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A Call to Include Plastics in the Global Environment in the Class of Persistent, Bioaccumulative, and Toxic (PBT) Pollutants

Juan José Alava,* Annika Jahnke, Melanie Bergmann, Gabriela V. Aguirre-Martínez, Leah Bendell, Paola Calle, Gustavo A. Domínguez, Elaine M. Faustman, Jill Falman, Tamara N. Kazmiruk, Natasha Klasios, Maria T. Maldonado, Karly McMullen, Marcia Moreno-Báez, Gunilla Öberg, Yoshitaka Ota, Dana Price, Won Joon Shim, Ana Tirapé, Jessica M. Vandenberg, Zeinab Zoveidadianpour, and Judith Weis

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In the Plasticene, an era when plastics have become eco-markers of anthropogenic pollution, nowhere on Planet Earth is plastic-free. Together with other anthropogenic pollutants and stressors, plastics are now suggested to threaten the oceans, biodiversity, and ecosystems worldwide.[1] Escalating plastic production is by far outperforming mitigation efforts to reduce plastic consumption, and as a result, the magnitude of plastic pollution in the environment continues to increase.

In March 2022, the UN-Environmental Assembly (UNEA) adopted a resolution to develop an international legally binding treaty to address global plastic pollution (https://wedocs.unep.org/bitstream/handle/20.500.11822/39812/OEWG_PP_1_INF_1_UNEA%20resolution.pdf). To develop this treaty, an ongoing comprehensive approach addressing the full lifecycle of plastics via the UNEP-Intergovernmental Negotiating Committee is underway, facilitating the participation of multiple stakeholders. Research has shown that improved waste management and recycling alone is insufficient and will be outpaced by the projected increase in production.[1] Scientists have therefore called for a cap on the production of new plastics or, at least, a reduction of plastic pollution sources. A weakness in the resolution is that it skirts questions about toxicity and does, for example, not mention risks related to the leaching of toxic chemicals from the plastic itself or pollutants sorbed from the environment.

We argue that categorizing plastics, including micro- and nanosized particles, as PBT (Persistent, Bioaccumulative, and Toxic) pollutants, which already undergo long-range transport, could be a powerful tool to support policy efforts directed at combating plastic pollution (Figure 1). It could open up a route to champion a risk categorization framework for governments to control or eliminate the manufacture and use of harmful or toxic plastics and require industry sectors to report annually how much of different types of plastics are released into the environment and/or managed through recycling, energy recovery, and treatment, as is presently required for substances categorized as PBTs under CEPA in Canada (https://www.canada.ca/en/environment-climate-change/services/management-toxic-substances.html), EU-REACH (https://environment.ec.europa.eu/topics/chemicals/reach-regulation_en), and US EPA-TRI program (https://www.epa.gov/toxics-release-inventory-tri-program/what-toxics-release-inventory). Below, we provide scientific evidence to support each of the three criteria.

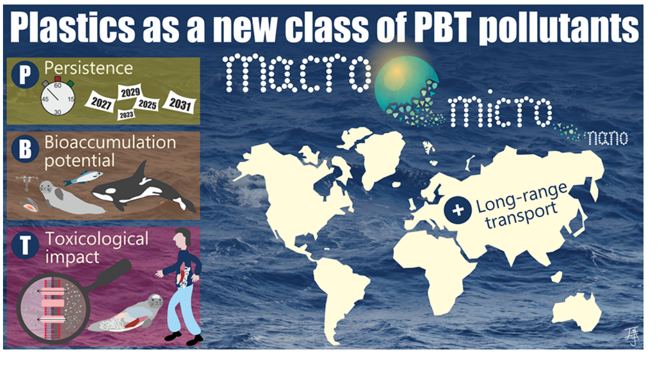

Figure 1. Conceptual framework illustrating the criteria to categorize macro-, micro-, and nanoplastics and their associated chemicals in the global ocean and terrestrial environments as a new class of persistent (P), bioaccumulative (B), and toxic (T) pollutants, subject to long-range atmospheric and oceanic transport (+), based on the weight of evidence described here. Artwork by A. Jahnke.

First, (micro)plastics are persistent environmental pollutants, as they have been detected worldwide from the oceans' bottom and seamounts through the sea ice to mountains' snow. As most plastics exhibit high durability and very low degradation rates with long half-lives that have been estimated to be up to a thousand years or more, the persistence criterion no doubt applies to plastics in the environment. The transport and fate processes of weathering plastics (macro-, micro-, and nanoplastics) in the oceans lead to poorly reversible pollution.[1] Thus, the vast global ecological footprint, reinforced by the persistence of plastics, reshapes biogeochemical processes and impacts the global oceans for an undetermined time.

