Removing Persistent Plastic Pollution from Open Water

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The Problems

Plastic is amazing stuff. It's cheap, easily formed into complex shapes, flexible, strong and durable.

When it comes to its characteristics as a pollutant, it is unfortunate that plastic is cheap, strong, and durable, comes in myriad shapes and a rainbow of colours, and leaches out toxins, carcinogens and greenhouse gases; above all, it becomes readily ingestible when it breaks down.

Floating plastic pollution patch. Photo credit: Canadian Packaging.

The issue of plastic pollution is pervasive, but also comprises more than one issue. For example, because plastic is cheap to make, there is no financial incentive to collect and recycle lower quality input streams like post-consumer plastic. Which means our consumer society just makes and throws away more new plastic, creating more pollution.

There is plastic which floats, sinks to the water bottom, or is suspended in the water column due to the similar densities of the water and plastic, water movement and turbulence, depending on the size of the plastic pieces. These different behaviours mean that one means of capturing plastic pollution won't capture all of it. A small air bubble in a bag or bottle changes its effective density, which means that a heavier type of plastic may still float for years.

Different resin types are used to make different plastics (1. polyethylene terepthalate [PETE]; 2. high-density polyethylene [HDPE]; 3. polyvinyl chloride [PVC]; 4. low-density polyethylene [LDPE]; 5. polypropylene [PP]; 6. polystyrene [PS]; 7. other). Even within a resin type, the resulting plastics can have a range of densities and varying properties (e.g. extruded polystyrene vs. expanded polystyrene [EPS] (bead-board). Other common plastics like polycarbonate, nylon, rayon, polylactic acid and acrylic don't even have standard resin codes, and are lumped into code 7 (other).

Mesoplastic pollution (washed ashore). Photo credit: Sarah-Jeanne Royer.

Plastics range in size from nanoplastic to microplastic to mesoplastic (bottles, straws, bags) to macroplastic.

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Macroplastic pollution (washed ashore). Photo credit: Sarah-Jeanne Royer.

While images of the gyres and beaches covered with mesoplastic get the media focus, as they are comprehensible to the human eye, it is actually microplastics and nanoplastics which are the biggest problem. Biggest because large pieces of plastic degrade into small pieces over time (decades), and studies show that the volume of microplastics in the oceans is increasing year over year.[1] While microplastics may not yet be the largest mass of plastic pollution, they certainly represent the greatest number of individual pieces. Biggest because microplastic is the form that most easily enters the food chain, which includes us. Biggest because having a high surface area relative to volume means that microplastics leach out more toxins and carcinogens per unit mass than larger pieces. Biggest because this is the form we don't know how to effectively remove from open water. Biggest because this form of plastic pollution emits the

[1] Erik van Sebille et al. *A global inventory of small floating plastic debris*, https://iopscience.iop.org/article/10.1088/1748-9326/10/12/124006 [accessed 2019-04-04].

most methane and ethylene[2] – potent greenhouse gases – likely due to their high surface area to volume ratio.

Microplastics on a beach. Photo credit: National Oceanic and Atmospheric Administration.

We can collect mesoplastics and macroplastics with fishing nets, aquatic weed harvesters and our bare hands. But these approaches do not work on microplastics and nanoplastics.

As humans, we typically don't even see microplastics and nanoplastics, and don't make an effort to actually remove them from open water. Which is a problem because microplastic is the stuff ingested by marine life, starting with zooplankton and small fish and from there up the food chain to us.

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[2] Sarah-Jeanne Royer et al. *Production of methane and ethylene from plastic in the environment*, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0200574 [accessed 2019-04-04].

Lots of environmental non-governmental organizations (ENGOs) are campaigning to reduce our continuing contribution to plastic pollution. That's a worthwhile undertaking. However, it ignores the current problem – the plastic which is already in the environment, harming marine life.

We can subdivide plastic pollution according to where it collects over time: on the water surface, in the water column or on the water bottom. As seawater is denser than freshwater, more types of plastics (and therefore more volume) float on the ocean than on freshwater. Larger pieces of very dense plastic will sink to the water bottom, where they quickly become habitat. Other than in very shallow water, this plastic is expensive to separate from other material on the water bottom and remove. Extracting microplastics from the water bottom would essentially require dredging, which is likely more harmful to the local biota than the existing plastic pollution inventory. (Which is not to say that we should keep adding to that pollution inventory.)

Plastics with a density very close to that of water may stay suspended in the water column, where they may enter the food chain or otherwise harm marine life. It may be feasible to 'drag' areas known to have a high density of such pollution in the water column, but such areas are few and the work would be challenging and not financially viable.

