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PARTICULATE POLLUTION
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Sources

We are constantly exposed to particles in our environment: in the air we breathe, the food we eat and the water we drink. This article addresses the latter.

Particles can be classified as either natural in origin (dirt, slit, dust, microorganisms, etc.) or from "anthropogenic" sources (human made). This article addresses particles generated by human activities.

A significant contributor to this contamination is tire particles. As of 2017, the quantity of these particles is estimated to be 270 million tons/year.[1] And yet, the major contributor to anthropogenic pollution is plastics.

It is estimated that since the beginning of large-scale production and use in about 1950, more than 7000 million tons (8300 million metric tons) of virgin plastics have been manufactured to date.[2] These include all plastics, but the primary resins are the low and high density polyethylenes. As of 2015, less than 9% of plastics are recycled, 12% incinerated, and the remaining 79% thrown away or landfilled every year.[2] Virtually none of these plastics is biodegradable.

Figure 1 illustrates the global production, use and fate of plastic resins, fibers and additives (in metric tons).[2] Figure 2 is chronological and based on assuming the same use and disposal practices. The solid lines show historical data to 2015; the dashed lines are projections to 2050.[2] Globally, more than 300 million tons of plastic per year are manufactured and eventually thrown away.[2]
Think about it: one million plastic bottles are manufactured every <u>minute</u> throughout the world, and that rate is expected to increase 20% by 2021.[3] The National Park Service estimates that Americans use (and discard) 500 million plastic drinking straws each day!

Destinations

Regardless of where they originate (household, toilet, store, manufacturing plant, etc.), plastics are flushed down the sink and toilet, landfilled, incinerated or just carelessly discarded. Those that become part of sewage sludge or a landfill ultimately end up in the soil or in a water body (lake, river, ocean). It is estimated that between 10 and 20 million tons of plastic reach the ocean every year, and the rest end up in the soil.[1,4,5] Note that virtually every lake and river ultimately discharges into an ocean, sea or gulf.

Somewhere between 90,000 and 1,000,000 tons of plastic bits are estimated to be inadvertently added to soils during agricultural activities annually.[6] Figure 3 illustrates an overview of plastic pollution (data are metric).[6]

Particle Sizes

Although plastics will not biodegrade, most are readily broken down by ultraviolet radiation from the sun and movement within the oceans. Regarding the sizes of these particles, some experts use the following designations:

Largest Dimension	Designation
>50 mm (50,000µ)	Macroplastic
5-50 mm (5000-50,000µ)	Mesoplastic
0.0001-5 mm (0.1-5000µ)	Microplastic
<0.0001 mm (0.1µ)	Nanoplastic

Concentration measurements of the smaller Microplastics (as well as all of the Nanoplastics) using the traditional TSS analytical procedure (Standard Methods 2540 D) are difficult because this procedure specifies that filter disc products from any one of five manufacturers be used, and the pore sizes of these discs vary from 0.7µ to 1.5µ. This means that particles below at least 0.7µ are not even counted.

Quantities

Some particles will sink, while others will float. Considerable publicity has been devoted to gyres, huge masses of floating plastic in the oceans. Five separate gyres have been identified, with the area of the largest claimed to be as big as the state of Texas.[4] One study estimates that that there are 5.25 trillion (that's 5,250,000,000,000) particles floating on the ocean surfaces, weighing almost 270,000 tons.[7] And yet, floating particles are believed to represent only 1% of all the plastics in the oceans.
Whereas about 5% of the total weight of plastics is located on beaches, the remaining 94% is either on the ocean floor or trapped in glaciers.[8]

Figure 4 illustrates the sources and weight of plastic particles in the oceans.[8]

The ubiquitous nature of these particles on and in ocean sediment is underscored by the fact that a recent study found particles in crustaceans dwelling at the bottom of the deepest trenches in the oceans. Between one-half and all of the animals sampled had particles in their guts.[9] These trenches are as deep as 36,000 feet below the surface. Plastic particles also include synthetic fibers in textile products. Although fibers can enter the environment simply through the wearing of clothes, the greatest contribution to our water supplies is from the action of washing. One study found that acrylic fabrics released 730,000 fibers per wash, five times more that polyester/cotton fabric and 50% more than polyester.[1] A comprehensive academic study examined 159 globally sampled tap waters and found that 81% contained plastic fibers greater than 2½ microns in length.[10]

Accurate data on quantities of particles in our water supplies are extremely difficult to obtain; however, there are numerous estimates out there, and one predicts that if our rate of plastics production continues and no mitigation measures are taken, by 2050, on a weight basis, there will be more plastic in the oceans than fish.[11] The same study indicates that nearly all sea birds and half of sea turtles have plastics in their bodies. In 2005, an albatross was found with plastic debris in its gut from a World War II plane that had crashed in the ocean more than 5000 miles away.[6]

Decomposition Rates

An indication of the extremely slow rate of plastics decomposition in the water environment can be found in the following table.

