OPINION

Why we need an international agreement on marine plastic pollution

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Plastic pollution is strewn across beaches and in oceans, bays, and estuaries. Tiny particles of plastic debris (often called microplastics) are so pervasive in aquatic ecosystems that we find them in seafood (1) and table salt (2). Marine organisms ingest or are entangled by plastic, sometimes with fatal consequences. Research suggests plastic pollution may impact biodiversity, ecosystem services, food security, and human health. In short, plastic pollution is a global threat.

Despite the ubiquity, persistence, and cross-boundary nature of plastic pollution, stemming it is not an insurmountable task. Motivation for addressing the issue is building at the international level. The time is ripe for the initiation of an international agreement with measurable reduction targets to lessen the plastic pollution in the world's oceans.

Pollution Without Borders

An estimated 4.4–12.7 million metric tons of plastic are added to the oceans annually (3). Like many other contaminants (such as greenhouse gases and ozone-depleting substances), plastic is not constrained by national boundaries, because it migrates via water and air currents and settles in benthic sediments. More than 50% of the ocean's area sits beyond national jurisdiction, including the

Plastics are accumulating across the globe at an astounding pace, even in remote places like the one pictured here—the uninhabited Henderson Island in the South Pacific. The time is ripe for an international agreement with measurable reduction targets to lessen the plastic pollution in the world's oceans. Reprinted with permission from ref. 19.

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infamous "garbage patches" in oceanic gyres where plastic accumulates.

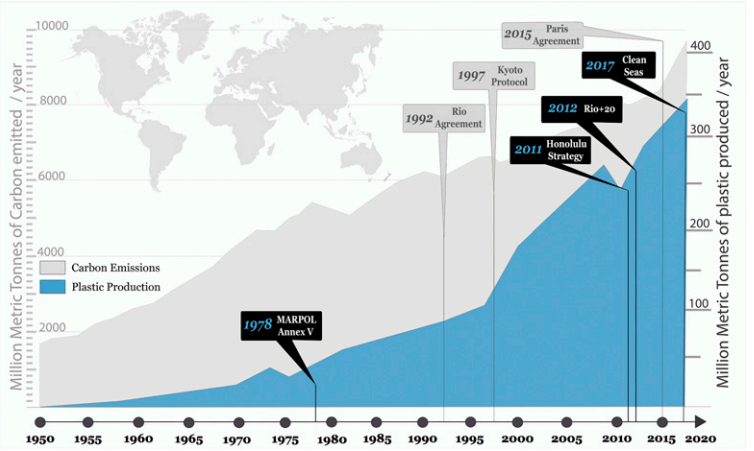
Plastic can affect organisms at every level of biological organization—altering gene expression, cells and tissues, causing death, and altering population size and community structure (4). Microplastics can impair reproduction and development (5) and alter how species function, disperse, and assemble (4, 6). These impacts, combined with evidence for accelerating plastic production and emissions into the environment, suggest the international community should come together to limit future emissions of plastic now, before they transform ecosystems irreparably.

Plastic pollution has received little attention in terms of international agreements—a notable contrast to carbon emissions and other global pollutants, such as chlorofluorocarbons (CFCs), and Persistent Organic Pollutants (POPs). There are many regional, national, and international strategies aimed at preventing and mitigating plastic pollution, but none has a level of commitment that scales with the global magnitude and accelerating growth of the problem. Local policies and actions (e.g., bans on microbeads and single-use plastic bags) are spreading across the globe, but there is only a handful of international documents focused on plastic pollution, including MARPOL, the Honolulu Strategy, and the United Nations Environmental Program's (UNEP) new Clean Seas campaign. Although these international strategies acknowledge global contamination, they contain no binding commitment that meets the challenge.

