding suggest that microplastics can compromise host tissues, allowing pathogens to bypass defenses.[38]

Summary

As a scientist and physician, it is clear to me that we have barely scratched the surface of the problem of plastics in the environment and that the consequences of these human actions will be highly significant:

- Plastics and their breakdown products including microplastics are ubiquitous, occupying all portions of our world from the deepest oceans to the highest mountains.
- The quantity of plastic being created, dispersed and degraded is massive, with no reasonable possibility of recovery at this time.
- Microplastics have been incorporated into the living tissues of every living thing in our world.

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[35] Yan et al., "Analysis of Microplastics in Human Feces Reveals a Correlation between Fecal Microplastics and Inflammatory Bowel Disease Status."
[36] Imran, Das, and Naik, "Co-Selection of Multi-Antibiotic Resistance in Bacterial Pathogens in Metal and Microplastic Contaminated Environments."
[37] Vlaanderen et al., "Plastic Leachate Exposure Drives Antibiotic Resistance and Virulence in Marine Bacterial Communities."
[38] Seeley et al., "Microplastics Exacerbate Virus-Mediated Mortality in Fish."

- There are considerable known health impacts from the myriad of chemicals and heavy metals which are employed in the manufacture of plastics affecting the health of diverse life on earth, including humans.
- The intentional and unintentional placement of plastics in our oceans leads to formation of microplastics which are now notably present in seafood.
- At the apex of the food chain, it is likely that humans and other higher mammals such as Orca whales will suffer the greatest health impact from the fallout of plastics
- There is a high likelihood, given our early state of scientific knowledge, that the negative effects of microplastics on our health will be much more extensive than we currently imagine.

Recommendations

- Education of the public as to the extent of the problem
- Funding of research into impacts of plastics
- Funding for research into safer alternative products to reduce ongoing environmental impact
- Development of responsible public policy to reduce the burden of microplastics on both terrestrial and aquatic environments. **In my opinion and in light of the material presented here, in the particular case of Burley Lagoon it is irresponsible for Pierce County to permit placement of 1 million individual plastic tubes into a marine estuary for the cultivation 25 acres of geoduck clams.**

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1. Jenkins, Tia, Bhaleka D. Persaud, Win Cowger, Kathy Szigeti, Dominique G. Roche, Erin Clary, Stephanie Slowinski, et al. "Current State of Microplastic Pollution Research Data: Trends in Availability and Sources of Open Data." *Frontiers in Environmental Science* 10 (2022). https://www.frontiersin.org/articles/10.3389/fenvs.2022.912107.
2. Frias, J. P. G. L., and Roisin Nash. "Microplastics: Finding a Consensus on the Definition." *Marine Pollution Bulletin* 138 (January 2019): 145–47. https://doi.org/10.1016/j.marpolbul.2018.11.022.
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