Fate, Transport, and Impacts of Microplastics in the Environment: A Planetary Health Perspective

Michael S. Bank, Ph.D.
Institute of Marine Research, Bergen, Norway
University of Massachusetts, Amherst, MA, USA
Michael.Bank@hi.no

PHOTOGRAPH BY DAVID LIITTSCHWAGER

Mattilsynet

Nansen Programme

Norwegian Environment Agency

MERFISH

UNIVERSITY OF MASSACHUSETTS 1863

INSTITUTE OF MARINE RESEARCH

The Research Council of Norway

AMAP Arctic Monitoring and Assessment Programme

GESAMP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

GEO

unesco Intergovernmental Oceanographic Commission

UN environment programme

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

The power of network…

- R. Ingvaldsen, Q.T. Ho, A. Maage, Y. Zhu, S. Rastrick, I. Johnsen, E. Olsen, L. Frøyland, D. Hou, O. Travnikov, D. Amouroux, E. Tessier, Z. Pedrero, J. Barre, M. Horvat, M. Rillig, C. Li, N.L. Jin, and S. Berail, L. Wang, Y. Zhang, D. Hou. C. Li, H. Zhong, et al….

IAEA International Atomic Energy Agency

Food and Agriculture Organization of the United Nations

UNDP

UNIDO

Advisory & Policy-Based Research on Planetary Health, Machine Learning, Ocean Modeling, and Isotope Biogeochemistry

Machine Learning & Data Mining → Complex Systems Mathematics & ***Logic*** Modeling

3PC - Climate Pollution Biodiversity → Toxic Metals & Rare Earth Elements

Emerging Contaminants & Microplastics → Antibiotic & Anti-Fungal Resistance

All Works Use Open Access Code & Data Protocols

Presentation Outline

- Environmental Pollution Background
- Planetary Health & Microplastic Pollution
- Case Studies – Lithification, China/India Plastispheres
- Policy, Outlook, & Synthesis

Food Systems as a driver of the Triple Planetary Crisis (3PC) – UNEP-GEO-7

*Food systems can be incredibly damaging to the environment and along with **fossil fuel production** are leading threats ($5 billion per hour in environmental damages)*

SPECIES LOSS (BIODIVERSITY)

CLIMATE CHANGE

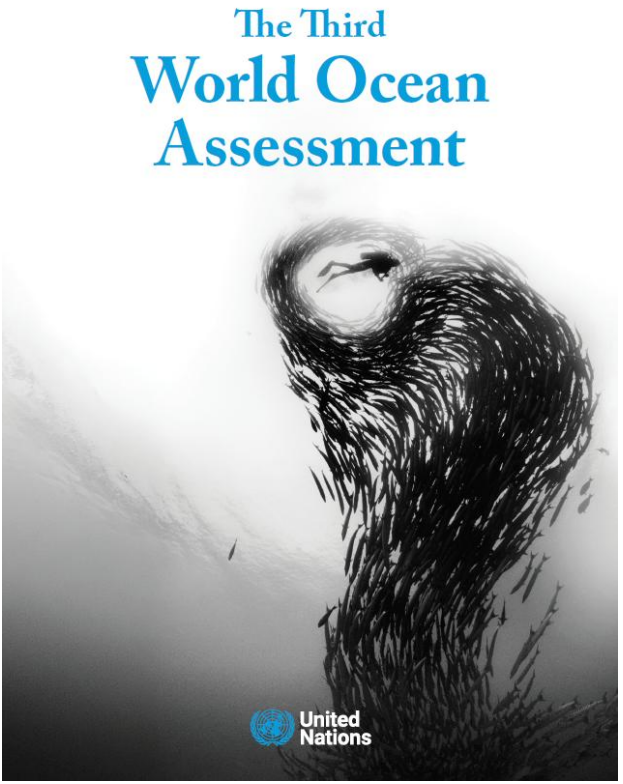
POLLUTION

*"The triad of **pollution**, **climate change**, and **biodiversity loss** are the key global environmental issues of our time. These issues are intricately linked and solutions to each will benefit the others"* – Fuller et al. (2022).

Bank et al. 2026, in prep.

Planetary Health Definition / World Ocean Assessment (WOA-3)

'Put simply, planetary health is the health of human civilization and the state of the natural systems on which it depends (*Horton & Lo 2015*).'



Plastic waste covering the shoreline of Hann Bay in Dakar, Senegal. Photograph Source: Anadolu/Getty Images.

Microplastics accumulate on the seabed.
Photo: Erling Svensen / Institute of Marine Research

- ***The WOA-3 report calculated that 52.1m tonnes of plastic, per year, enter the ocean, contributing to the 24.4tn microplastic particles that impact more than 4,000 marine species.***

How Did We Get Here?

Animals at Midway Atoll Indicate the Global Scale of Plastic Pollution

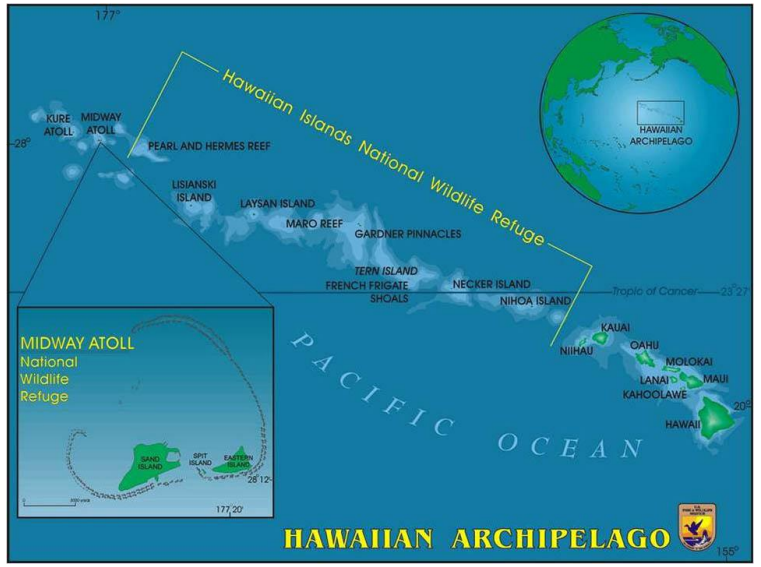
2009 - *A Turning Point for Conservation*

Photo by Chris Jordan, 2009

- *"A lot of the plastic comes onto the island inside the birds' bellies. They are foraging across the entire expanse of the North Pacific Ocean and collecting the plastic that's floating out there. They are telling us our story, which is that we are not very good at taking care of our waste" – USFWS.*

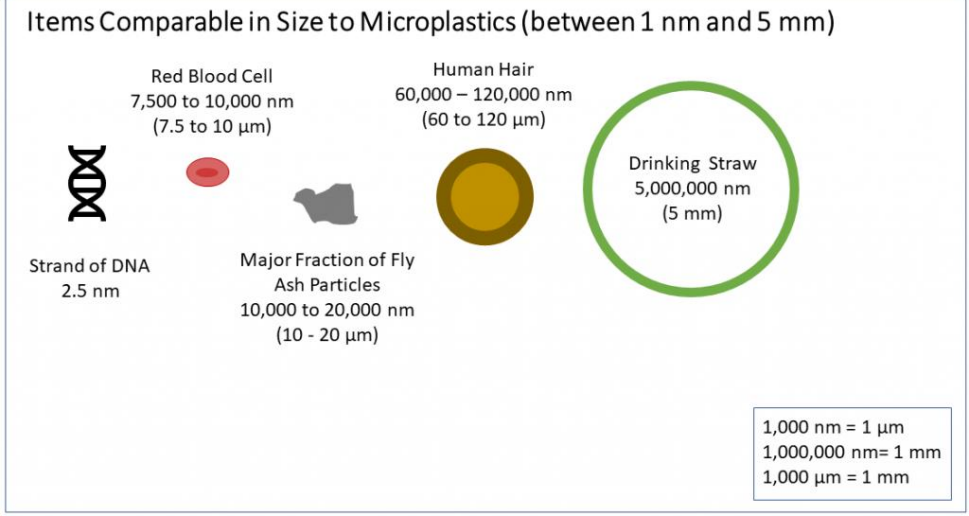
"What makes Chris Jordan's 2009 albatross photos resonate with people is that they recognize things they have thrown away." – Jo Ruxton, Source: BBC.

