Environmental Science & Technology

pubs.acs.org/est

Perspective

Global Plastic Pollution Observation System to Aid Policy

Michael S. Bank,* Peter W. Swarzenski, Carlos M. Duarte, Matthias C. Rillig, Albert A. Koelmans, Marc Metian, Stephanie Wright, Jennifer F. Provencher, Monica Sanden, Adrian Jordaan, Martin Wagner, Martin Thiel, and Yong Sik Ok*

Cite This: *Environ. Sci. Technol.* 2021, 55, 7770−7775

Read Online

ABSTRACT: Plastic pollution has become one of the most pressing environmental challenges and has received commensurate widespread attention. Although it is a top priority for policymakers and scientists alike, the knowledge required to guide decisions, implement mitigation actions, and assess their outcomes remains inadequate. We argue that an integrated, global monitoring system for plastic pollution is needed to provide comprehensive, harmonized data for environmental, societal, and economic assessments. The initial focus on marine ecosystems has been expanded here to include atmospheric transport and terrestrial and freshwater ecosystems. An earth-system-level plastic observation system is proposed as a hub for collecting and assessing the scale and impacts of plastic pollution across a wide array of particle sizes and ecosystems including air, land, water, and biota and to monitor progress toward ameliorating this problem. The proposed observation system strives to integrate new information and to identify pollution hotspots (i.e., production facilities, cities, roads, ports, etc.) and expands monitoring from marine environments to encompass all ecosystem types. Eventually, such a system will deliver knowledge to support public policy and corporate contributions to the relevant United Nations (UN) Sustainable Development Goals (SDGs).

KEYWORDS: *public policy, monitoring, reporting, plastic waste, pollution, ecosystem*

■ INTRODUCTION

As the global scale and impacts of plastic pollution (now found in air, ice, soils, water, biota, and potentially humans) have become evident, public demand has required policymakers to devise a range of mitigation efforts.[1−3] Yet the scale of plastic pollution is likely to increase over the coming decades,[4] propelled by the projected increase in human population size and worldwide plastic use, including the recent surge in single-use plastics during the current COVID-19 pandemic.[5] Tracking progress in curbing this mounting problem and providing decision-making support for solutions are hindered by the lack of baseline information and consistent assessments and methodologies that are able to resolve the complex cycle of plastic pollution,[1] including both aquatic and atmospheric transport pathways that spread progressively smaller plastic debris (i.e., microplastics <5 mm) ubiquitously, even to remote wilderness areas in national parks.[2] Here we propose the creation of a Global Plastic Pollution Observation System (GPOS) and outline the functions and benefits it would provide to mitigate this global problem.

A Need for Evidence-based Policy. Plastic pollution has received widespread attention from scientists, civil society, policymakers, and the media as the sheer scale of the problem has been realized.[6] While many uncertainties remain, plastic pollution is linked to broad-scale environmental and public health issues such as climate change,[7] negative impacts on biota, and the potential spread of antibiotic resistance and human pathogens.[8] Yet we lack a robust and systematically collected baseline on the extent of plastic pollution, as current estimates of the level of pollution range across orders of magnitude for specific biomes. This uncertainty is partly due to methodological differences and inconsistencies in sampling, analyses, and reporting. In addition, combining data across large spatiotemporal scales likely confounds upscaled estimates, as plastic production, and releases to the environment, have been increasing exponentially.[4] Importantly, there are biases in current plastic and microplastic monitoring, and certain ecosystems and ecoregions remain very much under-studied. For example, in terrestrial ecosystems, efforts thus far