Plastics Rate of Decomposition

Monofilament Fishing Line	600 years
Plastic Beverage Bottles	450 years
Disposable Diapers	450 years
Foamed Plastic Cups	50 years
Nylon Fabric	30-40 years
Plastic Film Container	20-30 years
Plastic Bag	10-20 years

Source: U.S. National Park Service; Mote Marine Lab, Sarasota, FL

It is important to note that the decomposition of plastics does not make them go away; they just break down into smaller and smaller particles.

PPCPs

Another issue with plastic particles in water is that they adsorb soluble pollutants known as PPCPs (pharmaceutical and personal care products). There are estimated to be more than 85,000 dissolved organic chemicals in all water supplies, ranging from prescription drugs to soluble consumer, industrial and agricultural products.[4] In addition, bacteria readily attach to surfaces and form biofilm colonies on the particles which then absorb even more chemicals. These attached contaminants are often released into the water stream.

Although THMs (trihalomethanes) are disinfection byproducts, they are dissolved organic compounds similar to PPCPs.

Health Effects

Obviously, the presence of particles in water means that they are in our drinking water. Treatment plant filtration technologies are incapable of removing particles much below 10μ in size. Although accurate counts are virtually impossible to obtain, a significant percentage of the total volume of plastics in the environment is estimated to be in the Micro- and Nano- size range - less than 10μ

Whether plastic particles have an effect on human health is unknown at this time, but, intuitively, particularly with the fact that PPCPs are associated with them (and supported by documented effects on aquatic creatures), it's difficult to believe that a link will not ultimately be identified.

Mitigation Strategies

As the result of behavior based on ignorance, carelessness, or just plain arrogance, we have gotten into this mess of contaminants that just won't go away. Is there anything we can do about it? Well, yes, we can, and here are some strategies.

Regulatory – The USEPA Long Term 1 Enhanced Surface Water Treatment Rule (virtually identical to the WHO requirements) mandates that for drinking water produced by conventional and direct filtration systems, "…samples for turbidity must be less than or equal to 0.3 NTU in at least 95 percent of the samples in any month."

While there is technically no direct relationship between turbidity and suspended solids (one is light scattering by suspended materials and the other total weight of particles above a certain size), they are both related to the suspended solids content of a water sample. These solids include dirt, dust, sand, colloids, algae, pollen, and all microorganisms such as Cryptosporidium and Giardia. A turbidity of 0.3 NTU is roughly equivalent to a TSS level in the range of 0.05 to 0.10 mg/L.

For municipal supplies, this Rule ensures that the total concentration of particles in our drinking water is probably less than 0.10 mg/L (ppm).

Material changes – There have been a number of biodegradable plastic polymers developed over the years (primarily based on corn starch), but cost and some questionable claims have limited their acceptance by the consumer. Biodegradable plastic bags for kitchen scraps are widely available in Europe now.
Plastic straws are virtually always used only once and are so small and light that they are rarely recycled. An edible (and biodegradable) drinking straw made from seaweed is now on the market.[13] Known as "Lolistraw," this product exemplifies the "out-of-the-box" thinking required to address these issues.

Behavioral changes – Humankind must rethink how we look at particle pollution. If we continue to use chemical products based on fossil fuels, we must be aware that they cannot decompose into the basic chemical building blocks of carbon and water. We must embrace recycling as never before. Most thermoplastics can be recycled, and such plastics as polyethylene terephthalate (drinking and soda bottles) are readily recycled. Consumers must demand deposits on bottle purchases. Deposits provide a strong incentive to take the bottle back to the store where recycling is facilitated. A number of states have mandated this, and it is widely practiced in Europe.