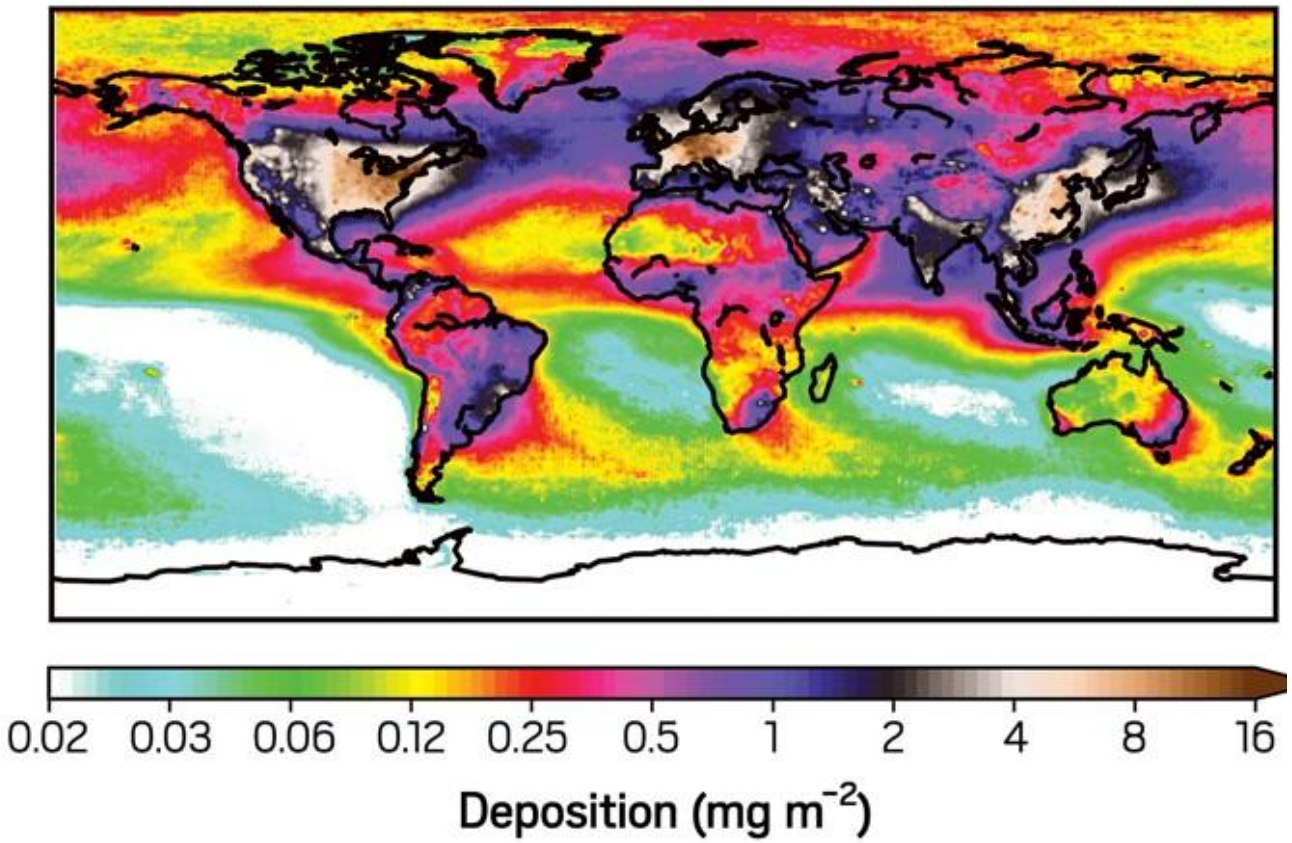
Midway Atoll is in the Hawaiian Islands and is >1000 miles from any landmass…..



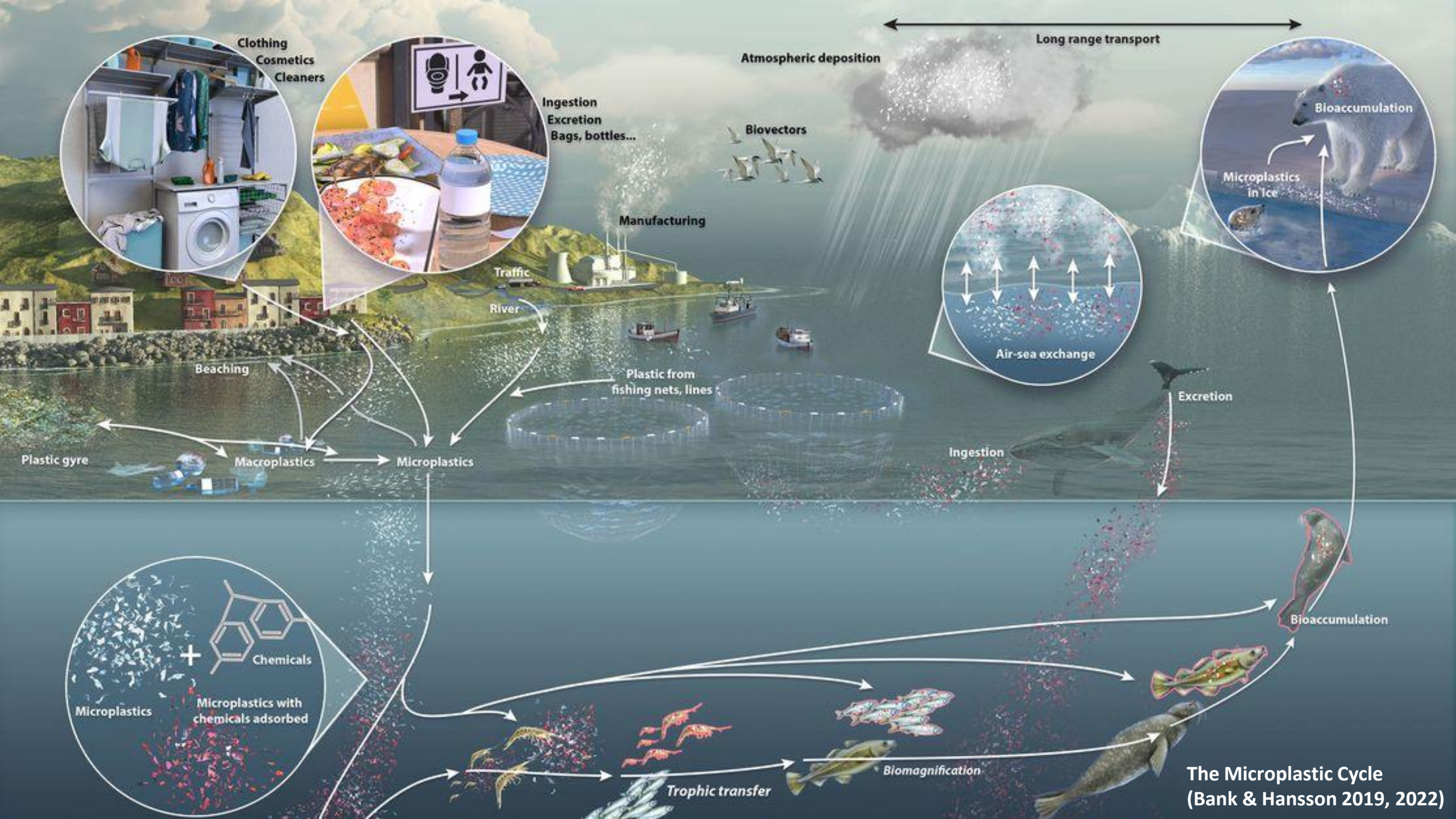
Microplastic Size, Scale, and Air Pollution

Microplastics from tires get picked up by *wind* and ocean currents and are deposited in remote areas like the *Arctic* which are *sensitive receptor regions*.