Received: February 4, 2021
Published: May 24, 2021

Table 1. Potential Sampling Matrices, Units of Measurement, and Relevant Organizations, Networks, and Existing or Proposed Initiatives to Be Considered for the Development of a Policy-Relevant and Science-Based Global Plastic Pollution Observation System

sampling matrix examples[a]	units of measurement	examples of relevant organizations, networks, and existing or proposed initiatives
air: atmospheric deposition and air pollution	number or mass of plastics per surface per time or per volume	North America Atmospheric Deposition Programme (NADP)
		European Monitoring and Evaluation Programme (EMEP)
		Arctic Monitoring and Assessment Programme (AMAP)
		International Network to study Deposition and Atmospheric composition in Africa (INDAAF)
		Asia Pacific Mercury Monitoring Network (APMMN)
		Global Atmosphere Watch (GAW), World Meteorological Organization (WMO)
land: soils, crops, and foods	number or mass of plastics per mass or per area	Global Soil Partnership (GSP, FAO)
		USDA-NSRC Programme, USA
		German Permanent Soil Monitoring Programme
		Soil Geographical Database of Europe
		Intergovernmental Technical Panel on Soils (UN-FAO)
		Asian Soil Partnership
		Australian Soil Assessment Programme
		Regional Soil Laboratory Network (Africa)
		Canada National Soil Database
		Norwegian Environmental Monitoring Programme
		Food and Agricultural Organization of the United Nations (FAO)
		World Health Organization (WHO)
		United States Department of Agriculture. Food Safety and Inspection Service
freshwater: sediments, water, and shoreline surface	number or mass of plastics per mass or per volume per area	European Union Water Framework Directive (WFD)
		United States of America Environmental Protection Agency Environmental Monitoring and Assessment Programme (EMAP) Surface Water (US-EPA)
		Norwegian, Sweden and Finland Environmental Monitoring Programme
		Arctic Monitoring and Assessment Programme (AMAP)
biota	number or mass of plastics per individual or per body weight	Freshwater:
		Canadian Department of Fisheries and Oceans Freshwater Fish Monitoring Programme
		Arctic Monitoring and Assessment Programme (AMAP)
		United States Department of Agriculture. Food Safety and Inspection Service
		Marine:
		Institute of Marine Research, Norway Seafood Monitoring Programme
		International Atomic Energy Agency
		FAO Databases
		Integrated Marine Debris Observing System (IMDOS)
		GLOBEFISH (Fish Trade)
		U.S. National Oceanic and Atmospheric Administration Seafood Inspection Programme
		Environment and Climate Change Canada
		Arctic Monitoring and Assessment Programme (AMAP)
		Codex Alimentarius Food and Agricultural Organization of the United Nations (FAO) and World Health Organization (WHO)
		Partnership for Observation of the Global Ocean (POGO) Organization
		Regional Seas (UN Environment)
ocean: seawater (surface and water column) and sediments	number or mass of plastics per mass or per volume per area	International Atomic Energy Agency
		GEOTRACES Programme
		Continuous Plankton Recorder Survey
		Global Ocean Observing System (GOOS)
		EMODnet
		Regional Seas (UN Environment)
		Arctic Monitoring and Assessment Programme (AMAP)
		Ministry of Environment of Japan G20 Harmonization of Micro Floating Marine Microplastics Monitoring Programme
		EU Marine Strategy Framework Directive
		Baltic Marine Environment Protection Commission—also known as the Helsinki Commission (HELCOM)

[a]Example essential variables include particle counts and weight, size distribution, polymer type, and associated chemicals.

https://doi.org/10.1021/acs.est.1c00818
Environ. Sci. Technol. 2021, 55, 7770−7775

Table 2. Objectives and Tasks of a Global Plastic Pollution Observation System and Examples of Existing Initiatives That Can Contribute

objective	task	examples of relevant programs, initiatives, and frameworks
Harmonization of analytical methods to quantify and characterize plastic pollution	•Collect, assess, and advance existing methods •Contribute to global standardization efforts •Publish recommendations on best available methods	GESAMP, ISO, FAO, OECD, IAEA, WMO, AMAP
Collect and make publicly available data on plastic pollution in air, water, soil, and biota	•Publish reporting guidelines and common formats •Make data interoperable (e.g., via conversion of metrics) •Develop and maintain global data management and curation infrastructure •Populate that infrastructure with data	IAEA, WMO, FAO, POGO, GSP, EMEP, US-EPA, GOOS
Coordinate global plastic pollution monitoring	•Stocktake existing initiatives •Establish governance structure and liaise with funding agencies •Determine priority ecosystems and sentinel species to be monitored	Basel Convention Global Plastic Waste Partnership and Conference of Parties, GESAMP, WMO, IAEA, UN-Environment
Assess the scale of plastic pollution	•Systematically collect and scrutinize the available data on plastic pollution in the atmosphere, aquatic, and terrestrial ecosystems •Provide science and policy recommendations	IAEA, UN-Environment, GESAMP, AMAP