We recognize that the 1973 Annex V of the International Convention for the Prevention of Pollution from Ships, as modified by the Protocol of 1978 (MARPOL), is an international agreement that addresses plastic pollution. MARPOL, which bans ships from dumping plastic at sea, was a great first step. However, since MARPOL entered into force in 1988, the oceans have not benefited from reductions of plastic pollution. Instead, emissions have accelerated at a pace commensurate with plastic production (3). This is because Annex V is limited to maritime emissions, and 80% of plastic enters the ocean from land (3).

Despite the growing problem of plastic pollution in the decades after MARPOL, steps to prevent plastic emissions from land have been voluntary and lack defined reduction targets, methods to monitor progress, and signatories from UN member states. In 2011, the National Oceanic and Atmospheric Administration (NOAA) in the United States and UNEP created the Honolulu Strategy—a planning tool to reduce plastic pollution and its impacts. In 2012, a voluntary commitment of a significant reduction of marine debris was introduced at Rio+20 with a deadline of 2025. Similarly, in February 2017, UNEP announced the Clean Seas campaign, asking for individuals, industries, and member states to voluntarily commit to an action of their choice to reduce plastic pollution.

Recent developments in international climate change policy may provide a template for global policy for plastic pollution. Although the pace of the international response to climate change is arguably misaligned with the scale of the problem, the global community has more than 25 years of experience building international agreements to limit carbon emissions.



The graph compares global carbon emissions (data from ref. 20) with plastic production (21); ratification of international policy interventions are also noted. These two immensely complex challenges may be progressing at a similar pace in terms of emissions, but the development of policies meant to reduce and prevent further plastic pollution lags behind those that have been created and agreed upon to limit carbon emissions.

From the perspective of global policy, international plastic pollution agreements are now where climate change agreements were in 1992, when the UN Framework Convention on Climate Change (UNFCCC) formally recognized the climate change problem and simply encouraged voluntary, undefined support. If policies for plastic pollution maintain the same pace as international carbon emissions deliberations, in terms of crafting international discussions and forging agreements, an effective agreement may not happen until after 2040. By this time, emissions of plastic into the ocean are predicted to increase by an order of magnitude (3). To avoid waiting 25 years for an international plastics agreement with reduction targets, reporting, and signatories, we seek to apply lessons learned from the policy processes related to carbon emissions. The scale and pace of solutions must match the scale and pace of emissions.

Local Solutions Fall Short

Local and national actions have been the primary approach for mitigating plastic pollution, using mechanisms such as bans (e.g., microbeads, plastic bags), maximum daily limits for emissions into watersheds, and incentives for fishing gear retrieval. Positive and measurable progress occurs at these local and national scales. For example, a ban on microbeads in the United States will prevent billions of plastic beads from entering watersheds daily. Still, the pace of this piecemeal progress is not commensurate with the pace of plastic emissions.

Importantly, the ability to prevent and mitigate plastic pollution locally and nationally varies by nation and region because of resource availability for waste management. Many regions receive large imports of single-use plastic products yet have inadequate

infrastructure for waste collection and management. This leads to large volumes of plastic litter dumped in the environment, deposited in makeshift landfills, and/or treated by open burning that leads to emissions of hazardous chemicals. This lack of an explicit link between the plastic that is marketed and the capacity for waste management makes it nearly impossible for many local governments to effectively prevent plastic pollution. At an Inter-Parliamentary Union hearing to plan for The Ocean Conference in February 2017, some member states declared they wanted to act but lacked the legislative or infrastructural tools to address marine plastic pollution.

Cross-border Solutions

The time has come for a meaningful international agreement—one with clearly defined waste reduction targets and a solid foundation to provide all nations with the resources necessary for local reductions to be possible. Successful prevention and mitigation strategies that have already been implemented at national and regional levels are case studies that can be replicated around the world—e.g., beverage container deposit schemes or legislation to eliminate single-use plastic products.

International collaboration is necessary to reduce the demand for single-use plastic products, shift to a sustainable plastics economy, and improve waste management infrastructure that promotes zero-waste.