(**Evangeliou *et al*. 2020**)



The Microplastic Cycle
(Bank & Hansson 2019, 2022)

Case Study: An Anthropocene Indicator - Plastic-Rock Complexes (L. Wang, M.S. Bank, *et al*. 2023. *Env. Sci & Technol.*)

- *Discovery made in Hechi City, China, along the banks of a freshwater creek.*

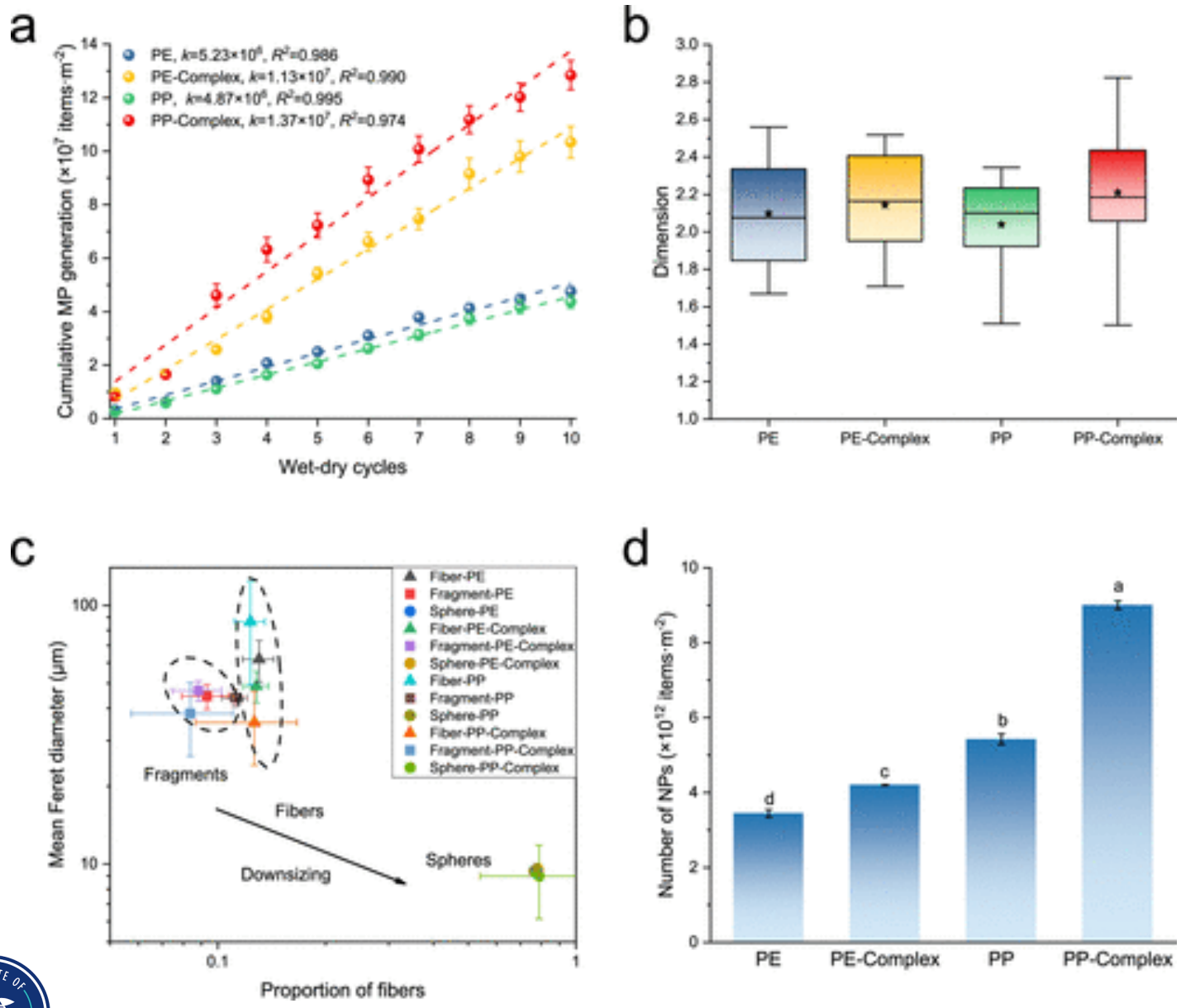
Photo Credit: Deyi Hou & Liuwei Wang/Tsinghua University, Beijing, China

nature news

- **Polyethylene films** were chemically bonded to silicon in the rock with the help of oxygen atoms.
- **Polypropylene films** were attached to rocks by physical forces rather than chemical bonds.
- **Hypotheses** - Sun/UV light, and/or Microbial Communities

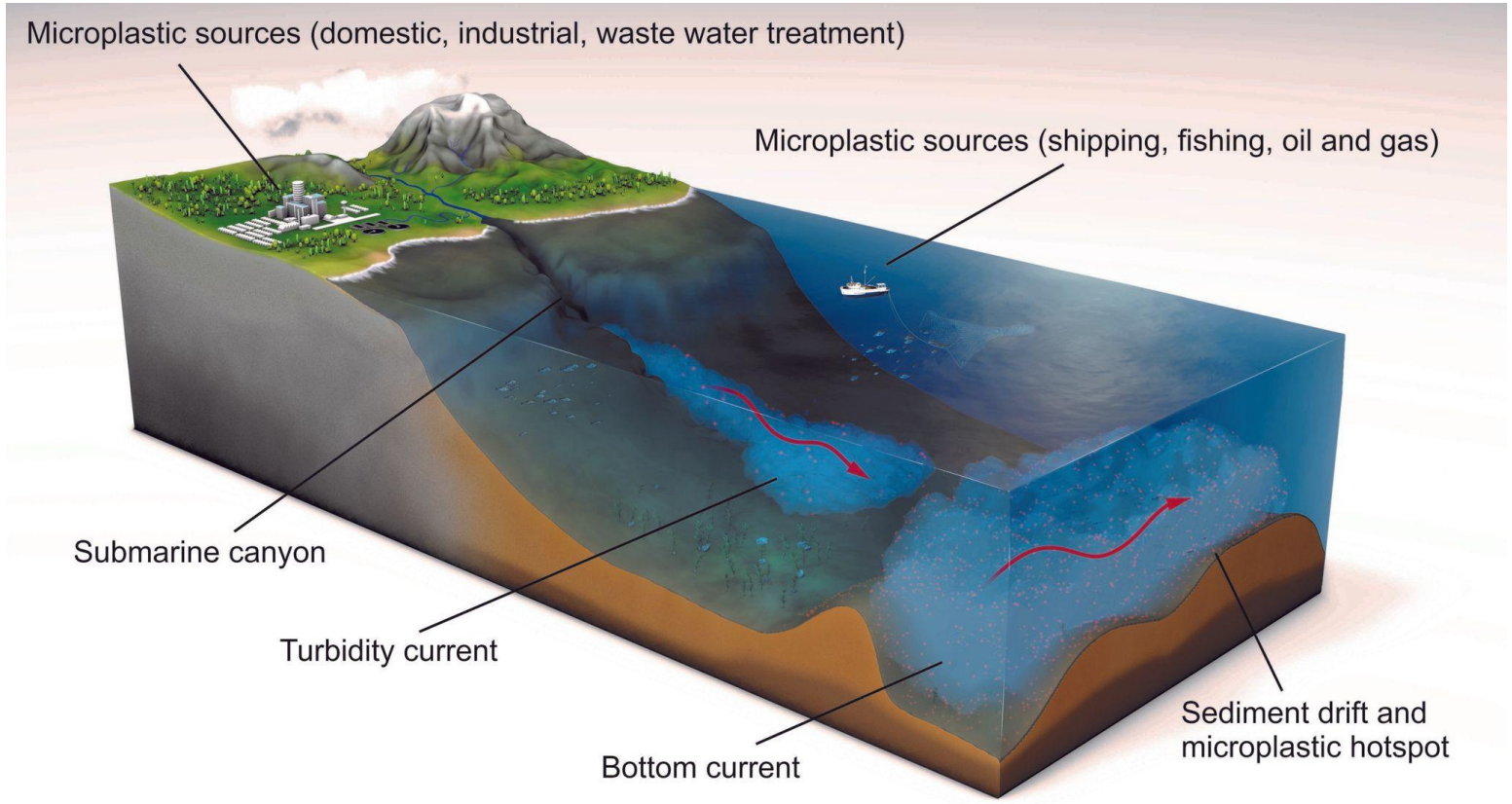
Methods: X-Ray diffraction & micro-FTIR. More details available in Wang et al. (2023) ES&T.