Microplastics on the water surface have several characteristics which have made them a priority for RESTCo's research and activity related to plastic pollution. A lot of life happens at the air–water interface, including feeding. Birds, some terrestrial life and marine life are impacted in this zone. Plastic that floats can wash ashore, affecting land-based life. Plastic on land and the water surface has the maximum exposure to sunlight, which accelerates its physical breakdown into smaller pieces – eventually into microplastics and nanoplastics. Furthermore, microplastics which are exposed to sunlight are also a source of greenhouse gases, notably CH_4 (methane) and C_2H_4 (ethylene).[3] Given the growing mass of plastic pollution, this is an emerging driver for climate change. In the same way that use of conventional hydrocarbons is a driver of rising greenhouse gas emissions, it should come as no surprise that plastics made from hydrocarbons also produce greenhouse gases as they degrade.

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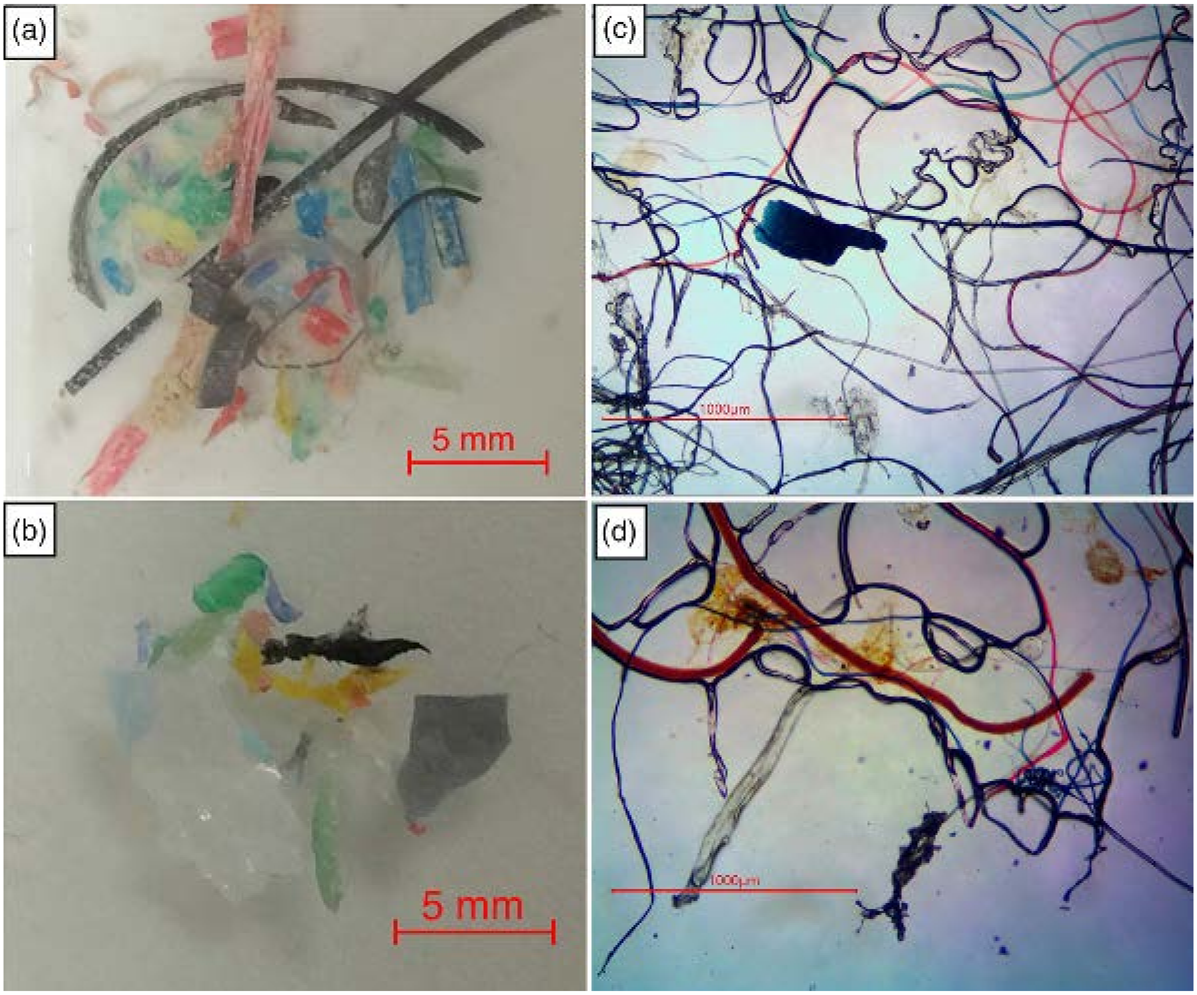
[3] Sarah-Jeanne Royer et al. *Production of methane and ethylene from plastic in the environment*, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0200574 [accessed 2019-04-04].



Microplastics removed from rivers near Ottawa. Photo credit: Jesse Vermaire.

One study[4] estimates that there were roughly 236,000 metric tonnes of microplastics in the oceans in 2014.