Effective policies must take into account all stages of the lifecycle of plastic—connecting producers to users and ultimately to waste managers. Based on studies from nongovernmental organizations (7), industries (8), scientists (9, 10), consultants (11, 12), and policy-makers (13, 14), several steps could be taken to address the plastics problem and provide the starting points for a meaningful international agreement.

Countries should end fossil fuel subsidies. Annually, 4–8% of oil is used to produce raw plastic (15). To reduce production of plastic from raw materials, plastics must be decoupled from fossil fuels (11). Fossil fuel subsidies incentivise the plastic market, allowing the cost of production to be less than production of an alternative.

Countries should come together to establish measurable reduction targets for plastic waste, aimed toward zero-waste, stimulating actions that reduce plastic pollution. These may include container deposit schemes; legislation to reduce single-use plastics; reclassification of plastic pollution (9, 10) (e.g., to hazardous substance or priority pollutant) to qualify for funds under existing programs for monitoring, prevention, and clean-up; and mechanisms that incentivize fishers to collect abandoned fishing gear.

Countries should agree on incentives that ensure plastics are produced with a sustainable end of life. To date, 60% of all plastics produced are accumulating in landfills or are in the natural environment (16). An international agreement should work toward achieving a circular economy (11), whereby all plastics produced are recovered and valued. In a waste hierarchy, materials should be first reused, second repurposed for an alternative use, and/or third mechanically recycled into a new product. For some products (e.g., sachets and films for food packaging), truly biodegradable materials may replace oil-based synthetic polymers.

Under this framework, no plastic is sent to landfills and fewer raw materials are needed. Similar to the goals of a "green economy," the plastic economy can be stabilized, becoming more environmentally and socially responsible. To do this, producers and waste managers must work together to produce materials that can be managed sustainably. This should entail incentivizing the production of plastics made from inert chemicals and that can be completely recycled and reused or from truly biodegradable materials that break down completely and assimilate back into the natural carbon cycle (17). This will stimulate innovation and the redesign of materials that are chemically inert, truly biodegradable, 100% recyclable, and/or made from postconsumer recycled material.

Policies could also reward member states that agree to market only plastic products that are recyclable and/or reusable in their region. We recognize that for some countries this will come at an unbearable economic cost. As such, an extended producer responsibility program (i.e., integrating the environmental cost of products throughout their life cycles into the market price) can be implemented to create a global fund that can ultimately be used by member states for waste management infrastructure that is appropriate for them.

Such a global fund is a key measure. Many regions wish to prevent plastic emissions into the environment, but as noted, they lack the means for waste management infrastructure. As the global fund builds, developing economies may access it, much like developing economies can access the UNFCCC's climate fund to combat, mitigate, and prepare for the repercussions of climate change. Solutions for one region may not be appropriate for another, and a global fund should not dictate a specific solution, but it should provide the financial means for each region to flexibly reach an agreement's targets.

Reason to Act

If current plastic production and waste management trends continue, roughly 12,000 million metric tons of plastic waste will be in landfills or in the natural environment by 2050, according to a recent analysis—an order of magnitude above current levels (16). Researchers continue to try to understand how steadily increasing plastic pollution will impact wildlife populations and fisheries stocks. If we continue on our current trajectory, we may not need experiments to determine the answers.

No single solution will stop marine plastic pollution. International collaboration is necessary to reduce the demand for single-use plastic products, shift to a

sustainable plastics economy, and improve waste management infrastructure that promotes zero-waste. To do this, the international community must commit to specific, measurable, time-bound targets to reduce plastic emissions into our oceans. By learning from climate change and other global environmental issues (e.g., ozone depletion) (18), we may be able to fast-track solutions at the global scale.