have been focused on specific agroecosystems, but little is known about other biomes, such as rice paddies, forests, grasslands, tundra, and drylands as well as their associated freshwater systems including groundwater, lakes, streams, and rivers.[3] Estuaries, fjords, marshes, mangroves, and coastal zones, in general, are an important interface between land and sea and deserve special attention, as these habitats are often densely populated and thus a major source of plastic pollution. Furthermore, urban areas and, in particular, roads also require special consideration because they represent a complex and dynamic nexus for microplastic pollution.[9] Research focus, from a geographical standpoint, is spatially biased, and sometimes little research exists in countries with high proportions of mismanaged waste or plastic waste imports, both of which constitute major sources of microplastics, including microfibers that are not explicitly covered in global plastic waste inventories.

The first step to mitigate a global environmental problem relies on ensuring that reliable monitoring systems, typically combining ground and airborne samplers, are in place to deliver robust data on sufficient scales to understand the nature and complexity of the problem. Many regional and international monitoring programs and initiatives exist for the sustained and collaborative monitoring of pollution in both abiotic and biotic matrices, including food (Tables 1 and 2). Therefore, implementing a systematic monitoring, assessment, and reporting strategy on the global status of plastic pollution that delivers the appropriate knowledge is essential to guide policy and track progress in mitigating this problem. The GPOS outlined here builds on scientific advances and strives to connect and coordinate research across the atmosphere, lithosphere, hydrosphere, biosphere, and anthroposphere.[1,10] Its aim is to support evidence-based policymaking and governance in the sectors that cause, and that are affected by, plastic pollution (e.g., food production).

Quantifying plastics in air, water, soil, food, and biota currently presents significant analytical challenges, compounded by the lack of harmonized procedures in sampling, quantification, analyses, and reporting.[11−18] The GPOS will incorporate approaches that harmonize, standardize, and validate the quality of sampling, processing, analytical, and quantification methods across a wide array of plastic particle sizes[11] to improve their robustness, minimize false-negatives and -positives alike, and support upscaling exercises. In addition, the need to quantify the smaller and most abundant size fractions of microplastics needs to be balanced with requirements for high-throughput, lower costs, and also, eventually, the automation of robust and faster methods to support accurate and rapid bioassessments. The latter will be critical, and countries with technical capacities to monitor plastic pollution could support capacity building efforts in other nations. In parallel, methodological advances can directly feed into human biomonitoring efforts.

Earth-System Design and Approaches. Plastic pollution flows between all ecosystem compartments[1] and thus requires an earth-system-level of thinking to be embedded in the design of GPOS to fully consider and accurately assess fluxes across a wide array of plastic particle sizes, types, and classes. The levels and impacts of plastics vary across time and space, forming an atmospheric, terrestrial, freshwater-to-sea continuum. Therefore, informed policy decisions that reduce emissions will need to consider the full plastic cycle, analogous to the way carbon cycling is tracked and evaluated in the context of climate change policies.[1] Because the main sources of plastic pollution originate from land, it is critical to monitor and mitigate these "upstream" sources to be able to reduce "downstream" impacts[19] and to harness the potential of material flow analyses. Taking this upstream-to-downstream perspective, the identification of relevant sources, fluxes, and impacts across terrestrial, freshwater, and marine ecosystems,[3] including land-based food chains, will support meaningful remediation measures and effective public policy.