Plastic-Rock Complexes: Hotspots for Microplastic Generation - Wang et al. 2023



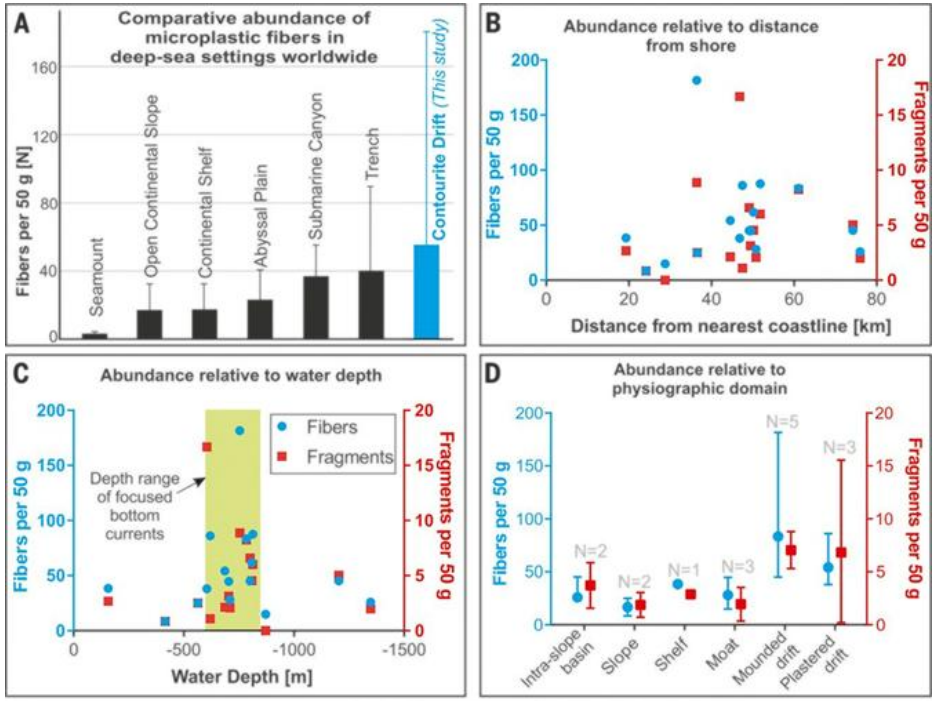
- **Rates of microplastic generation are orders of magnitude greater than those reported in lab tests mimicking plastic shedding in landfills, seawater, and marine sediment.**

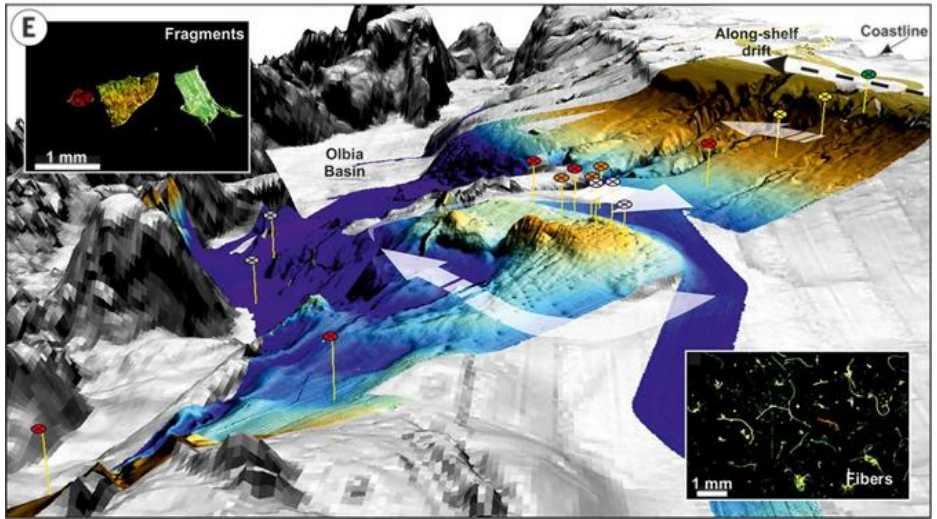
Ocean Currents and Seafloor Microplastic Hotspots



Deep ocean currents also carry oxygenated water and nutrients, meaning the seabed microplastic hotspots can house important ecosystems that can consume or absorb the microplastics.