There is no good reason why plastic carrier ("single use") bags should not be banned. This practice is widely accepted in Europe and some U.S. states and local communities have bans in place. Some communities mandate that stores only supply paper bags to the shopper; however, the carbon footprint of paper bags is as high as that of plastics, although paper is recyclable and renewable. Obviously, the real solution is to bring a reusable bag on all shopping trips, and many consumers have voluntarily embraced this practice.
Although a number of manufacturers of consumer products are advertising that they have (or intend to) adopt sustainable practices, the initiative really must come from the consumer.

The world's largest recyclable materials importer, China, has recently informed the World Trade Organization that it will ban imports of 24 categories of these materials. In 2017, China imported 16 million tons of waste plastics from the developed world, with the U.S. accounting for over 3 million tons.[14]

Regarding textiles, the current trend of fast fashion ("take-make-and-dispose") is frightening, and it is estimated that the equivalent of one garbage truck of clothes is discarded every second. 500,000 tons of microfibers end up in the ocean every year.[15] This reference outlines a movement to persuade manufacturers to phase out the use of hazardous materials, to recycle old fabrics, and to use renewable resources.

Treatment Technologies - Concerning our drinking water, those technologies capable of extremely fine filtration will remove particles. The crossflow, pressure-driven membrane separation technologies of microfiltration, ultrafiltration, nanofiltration and reverse osmosis are all capable of removing particles to one degree or another. The key is particle size. Most microfiltration membranes are effective down to at least 0.1µ; ultrafiltration can remove particles at least in the 0.01µ range, and nanofiltration should be able to remove down to 0.005µ. Reverse osmosis, the tightest of all, should remove virtually any size particle. Additionally, this technology, combined with activated carbon adsorption, will also significantly reduce the concentration of PPCPs and other dissolved chemicals.[4]

Conclusions

There isn't much we can do about the huge quantity of plastics now covering this planet. Certainly, efforts can be made to recover and recycle plastics in landfills and gyres; however, our primary activity should concentrate on minimization of disposable and other discarded plastics in the future. Although the manufacturer has the ultimate responsibility for this remediation activity, to ensure success, the initiative must begin with the consumer.

Figure 1, Global production, use and fate of plastics today (million metric tons)