The earth-system-level approach advocated here requires designing the GPOS to deliver an understanding of fluxes and transport pathways in addition to the identification of sources and hotspots. This knowledge will support achieving its primary goal of providing a global mass balance that can quantify the fate of different size fractions and types of plastics.

https://doi.org/10.1021/acs.est.1c00818
Environ. Sci. Technol. 2021, 55, 7770−7775

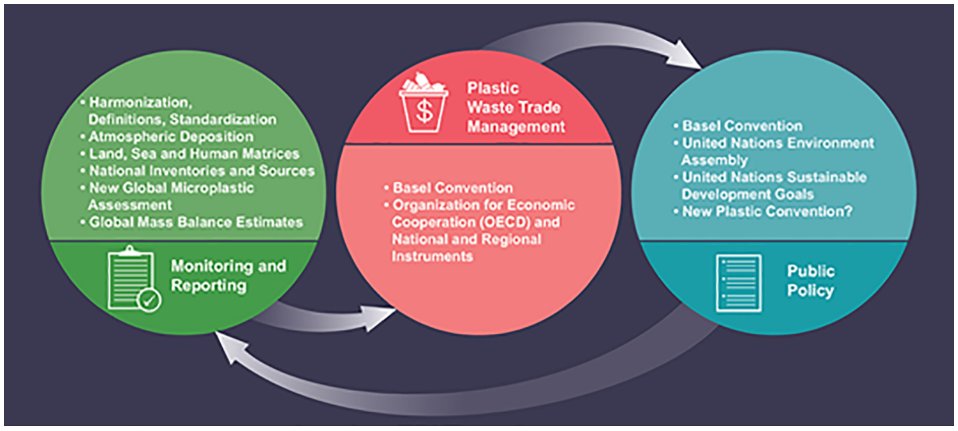

Figure 1. Conceptual figure of a Global Plastic Pollution Observation System and policy framework based on pillars of monitoring, reporting, trade data, and management partially identified by UNEA member states.[23] See Table 1 for a list of potential sampling matrices, relevant organizations, networks, and existing or proposed initiatives.

The GPOS should be designed to identify primary sources, fluxes, and sinks along the complex gradient from atmospheric, terrestrial, and freshwater systems to coastal zones, seabed environments, and the open ocean. Understanding fluxes across systems will, in turn, enable the identification of key hotspots and plastic pollution export dynamics that trigger specific risks or act as reservoirs for plastics to other systems (e.g., extreme flood events transporting microplastics to the ocean).

In addition to transport through terrestrial and freshwater systems,[3] atmospheric deposition has been clearly identified as an important vector for plastic pollution, in particular, synthetic fibers.[2,9] This has critical ramifications for sustainable development, food safety, and security as well as environmental governance and policy specifically regarding transboundary movements of plastics across ecosystem compartments. On the basis of the current state of knowledge, the long-distance atmospheric transport of microplastics is an important part of its environmental cycling, and wet and dry deposition measurements will be critical components of the GPOS. Monitoring activities could be organized by the Global Atmosphere Watch (GAW) program established by the World Meteorological Organization, which coordinates several international, national, and regional efforts (Tables 1 and 2).

The transboundary nature of plastic pollution concerns not only ecosystems but also nation states. Source nations often send their plastic waste abroad, typically to developing countries with low labor costs, for recycling. For instance, Australia exports large volumes of plastic waste to Malaysia, Indonesia, and Thailand.[20] This waste represents a major pathway for the long-range redistribution of plastic waste, potentially adding to plastic pollution in developing nations and impeding efficient solutions. In addition, plastic pollution is redistributed in nature, in particular, in the open ocean and transnational watersheds. This will result in a situation in which countries contributing very little to the problem sometimes experience more severe impacts than the polluters themselves. The inequalities arising from both types of transboundary movement of plastics need be addressed within the proposed GPOS framework. This will require the participation of regional and international institutions, such as representatives of regional sea and watershed conventions, trade organizations, and the United Nations Environment Programme (Figure 1).[10]