Global and local abundance of seafloor microplastics

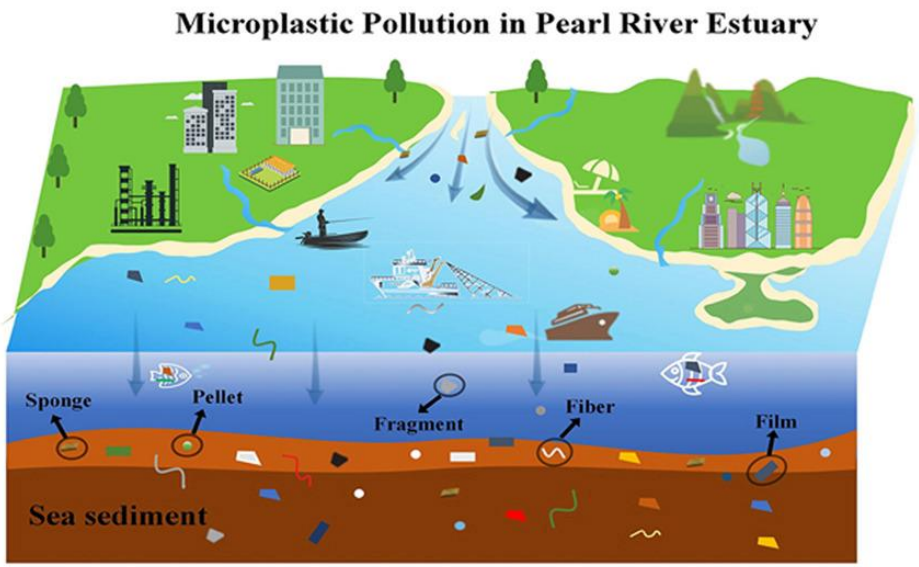


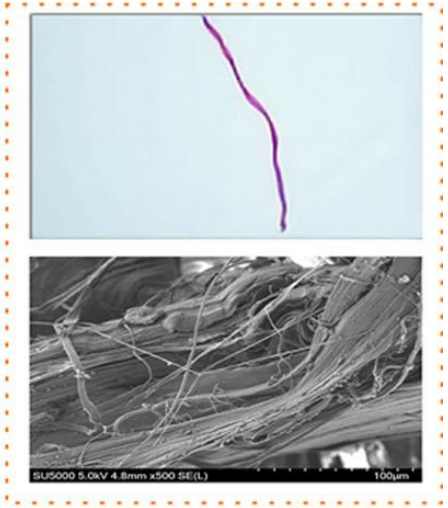


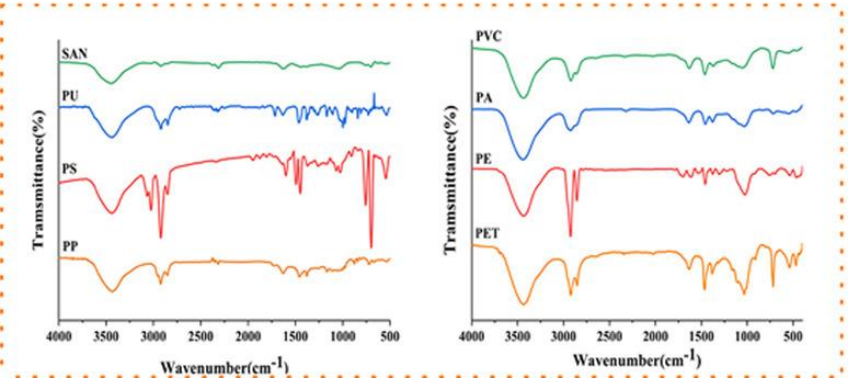
Science AAAS

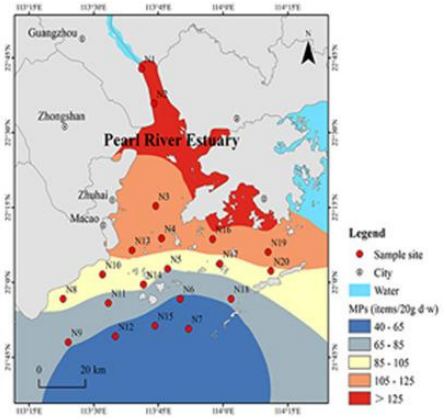
Ian A. Kane et al. Science 2020;368:1140-1145

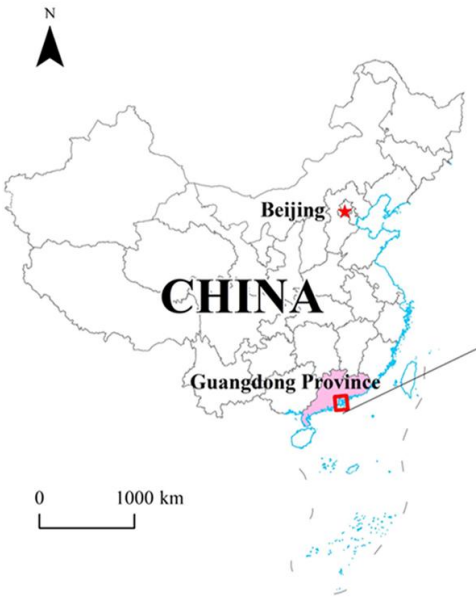
China Case Study:
Pearl River Estuary (PRE) Marine Sediment & Microplastic Pollution