Second, it is well-documented that plastic particles of micro- and nanometer size are prone to accumulate in aquatic organisms, through direct exposure (bioconcentration via water) and/or via bioaccumulation (i.e., dietary exposure and water) pathways, depending on the exposure and organisms' uptake and excretion rates.[2] These findings demonstrate that the bioaccumulation potential criterion also applies to micro- and nanoplastics. While questions still linger on the health effect risks of plastic particles in humans, micro- and/or nanoplastics have, for example, been detected in human placenta, blood, breast milk, colon, and lungs.[3] These findings indicate the capacity of plastic particles to accumulate in human tissues or organs and suggest that coastal communities heavily dependent on seafoods are at a larger risk of exposure than other groups.

Third, laboratory studies suggest that plastics can elicit adverse effects both in the short- and long-term, demonstrating that the toxicity criterion also applies.[1] These studies demonstrate that micro- and nanoplastics can be toxic to aquatic organisms, inflicting either immediate acute toxicity or sublethal chronic effects.[4,5] Depending on the mode of toxic action, micro- and nanoplastics can trigger changes in gene and protein expression, produce inflammatory responses, disrupt feeding behavior, decrease growth rates, affect brain development, reduce filtration and respiration rates, and alter the reproductive success of many aquatic organisms.[4,5,7,8]

The observed toxicity can be tied to the physical effects caused by the shape, size, volume, density, and roughness of the particles themselves and to chemicals leaching from the plastic (e.g., bisphenol A, phthalates, polybrominated diphenyl ethers [PBDEs], per- and polyfluoroalkyl substances [PFASs], alkylphenols and alkylphenol ethoxylates).[4,5,6] Chemicals added to microfibers (which are the most abundant microplastics in the environment) during textile production processes include pigments and dyes, wrinkle-resistance chemicals, antimicrobial agents, and water and stain repellents.[6] Many of these chemicals are PBT substances themselves and have been identified as chemicals of concern due to their potential impacts on human and environmental health. While more research is needed on the releases of chemicals from microplastics, emerging studies are alarming. For instance, a recent study found a link between mortalities of coho salmon (*Oncorhynchus kisutch*) and toxic chemicals released (e.g., 6PPD and 6PPD-quinone) from tire rubber microplastic particles (i.e., tire wear particles, TWPs) in the U.S. Pacific Northwest.[5] The toxicity may also be caused by pollutants sorbed to microplastics from the aquatic environment (e.g., hydrocarbons, metals, and persistent organic pollutants [POPs] such as polychlorinated biphenyls).[7,8]

As the findings on POPs toxicity via desorption are mixed (i.e., using fish, cell lines, and molecular bioassays exposed to virgin microplastics vs nonvirgin microplastics, collected from the environment), it is not possible today to conclude whether or not POPs sorbed to and desorbed from plastics are harmful.[6−8] The diverging findings may be explained by differences among polymer types (e.g., polyethylene, polypropylene), plastic properties (e.g., rubbery versus glassy), the physicochemical properties of chemical substances (e.g., octanol−water partition coefficient [Log k_{OW}], molecular weight), and exposure routes (via water, dietary ingestion, inhalation and trophic transfer).[2,5−8] In general, studies comparing "weathered" vs virgin microplastics report more severe effects from weathered microplastics amongst others due to the environmental contaminants sorbed during weathering.[1,6]

As elaborated above, the three PBT criteria apply to plastics in the environment, supporting our case to adopt this framework for these pollutants (Figure 1). Under the precautionary principle, attributing the PBT criteria to plastics as a binding science-based approach to mitigate pollution by micro- and nanoplastics is imperative and would proactively reinforce the UNEA-Treaty for abating global plastic pollution and its risks for biodiversity and marine resource-dependent communities. Concerted, bottom-up policy decisions along with precautionary actions and regulatory enforcement to cap and reduce plastic production, along with a reform for plastics' end-of-life solutions, are urgently needed to combat the roots of global plastic pollution and implement just-transitions.

These policy efforts should also champion global plastic governance by including equitable interventions and equal access to pollution prevention and mitigation strategies. This aspect is of paramount importance to address the inequality gap framework, with the aim to foster ocean equity and environmental justice in plastic pollution management for the most exposed people and impacted remote, oceanic-coastal communities of the global oceans.

AUTHOR INFORMATION

Corresponding Author

Juan José Alava − *Ocean Pollution Research Unit & Nippon Foundation-Ocean Litter Project, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver V6T 1Z4 BC, Canada; School of Resource and Environmental Management, Simon Fraser University, Burnaby V5A 1S6 BC, Canada;* orcid.org/0000-0002-6312-7776; Email: j.alava@oceans.ubc.ca

Authors

Annika Jahnke − *Department of Ecological Chemistry, Helmholtz Centre for Environmental Research−UFZ, Leipzig DE-04318, Germany; Institute for Environmental Research, RWTH Aachen University, Aachen DE-52074, Germany*

Melanie Bergmann − *Alfred-Wegener-Institute Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven DE-16227570, Germany;* orcid.org/0000-0001-5212-9808

Gabriela V. Aguirre-Martínez − *Química y Farmacia. Facultad de Ciencias de la Salud, Universidad Arturo Prat, Iquique 2120, Chile*

Leah Bendell − *Department of Biological Sciences, Simon Fraser University, Burnaby V5A 1S6 BC, Canada*