In summary, the GPOS will develop and promote prioritization strategies for harmonizing and standardizing methods and monitoring techniques to characterize and quantify plastics in the environment. It will design, deploy, and coordinate a global monitoring network providing regular global inventories of inputs, fluxes, and stocks of plastic litter in the environment, making the data publicly available to support policymakers at various scales. The GPOS will provide regular (e.g., 5 year intervals) assessments of progress and identify priority actions to mitigate risks associated with plastic pollution. To support these strategies, we propose that this new program will conduct an initial assessment to further develop its priorities and critical components that will be central to its success including: (1) identification of the scientific challenges related to the harmonization and standardization of methods, (2) installation of the global system and its associated governance, (3) financing to support data collection and observations, (4) use, availability, and access to interoperable data via an open data sharing platform, (5) the development of an expert group to support guidance on data interpretation, and (6) regular assessment of the state of the science and evidence of the scale and impacts of plastic pollution (Table 2).

Forging Partnerships. Proponents of GPOS will need to identify existing initiatives and stakeholders on national, regional, and global scales and work to form partnerships with existing stakeholders to codesign and create cost-effective global monitoring systems that meet the needs of key stakeholders. The use of established monitoring networks avoids redundancy and duplication of efforts and will be imperative to supporting initialization of GPOS. Utilizing existing infrastructure and frameworks will save resources and allow the program to quickly become functional. An example of such a coordinated and synergistic approach to integrate microplastics in existing networks is the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP) with its dedicated Litter and Microplastics Expert Group designed to support monitoring guidance and planning.

The GPOS should also develop a close partnership with the plastic production and waste sectors to develop a formal international tracking system using global positioning systems and advances in blockchain technology,[21] where possible, to enhance the traceability and accountability of plastic waste. Tracking should then be nested with models that predict the

https://doi.org/10.1021/acs.est.1c00818
Environ. Sci. Technol. 2021, 55, 7770−7775

continuum from macro- to microplastics during degradation.[22] Extending monitoring to include primary macroplastic pollution from hotspots, including plastic production facilities, cities, shipping ports, roads, and waste deposit areas, to the global environment will be required along with partnerships with industry and policymakers to ensure data access and sharing.

Long-term funding will be required to ensure the sustainable operation of GPOS. This will also require partnerships, possibly through the Global Environmental Facility, and contributions from multiple donors, including governments, industry, and philanthropists. Specifically, we envision that GPOS will be an umbrella for existing programs and initiatives (Table 1) and will work closely within the framework of the Basel Convention and in connection with its newly established global plastic waste partnership as a formal fate and transport working group. For example, the involvement of large-scale citizen science initiatives could help to identify plastic pollution sources and hotspots and would be a useful asset for GPOS. Data from GPOS could also follow guidelines established by the Basel Convention's electronic data reporting system. We also foresee that specific details of monitoring guidance, financing, and data reporting would also be driven by input from the Basel Convention's Conference of Parties or through the United Nations Environment Assembly (UNEA), especially in the absence of a formal multilateral environmental convention on plastic pollution. This approach must allow for input from a wide array of actors that support a more equitable approach to the development of the GPOS, which will be critical to its success.

Benefits of the Global Plastic Observation System. Plastic pollution is a top priority for governments and policymakers and a central part of the UN Decade of Ocean Science (2021−2030) and UN SDG 14 (Life Below Water), which calls for a significant reduction in marine pollution, in particular, from land-based sources and activities. Also, the G20 and United Environment Assembly (UNEA), which strives to strengthen global policy at the science−policy interface has identified marine plastic pollution as a major global problem in recent resolutions.[23]

The GPOS will contribute to informing these policies by establishing priorities for policy-based research, which, in turn, helps to achieve multiple relevant UN SDGs (Figure 1). Additionally, in the absence of a formal environmental convention on plastic pollution, regular state of the science assessments and global mass balance estimates produced by GPOS would be beneficial for the Conference of Parties and the Global Plastic Waste Partnership of the Basel Convention as well as for policymakers at the UN Environment Assembly *ad hoc* open-ended expert group to incorporate the most recent scientific advances into their policies. The GPOS will also deliver geographically balanced data, removing biases resulting from unbalanced research efforts around the world. GPOS will also further integrate thus-far neglected ecosystems, regions, and mechanisms of microplastic pollution to support a more holistic view of the plastic cycle and fluxes in the environment.[1,22] This will significantly help advance plastic pollution monitoring in regional and small-scale ecosystems that may be highly vulnerable but where dedicated surveillance programs may be minimal due to capacity limitations.