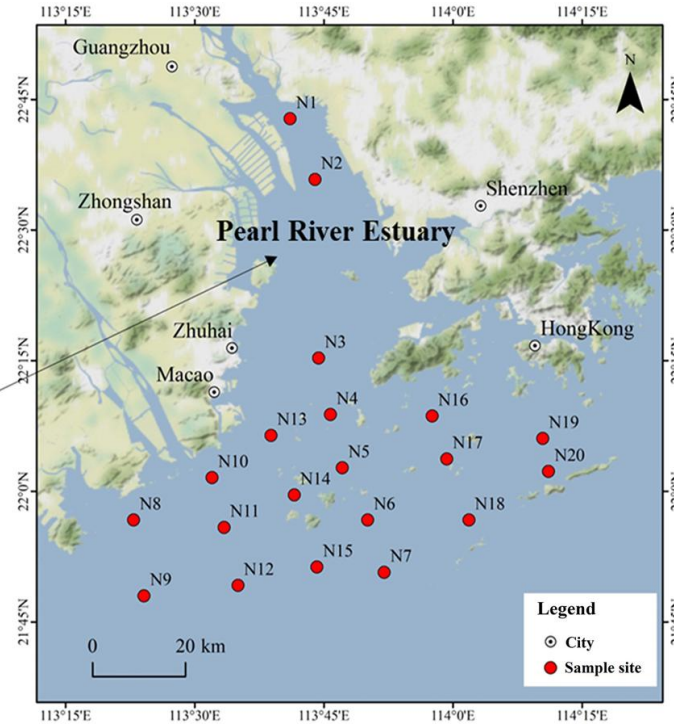






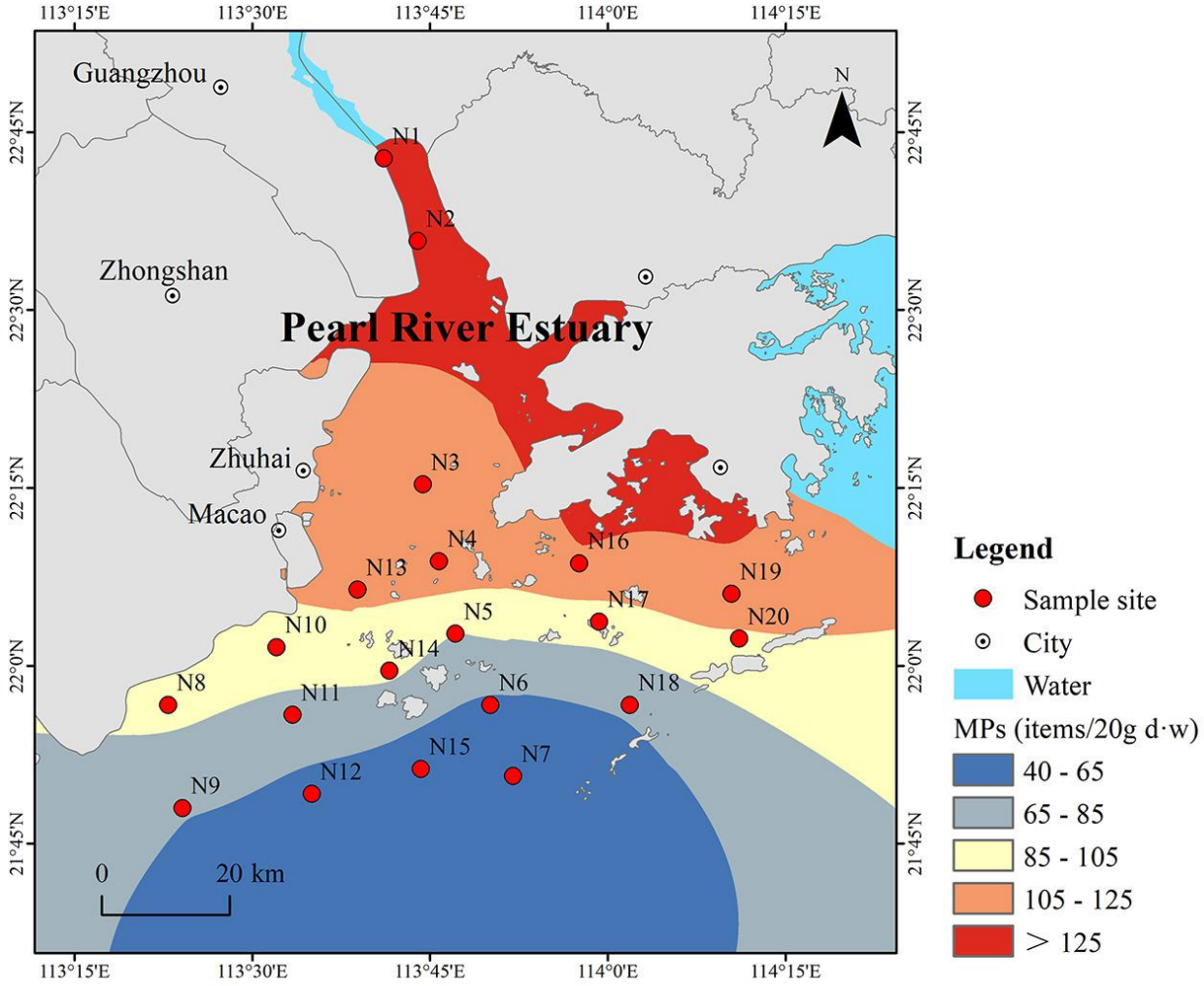




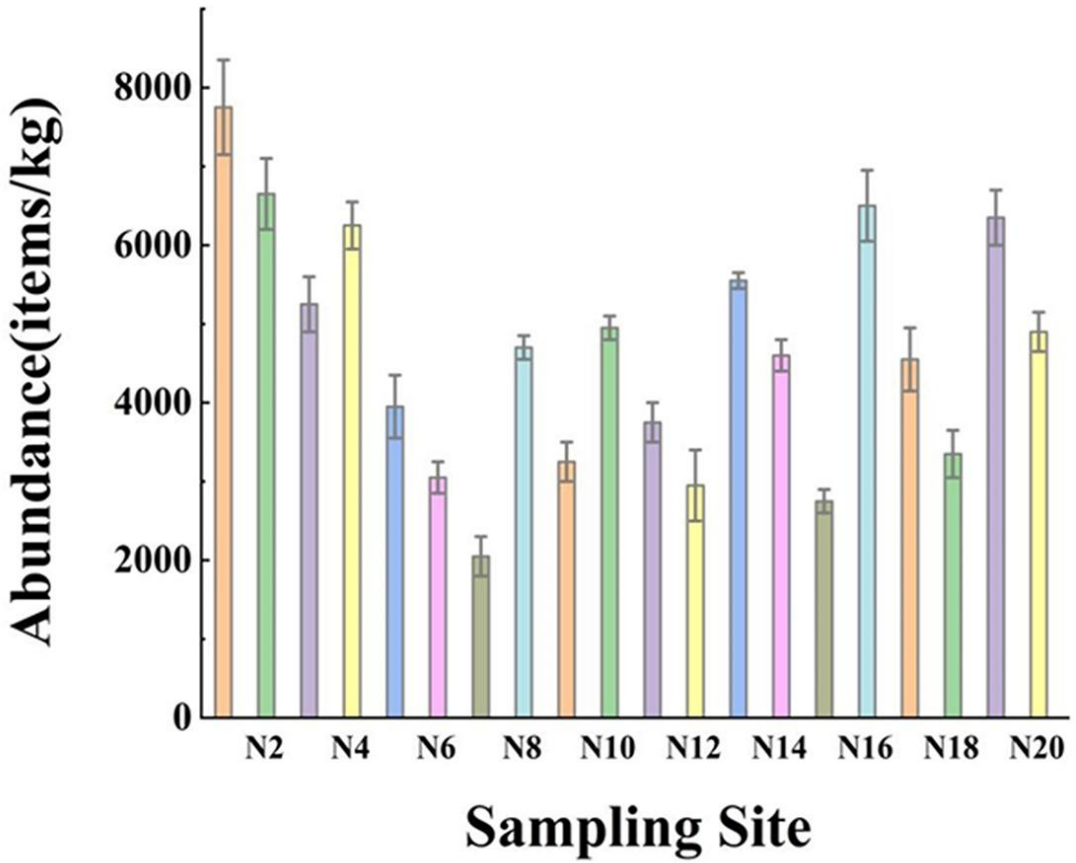


Xu et al. 2024, Emerging Contaminants (State Key Lab in Guangzhou, Chinese Academy of Sciences)

Land/Sea Exchange Processes: Sediment Microplastic Abundance in PRE



(a)



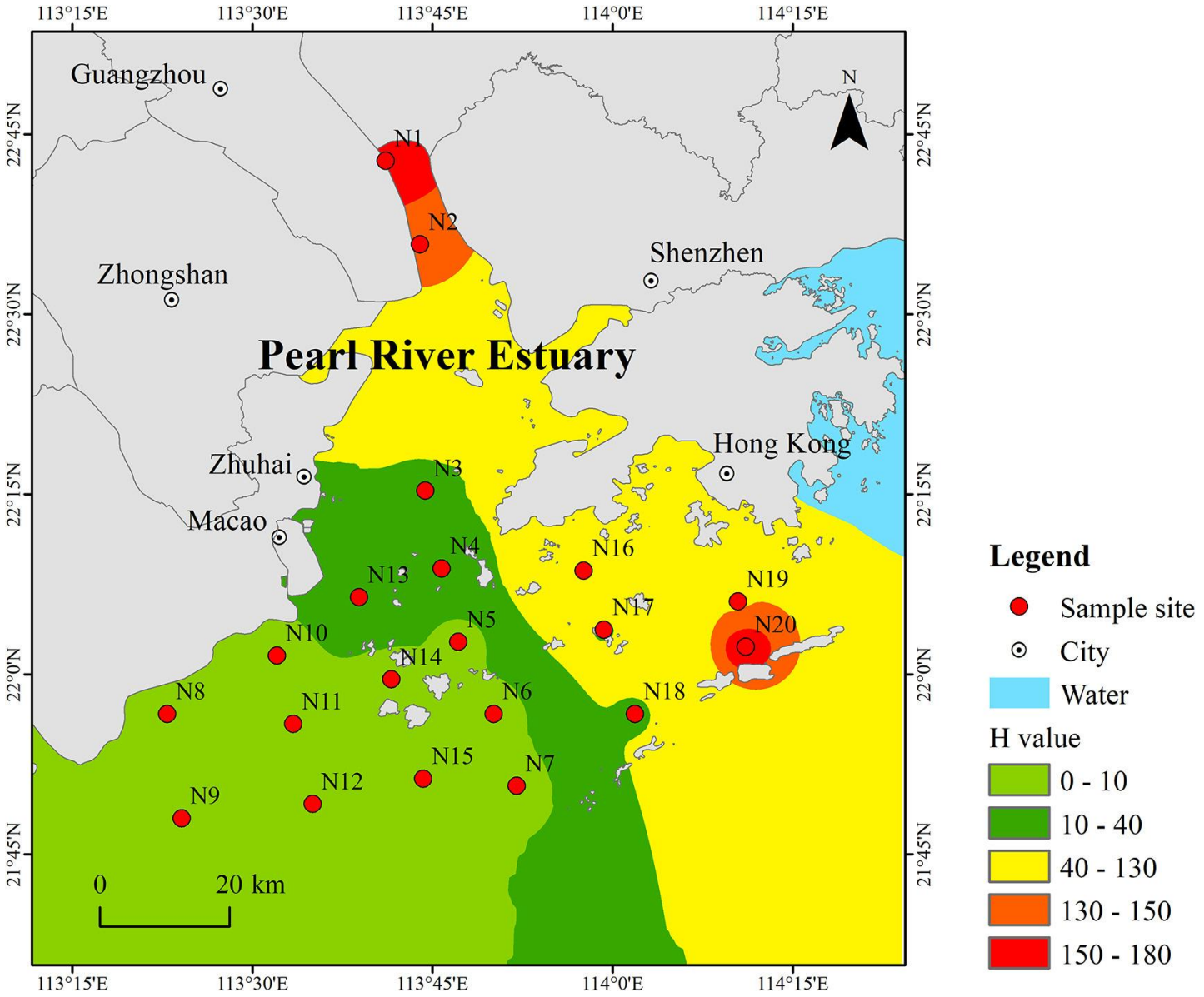
(b)