"The best research currently available estimates that there are over 150 million tonnes of plastics in the ocean today. In a business-as-usual scenario, the ocean is expected to contain 1 tonne of plastic for every 3 tonnes of fish by 2025, and by 2050, more plastics than fish (by weight)" (2016).[5]

[4]Erik van Sebille et al. *A global inventory of small floating plastic debris*, https://iopscience.iop.org/article/10.1088/1748-9326/10/12/124006 [accessed 2019-04-04].

"Microplastics were recovered from the soft tissues of both species … As a result, the annual dietary exposure for European shellfish consumers can amount to 11,000 microplastics per year. The presence of marine microplastics in seafood could pose a threat to food safety".[5]

The quotations above are but a small sampling of the work on human health effects that is just now getting established.[6]

RESTCo has been working on the microplastics and plastic pollution files for over a decade. In that time we have focused particularly on the effects of plastic pollution, measures to discourage the addition of more plastic pollution, use of existing technology to remove floating garbage from water, removal of microplastics from the municipal waste-water stream, development of more effective technology, specifically for removing all floating plastic garbage, including microplastics, and possible re-purposing of captured waste plastic.

Based on our testing and evaluation, we feel that there are two particular technologies, designed originally for recovering spilled oil on water, which show great promise for removing floating plastic pollution.

The first of these is a filter fabric which allows water to pass through while trapping particles larger than 10 microns and capturing hydrocarbons (adsorbent).

[5]Lisbeth Van Cauwenberghe et al. *Microplastics in bivalves cultured for human consumption*, http://www.expeditionmed.eu/fr/wp-content/uploads/sites/6/2015/02/Van-Cauwenberghe-2014-microplastics-in-cultured-shellfish1.pdf [accessed 2019-04-04].
[6]Madeleine Smith et al. *Microplastics in Seafood and the Implications for Human Health,* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6132564/ [accessed 2019-04-04].

Microplastic pieces captured on filter fabric. Photo credit: Darryl McMahon.

When the filter fabric is pulled through water containing plastic pollution, or water with plastic pollution is poured onto it, the water passes though while solids are collected – down to 10 microns in size. As a hydrocarbon adsorbent, the fabric will also trap any oil pollution accompanying the water and plastic. RESTCo has previously documented how this material can be used to remove small pieces of plastic from sand and gravel on shorelines.[7]

The second technology is a gravity tower carried on a boat or ship, with a specially designed planed hull leading to the tower, with the bottom rim of the tower just below the water surface. Prior to operation, the tower is filled with water using a top-mounted vacuum pump. As the vessel moves forward over the water, floating material like plastic waste is captured because it floats up into the tower, while the denser water continues to pass below the boat. As sufficient material is removed from the water, the pump is used to empty the plastic from the top of the tower, which refills from the bottom. The boat can continue operating this way for hours at a time, typically until crew or refuelling needs require a return to shore. A trash gate at the bow of the boat will capture larger items, which can be pulled up onto the deck manually, using a hoist or a conveyer.

[7] RESTCo. *De-plasticizing the Ocean*, https://www.restco.ca/De-plasticizing_the_Ocean.pdf [accessed 2019-04-04].

Gravity-tower model for proof of concept. Photo credit: Darryl McMahon.

In the above photograph of our flume test rig, the gravity tower, filled with water, is at the left. The plate to the right of the tower represents the inclined underside of the hull towards the bow.

Microplastics being pulled into the gravity tower (proof of concept). Photo credit: Darryl McMahon.

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In the above photograph, the red specks in the tower are microplastics. Boats using the patented gravity tower systems up to 12 metres long have been built and prove that the gravity-tower technology is scalable.

RESTCo is now working with a couple of Canadian businesses to develop harbour-class multi-function workboats from 5 to 15 metres long which can pick up floating plastic waste and potentially harmful algae blooms using the same platform.

RESTCo maintains a website with additional information on plastic pollution, including lists of scientific papers and media items. It also includes reviews of approaches to plastic-pollution reduction which work, and identifies some which do not.

Next Steps

RESTCo has received a grant from the National Geographic Society to further research and refine tools which can remove microplastics from open water and wastewater treatment plant outlets. We will be working with Dr. Jesse Vermaire and Shaun Forrest of Carleton University on this project.

Conclusions

Microplastics and nanoplastics are easy to overlook – literally. They get less attention than they deserve because they don't make a visual impact like bigger pieces of plastic waste do.

However, microplastics and nanoplastics represent our biggest current and future challenge with persistent plastic pollution.

With time and weathering, big plastic pieces in the environment degrade into microplastic and nanoplastic pollution.

Microplastics and nanoplastics leach out toxins and carcinogens.

Microplastics and nanoplastics emit greenhouse gases, notably methane (56 times more potent than carbon dioxide [20-year global warming potential]) and ethylene.

For the sake of our own health and the health of other species, and to mitigate the effects of climate change, we need to reduce plastic use and remove existing plastic waste – especially microplastic and nanoplastic pollution – from the environment. We now have the means of removing floating microplastics and nanoplastics from open water, which is cost-effective relative to the damage being caused by leaving this pollution in the environment.