Using the goals outlined here, the GPOS will facilitate bridging the gap between the science and policy realms of global plastic pollution by developing the first planetary assessment and regular reporting of the plastic pollution mass balance, sources, and fluxes to support public policies to help ameliorate this pressing environmental problem.

AUTHOR INFORMATION

Corresponding Authors

Michael S. Bank − *Institute of Marine Research, Bergen 5005, Norway; Department of Environmental Conservation, University of Massachusetts Amherst, Amherst, Massachusetts 01003, United States;* orcid.org/0000-0001-5194-7171; Phone: +47 468 32 673; Email: mbank@umass.edu, Michael.Bank@hi.no

Yong Sik Ok − *Division of Environmental Science and Ecological Engineering and Association of Pacific Rim Universities (APRU) Sustainable Waste Management Program, Korea University, Seoul 02841, Korea;* orcid.org/0000-0003-3401-0912; Email: yongsikok@korea.ac.kr

Authors

Peter W. Swarzenski − *International Atomic Energy Agency, Principality of Monaco 98000, Monaco*

Carlos M. Duarte − *Red Sea Research Center and Computational Biosciences Research Center, King Abdullah University of Science and Technology, Thuwal 23955-6900, Kingdom of Saudi Arabia*

Matthias C. Rillig − *Institute of Biology, Freie Universität Berlin, 14195 Berlin, Germany; Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), 14195 Berlin, Germany*

Albert A. Koelmans − *Aquatic Ecology and Water Quality Management Group, Department of Environmental Sciences, Wageningen University, Wageningen 6700 AA, The Netherlands;* orcid.org/0000-0001-7176-4356

Marc Metian − *International Atomic Energy Agency, Principality of Monaco 98000, Monaco*

Stephanie Wright − *School of Public Health, Faculty of Medicine, Imperial College, London W2 1PG, United Kingdom;* orcid.org/0000-0003-1894-2365

Jennifer F. Provencher − *Environment and Climate Change Canada, Ottawa K1S 5B6, Canada;* orcid.org/0000-0002-4972-2034

Monica Sanden − *Institute of Marine Research, Bergen 5005, Norway*

Adrian Jordaan − *Department of Environmental Conservation, University of Massachusetts Amherst, Amherst, Massachusetts 01003, United States*

Martin Wagner − *Department of Biology, Norwegian University of Science and Technology, 7491 Trondheim, Norway;* orcid.org/0000-0002-4402-3234

Martin Thiel − *Facultad Ciencias del Mar, Universidad Católica del Norte, Coquimbo 5651, Chile; Millennium Nucleus Ecology and Sustainable Management of Oceanic Island (ESMOI), Coquimbo 5651, Chile; Centro de Estudios Avanzados en Zonas Áridas (CEAZA), Coquimbo 5651, Chile*

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.est.1c00818

Author Contributions

Conceptualization: M.S.B and Y.S.O.; Writing, original draft: M.S.B.; Writing, review and editing: all authors; Visualization, M.S.B and Y.S.O.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

M.S.B. acknowledges funding from the Norway Ministry of Trade, Industry and Fisheries (Institute of Marine Research Ocean Health Strategic Initiative Project Number 15494). P.W.S and M.M. from IAEA are grateful for the support provided to the Environment Laboratories by the Government of the Principality of Monaco. M.C.R. acknowledges funding from an ERC Advanced Grant (694368), from the Federal Ministry of Education and Research (BMBF; projects BIBS and μPlastic), and from the Deutsche Forschungsgemeinschaft. S.W. is funded by the Medical Research Council, UK (MRC; MR/R026521/1). A.J. acknowledges support from a MA Seaport Economic Council grant. M.W. acknowledges funding from the Norwegian Research Council (301157) and the North Atlantic Microplastic Centre (NAMC). Y.S.O. acknowledges the support of the Cooperative Research Program for Agriculture Science and Technology Development (project no. PJ01475801), RDA, and the National Research Foundation of Korea (NRF) (NRF-2021R1A2C2011734) in Korea.