Xu et al. 2024, *Emerging Contaminants*

PRE Sediment Microplastic Risk Assessment

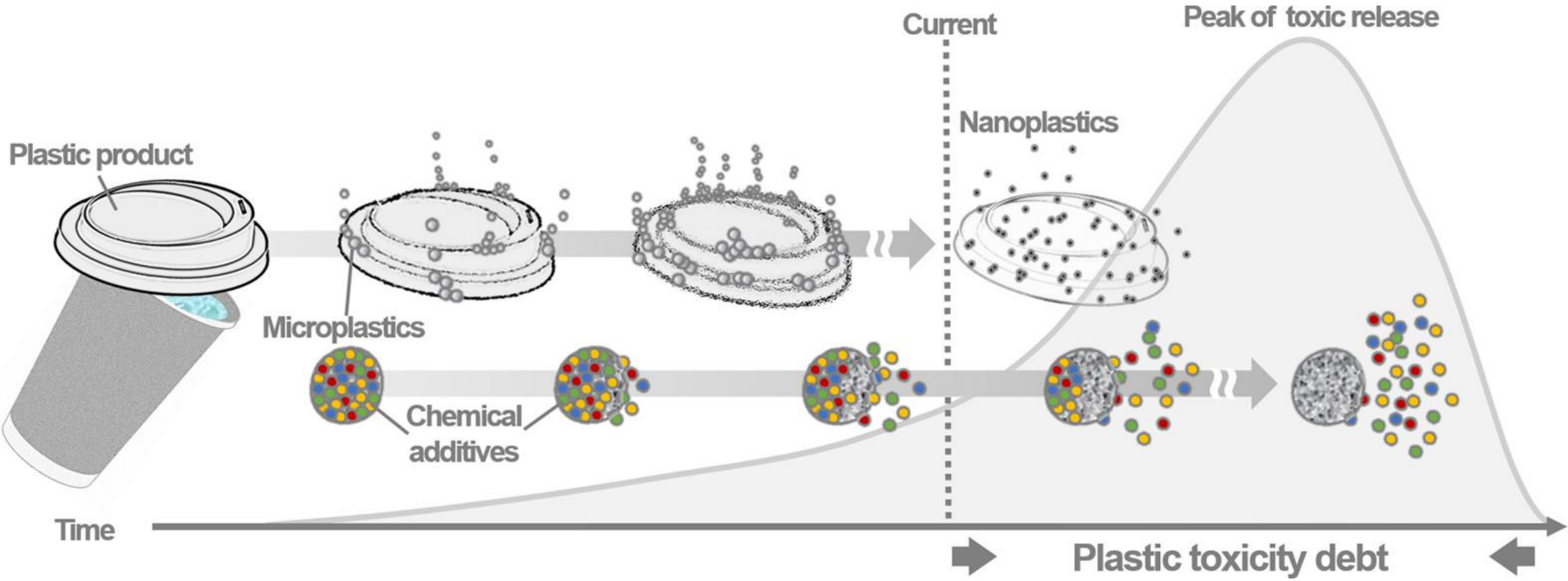
H = ∑Pn × Sn

H represents the polymer risk index, **Pn** refers to the proportion of each polymer, and **Sn** denotes the risk index of the polymers.



Xu et al. 2024, *Emerging Contaminants*

Plastic Toxicity: A Long-Term Problem



Rillig *et al*. (2021)

Plastispheres and Planetary Health Risk Assessment

nature

Li et al. 2024

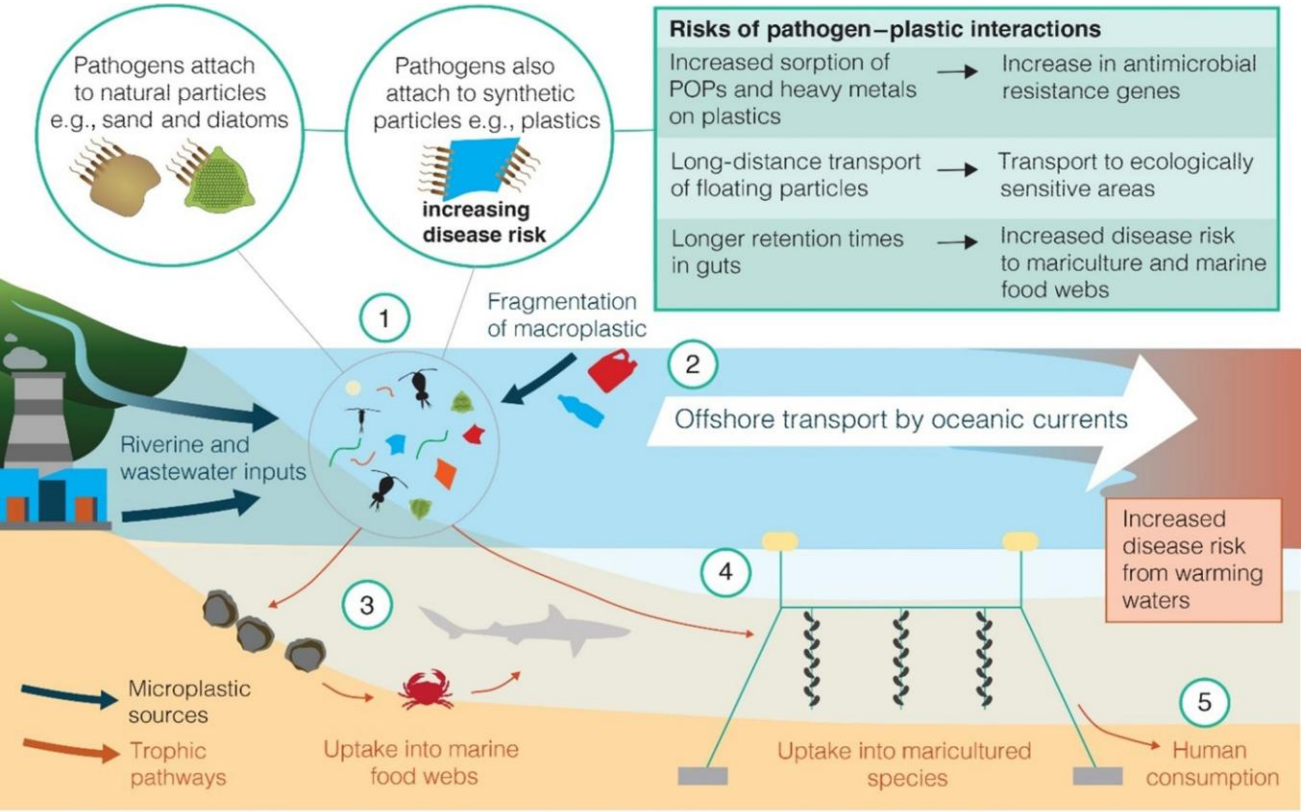
Microbes thrive on plastic, bringing biohazard risks that shouldn't be overlooked in efforts to tackle the pollution crisis.