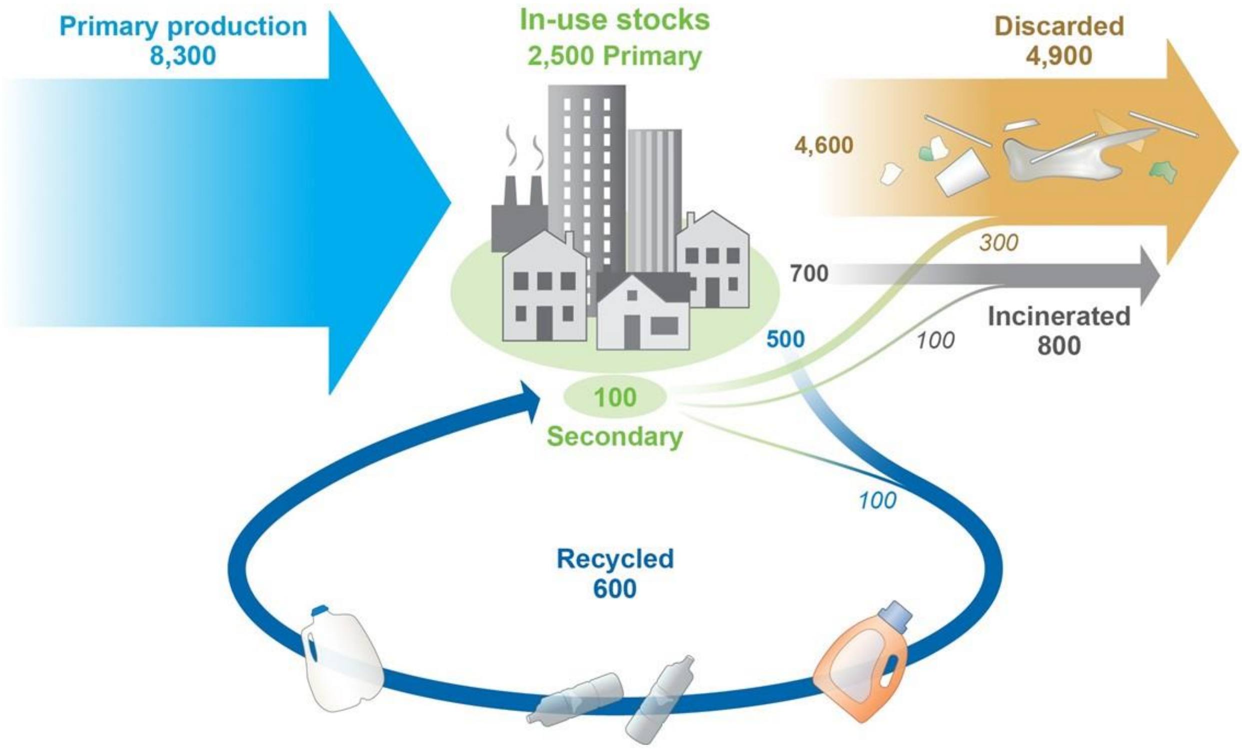

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Figure 2, Cumulative plastic waste generation and disposal (million metric tons)

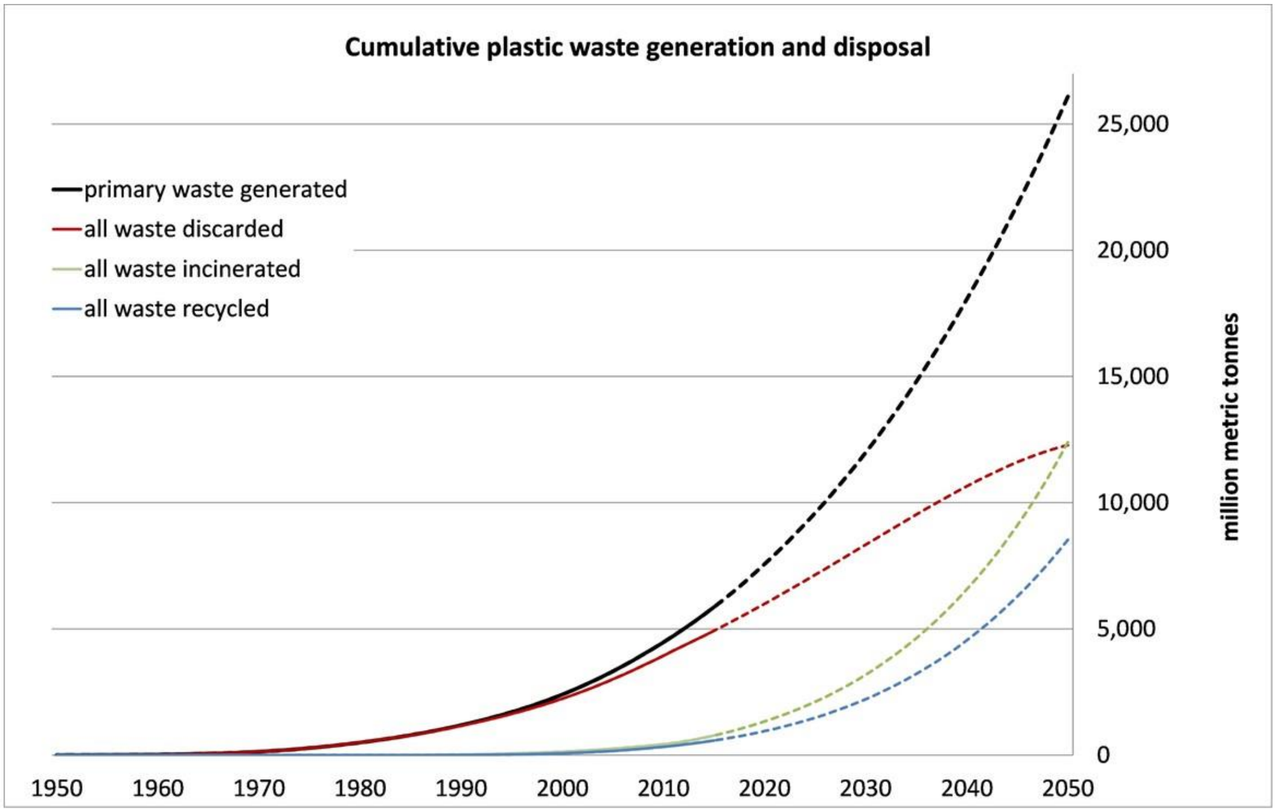

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Figure 3, Plastic pollution overview