■ REFERENCES

(1) Bank, M. S.; Hansson, S. V. The Plastic Cycle: A Novel and Holistic Paradigm for the Anthropocene. *Environ. Sci. Technol.* **2019**, *53* (13), 7177−7179.

(2) Brahney, J.; Hallerud, M.; Heim, E.; Hahnenberger, M.; Sukumaran, S. Plastic Rain in Protected Areas of the United States. *Science* **2020**, *368* (6496), 1257−1260.

(3) Rillig, M. C.; Lehmann, A. Microplastic in Terrestrial Ecosystems. *Science* **2020**, *368* (6498), 1430−1431.

(4) Lau, W. W. Y.; Shiran, Y.; Bailey, R. M.; Cook, E.; Stuchtey, M. R.; Koskella, J.; Velis, C. A.; Godfrey, L.; Boucher, J.; Murphy, M. B.; Thompson, R. C.; Jankowska, E.; Castillo Castillo, A.; Pilditch, T. D.; Dixon, B.; Koerselman, L.; Kosior, E.; Favoino, E.; Gutberlet, J.; Baulch, S.; Atreya, M. E.; Fischer, D.; He, K. K.; Petit, M. M.; Sumaila, U. R.; Neil, E.; Bernhofen, M. V.; Lawrence, K.; Palardy, J. E. Evaluating Scenarios Toward Zero Plastic Pollution. *Science* **2020**, *369* (6510), 1455−1461.

(5) Adyel, T. M. Accumulation of Plastic Waste During COVID-19. *Science* **2020**, *369* (6509), 1314−1315.

(6) Thompson, R. C.; Olsen, Y.; Mitchell, R. P.; Davis, A.; Rowland, S. J.; John, A. W.; McGonigle, D.; Russell, A. E. Lost at Sea: Where Is All the Plastic? *Science* **2004**, *304* (5672), 838.

(7) Shen, M.; Huang, W.; Chen, M.; Song, B.; Zeng, G.; Zhang, Y. (Micro)plastic crisis: Un-ignorable Contribution to Global Greenhouse Gas Emissions and Climate Change. *J. Cleaner Prod.* **2020**, *254*, 120138.

(8) Bank, M. S.; Ok, Y. S.; Swarzenski, P. W. Microplastic's Role in Antibiotic Resistance. *Science* **2020**, *369* (6509), 1315.

(9) Wright, S. L.; Ulke, J.; Font, A.; Chan, K. L. A.; Kelly, F. J. Atmospheric Microplastic Deposition in an Urban Environment and an Evaluation of Transport. *Environ. Int.* **2020**, *136*, 105411.

(10) Borrelle, S. B.; Ringma, J.; Law, K. L.; Monnahan, C. C.; Lebreton, L.; McGivern, A.; Murphy, E.; Jambeck, J.; Leonard, G. H.; Hilleary, M. A.; Eriksen, M.; Possingham, H. P.; De Frond, H.; Gerber, L. R.; Polidoro, B.; Tahir, A.; Bernard, M.; Mallos, N.; Barnes, M.; Rochman, C. M. Predicted Growth in Plastic Waste Exceeds Efforts to Mitigate Plastic Pollution. *Science* **2020**, *369* (6510), 1515−1518.

(11) Hartmann, N. B.; Huffer, T.; Thompson, R. C.; Hassellov, M.; Verschoor, A.; Daugaard, A. E.; Rist, S.; Karlsson, T.; Brennholt, N.; Cole, M.; Herrling, M. P.; Hess, M. C.; Ivleva, N. P.; Lusher, A. L.; Wagner, M. Are We Speaking the Same Language? Recommendations for a Definition and Categorization Framework for Plastic Debris. *Environ. Sci. Technol.* **2019**, *53* (3), 1039−1047.