Paola Calle − *Facultad de Ciencias de la Vida, ESPOL Polytechnic University, Escuela Superior Politécnica del Litoral, ESPOL, Guayaquil 00000, Ecuador*

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Gustavo A. Domínguez – *Facultad de Ciencias de la Vida, ESPOL Polytechnic University, Escuela Superior Politécnica del Litoral, ESPOL, Guayaquil 00000, Ecuador*
Elaine M. Faustman – *Institute for Risk Analysis and Risk Communication, Department of Environmental and Occupational Health Sciences, University of Washington, Seattle 98105 Washington, United States*
Jill Falman – *Institute for Risk Analysis and Risk Communication, Department of Environmental and Occupational Health Sciences, University of Washington, Seattle 98105 Washington, United States*
Tamara N. Kazmiruk – *Department of Biological Sciences, Simon Fraser University, Burnaby V5A 1S6 BC, Canada*
Natasha Klasios – *Department of Zoology, University of British Columbia, Vancouver V6T 1Z4 BC, Canada;* orcid.org/0000-0002-7527-6090
Maria T. Maldonado – *Earth, Ocean & Atmospheric Sciences, University of British Columbia, Vancouver BC V6T 1Z4, Canada*
Karly McMullen – *Ocean Pollution Research Unit & Nippon Foundation-Ocean Litter Project, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver V6T 1Z4 BC, Canada*
Marcia Moreno-Báez – *The Fletcher School/Tufts Technology Services, Tufts University, Medford 02155 Massachusetts, United States*
Gunilla Öberg – *Institute for Resources, Environment and Sustainability, University of British Columbia, Vancouver V6T 1Z4 BC, Canada*
Yoshitaka Ota – *Nippon Foundation Ocean Nexus Center, School of Marine and Environmental Affairs EarthLab, University of Washington, Seattle 98195-5674 Washington, United States*
Dana Price – *Ocean Pollution Research Unit & Nippon Foundation-Ocean Litter Project, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver V6T 1Z4 BC, Canada*
Won Joon Shim – *Korea Institute of Ocean Science and Technology (KIOST), Geoje 53201, Republic of Korea; University of Science and Technology, Daejeon 34113, South Korea*
Ana Tirapé – *Facultad de Ciencias de la Vida, ESPOL Polytechnic University, Escuela Superior Politécnica del Litoral, ESPOL, Guayaquil 00000, Ecuador*
Jessica M. Vandenberg – *Nippon Foundation Ocean Nexus Center, School of Marine and Environmental Affairs EarthLab, University of Washington, Seattle 98195-5674 Washington, United States*
Zeinab Zoveidadianpour – *Ocean Pollution Research Unit & Nippon Foundation-Ocean Litter Project, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver V6T 1Z4 BC, Canada; Department of Biological Sciences, Simon Fraser University, Burnaby V5A 1S6 BC, Canada*
Judith Weis – *Department of Biological Sciences, Rutgers University, Newark 07102 New Jersey, United States*

Complete contact information is available at:
https://pubs.acs.org/10.1021/acs.est.3c02476

Notes

The authors declare no competing financial interest.

Biography

Dr. Juan José Alava, originally from Ecuador, is a marine ecotoxicologist and biologist. His research envisions the assessment of the pollution footprint and risks of ocean plastics in the global ocean, and microplastics' bioaccumulation modelling in marine foodwebs with implications for marine policy and ocean equity. He led the Nippon Foundation-Ocean Litter Project at the Institute for the Oceans and Fisheries, University of British Columbia (BC, Canada), in close collaboration with the Nippon Foundation-Ocean Nexus Centre at University of Washington. He is the Principal Investigator of the Ocean Pollution Research Unit at UBC, where he focuses on the impact of environmental pollutants and multiple-anthropogenic stressors on marine fauna and ecosystems, using top predators such as marine mammals and seabirds as sentinels of ocean pollution and ecosystem health ('*canaries in the coal mine*') by conducting field work, lab analysis and foodweb bioacumulation modelling of legacy and emerging pollutants, as well as surveys in coastal communities to understand the perceptions and local knowledge for fostering bottom up solutions-oriented research. He also serves as an Adjunct Professor at the School of Resource and Environmental Management, Simon Fraser University (BC, Canada), and volunteers as the Science Director of Fundación Ecuatoriana para El Estudio de Mamíferos Marinos in Ecuador. He pioneered the first ecotoxicological studies of persistent organic pollutants (POPs) in endangered Galapagos sea lions and fur seals and fish, POPs and mercury in bottlenose dolphins of the Gulf of Guayaquil (Ecuador), and more recently microplastic research in the Galapagos Islands. His research also includes the effect, bioaccumulation and biomagnifcation of legacy and new POPs and chemicals of emerging concern in endangered Southern Resident Killer whales and threatened Bigg's (transient) killer whales from the Northeastern Pacific in tandem with the development of environmental quality guidelines to protect top predators. Dr. Alava is a member of the Academia of Sciences of Ecuador since 2014.

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