Nongovernmental organizations, UNEP, and several regional governments have established the groundwork for international policy on plastic pollution and there is sufficient evidence to demonstrate that reducing plastic pollution will mitigate impacts on marine ecosystems and the economy. Concerned countries and states should build on current policy and research efforts, pushing for international measures that can stem the rising tide of plastic into the world's oceans.

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1 Rochman CM, et al. (2015) Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Sci Rep* 5:14340.
2 Karami A, et al. (2017) The presence of microplastics in commercial salts from different countries. *Sci Rep* 7:46173, and corrigendum (2017) 7:46838.
3 Jambeck JR, et al. (2015) Marine pollution. Plastic waste inputs from land into the ocean. *Science* 347:768–771.
4 Rochman CM, et al. (2016) The ecological impacts of marine debris: Unraveling the demonstrated evidence from what is perceived. *Ecology* 97:302–312.
5 Sussarellu R, et al. (2016) Oyster reproduction is affected by exposure to polystyrene microplastics. *Proc Natl Acad Sci USA* 113:2430–2435.
6 Green DS (2016) Effects of microplastics on European flat oysters, *Ostrea edulis* and their associated benthic communities. *Environ Pollut* 216:95–103.
7 Ocean Conservancy (2015) Stemming the tide: Land-based strategies for a plastic-free ocean. Available at www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/saving-the-ocean-from-plastic-waste. Accessed July 23, 2017.
8 British Plastics Federation (2012) Operation clean sweep. Available at https://opcleansweep.org/. Accessed July 23, 2017.
9 Rochman CM, et al. (2013) Policy: Classify plastic waste as hazardous. *Nature* 494:169–171.
10 Worm B (2017) Plastic as a persistent marine pollutant. *Annu Rev Environ Resour*, 10.1146/annurev-environ-102016-060700.
11 World Economic Forum (2016) The new plastics economy: rethinking the future of plastics. Available at www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf. Accessed July 23, 2017.
12 Sherrington C, Darrah C, Hann S, Cole G, Corbin M (2016) Study to support the development of measures to combat a range of marine litter sources: report for the European Commission DG Environment. Available at ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/MSFD%20Measures%20to%20Combat%20Marine%20Litter.pdf. Accessed July 23, 2017.
13 United Nations (2016) Global partnership on marine litter (GPML). Available at https://sustainabledevelopment.un.org/partnership/?p=7471. Accessed July 23, 2017.
14 UNEP (2012) Global Programme of Action for the protection of the marine environment from land-based activities. Available at www.unep.org/ecosystems/resources/tools/global-programme-action-protection-marine-environment-land-based-activities. Accessed July 23, 2017.
15 Hopewell J, Dvorak R, Kosior E (2009) Plastics recycling: challenges and opportunities. *Philos Trans R Soc Lond B Biol Sci* 364:2115–2126.
16 Geyer R, Jambeck JR, Law KL (2017) Production, use, and fate of all plastics ever made. *Sci Adv* 3:e1700782.
17 McDevitt JP, et al. (2017) Addressing the issue of microplastics in the wake of the Microbead-Free Waters Act—a new standard can facilitate improved policy. *Environ Sci Technol* 51:6611–6617.
18 Raubenheimer K, McIlgorm A (2017) Is the Montreal Protocol a model that can help solve the global marine plastic debris problem? *Mar Policy* 81:322–329.
19 Lavers JL, Bond AL (2017) Exceptional and rapid accumulation of anthropogenic debris on one of the world's most remote and pristine islands. *Proc Natl Acad Sci USA* 114:6052–6055.
20 Carbon Dioxide Information Analysis Center CDIAC (2016) Global CO_2 emissions from fossil-fuel burning, cement manufacture, and gas flaring: 1751-2014. Available at cdiac.ornl.gov/ftp/ndp030/global.1751_2014.ems. Accessed July 23, 2017.
21 PlasticsEurope (2015) *Plastics—the Facts 2015: An Analysis of European Plastics Production, Demand and Waste Data* (PlasticsEurope, Brussels).