(12) Hanke, G.; Galgani, F.; Werner, S.; Oosterbaan, L.; Nilsson, P.; Fleet, D.; Kinsey, S.; Thompson, R.; Palatinus, A.; Van Franeker, J.; Vlachogianni, T.; Scoullos, M.; Veiga, J.; Matiddi, M.; Alcaro, L.; Maes, T.; Korpinen, S.; Budziak, A.; Leslie, H.; Gago, J.; Liebezeit, G. *Guidance on Monitoring of Marine Litter in European Seas*; EUR 26113; Publications Office of the European Union: Luxembourg, 2013.

(13) Masura, J., Baker, J., Foster, G., Arthur, C., Herring, C. *Laboratory Methods for the Analysis of Microplastics in the Marine Environment: Recommendations for Quantifying Synthetic Particles in Waters and Sediments*; NOAA Technical Memorandum NOS-OR&R-48; 2015

(14) Isobe, A.; Iwasaki, S.; Uchida, K.; Tokai, T. Abundance of Non-Conservative Microplastics in the Upper Ocean from 1957 to 2066. *Nat. Commun.* **2019**, *10*, 417.

(15) *Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean*; Kershaw, P., Turra, A., Galgani, F., van Franeker, J. A., Eds.; Reports & Studies Series; GESAMP: 2019.

(16) Cadiou, J. F.; Gerigny, O.; Koren, Š.; Zeri, C.; Kaberi, H.; Alomar, C.; Panti, C.; Fossi, M. C.; Adamopoulou, A.; Digka, N.; Deudero, S.; Concato, M.; Carbonell, A.; Baini, M.; Galli, M.; Galgani, F. Lessons Learned from an Intercalibration Exercise on the Quantification and Characterisation of Microplastic Particles in Sediment and Water Samples. *Mar. Pollut. Bull.* **2020**, *154*, 111097.

(17) Michida, Y.; Chavanich, S.; Cózar Cabañas, A.; Hagmann, P.; Hinata, H.; Isobe, A.; Kershaw, P.; Kozlovskii, N.; Li, D.; Lusher, A. L.; Martí, E.; Mason, S. A.; Mu, J.; Saito, H.; Shim, W. J.; Syakti, A. D.; Takada, H.; Thompson, R.; Tokai, T.; Uchida, K.; Vasilenko, K.; Wang, J. *Guidelines for Harmonizing Ocean Surface Microplastic Monitoring Methods*, version 1.0; Ministry of the Environment: Chiyoda-ku, Japan, 2019; p 71.

(18) van Mourik, L. M.; Crum, S.; Martinez-Frances, E.; van Bavel, B.; Leslie, H. A.; de Boer, J.; Cofino, W. P. Results of WEPAL-QUASIMEME/NORMANs first global interlaboratory study on microplastics reveal urgent need for harmonization. *Sci. Total Environ.* **2021**, *772*, 145071.

(19) Rochman, C. M. Microplastics research-from sink to source. *Science* **2018**, *360* (6384), 28−29.

(20) Galaiduk, R.; Lebreton, L.; Techera, E.; Reisser, J. Transnational Plastics: An Australian Case for Global Action. *Front. Environ. Sci.* **2020**, *8*, 115.

(21) Saberi, S.; Kouhizadeh, M.; Sarkis, J.; Shen, L. Blockchain technology and its relationships to sustainable supply chain management. *Int. J. Prod. Res.* **2019**, *57*, 2117−2135.

(22) Kooi, M.; Koelmans, A. A. Simplifying Microplastic via Continuous Probability Distributions for Size, Shape, and Density. *Environ. Sci. Technol. Lett.* **2019**, *6*, 551−557.

(23) Combating Marine Plastic Litter and Microplastics: An Assessment of the Effectiveness of Relevant International, Regional and Subregional Governance Strategies and Approaches; United Nations Environment Assembly of the United Nations Environment Programme, Nairobi, Kenya, December 4−6, 2017; UNEP/AHEG/2018/1/INF/3; pp 44−55.