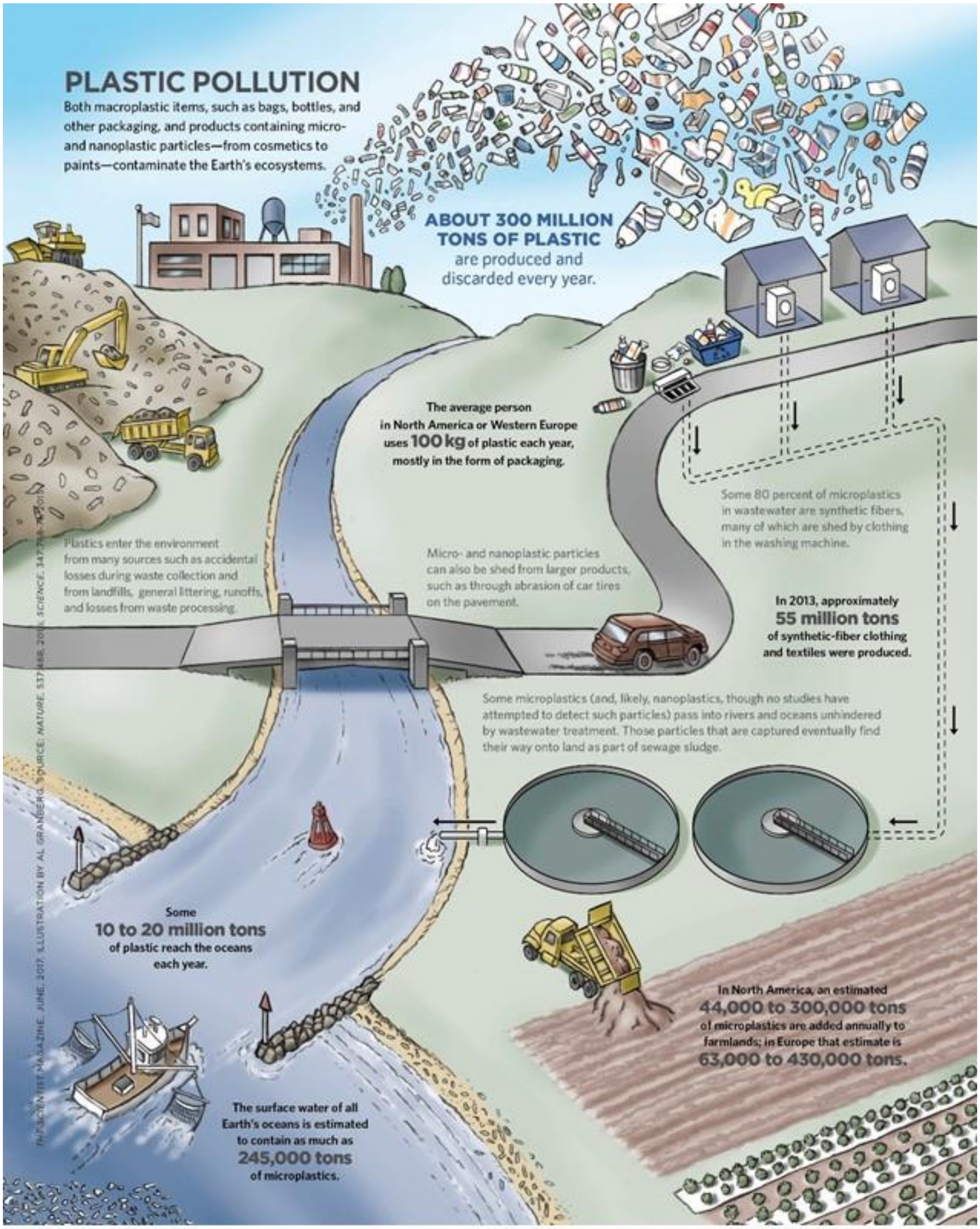

Illustration by Al Granberg

Figure 4

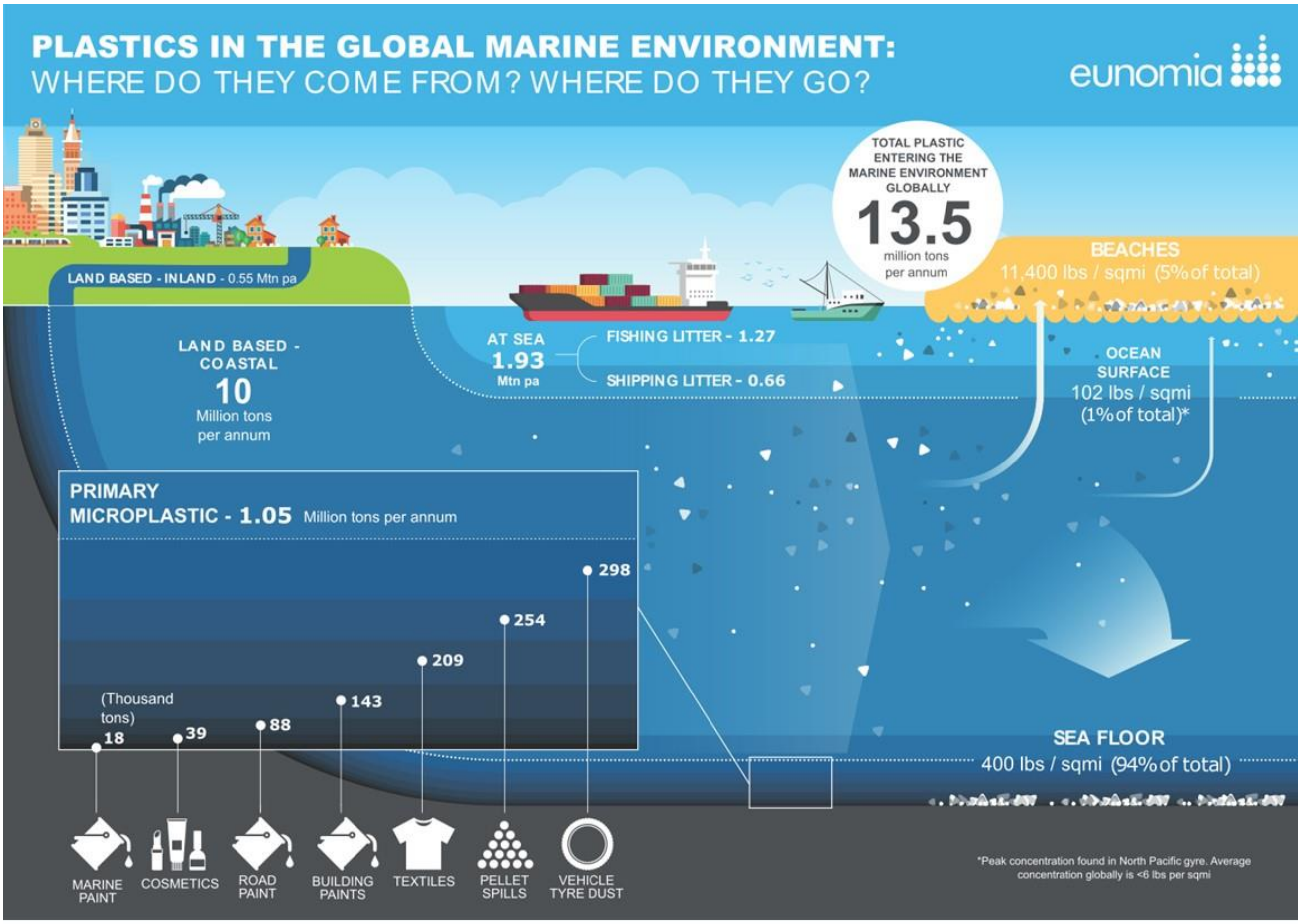

Diagram by Eunomia Research & Consulting

About the Author

Peter Cartwright entered the water purification and wastewater treatment industry in 1974, and has had his own consulting engineering firm since 1980.

He has a degree in Chemical Engineering from the University of Minnesota and is a registered Professional Engineer in that state.

Peter has provided consulting services to more than 250 clients globally. He has authored over 300 articles, written several book chapters, presented over 300 lectures in conferences around the world, and is the recipient of several patents. He also provides extensive expert witness testimony and technology training courses.

He is on numerous editorial advisory boards and technical review committees of several trade publications and a frequent lecturer in numerous technical conferences globally.

Peter is a recipient of both the Award of Merit and Lifetime Member Award from the Water Quality Association and is the Technical Consultant for the Canadian Water Quality Association.

He was the 2016 McEllhiney Distinguished lecturer for the National Ground Water Research and Educational Foundation and gave over 35 lectures throughout the world on groundwater contaminant mitigation.

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