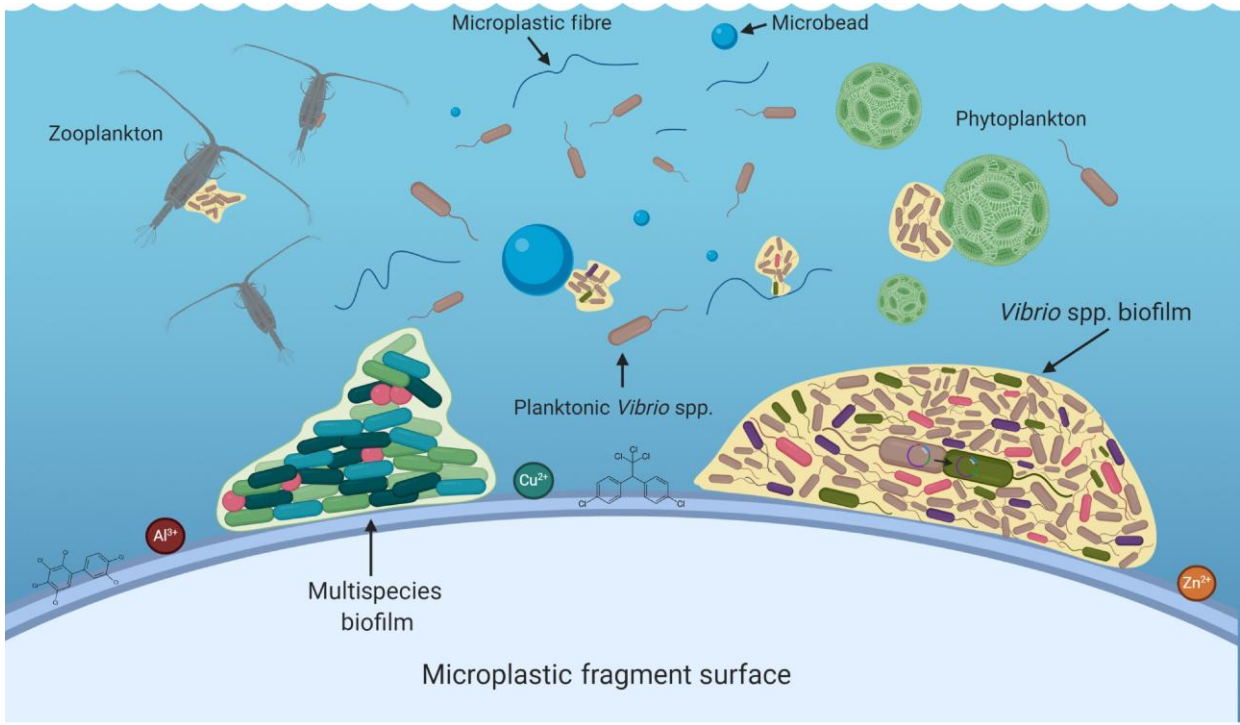
A fisher in Bangkalan, Indonesia, docks at a beach strewn with plastic waste.

SLIRYANTO SLIRYANTO/ANADOLU/GETTY

What lurks in plastic debris?

Changchao Li, Jian Liu, Matthias C. Rillig, Michael S. Bank, Peter Fantke, Dong Zhu, Yong-Guan Zhu & Ling N. Jin





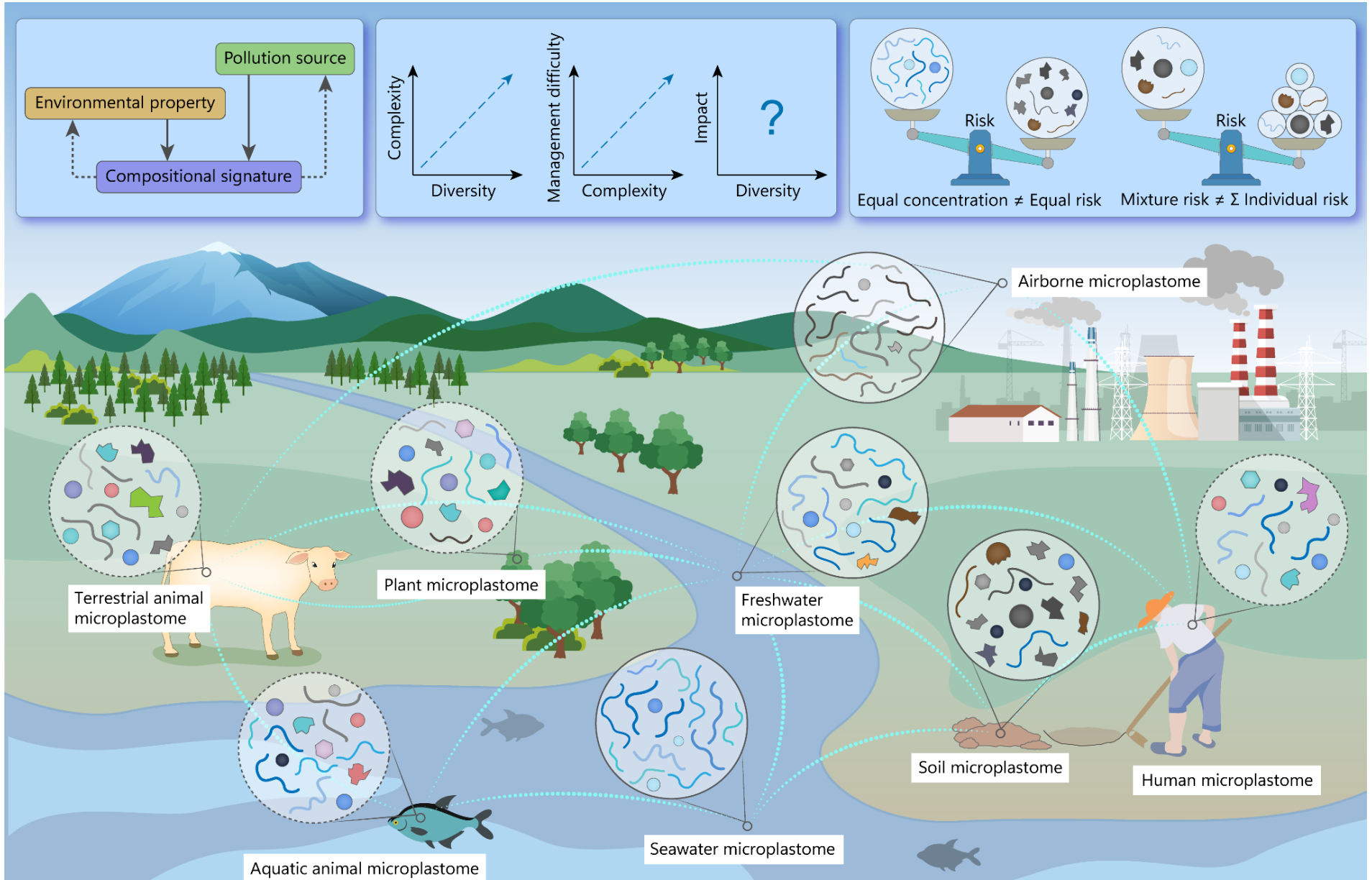
Microplastics and Human Health (Indirect Effects)

*Biofouling, Biofilm, The "**Plastisphere**" and the Role of MPs in Spread of Antibiotic Resistance*

Zettler, E.R., *et al*. (2013) introduced the term "***Plastisphere***" "to describe the distinct microbial communities that colonize plastic marine debris in aquatic environments."

Bank et al. 2020, Bowley et al. 2021, Guo et al. 2020

Microplastome Concept: A Holistic Approach

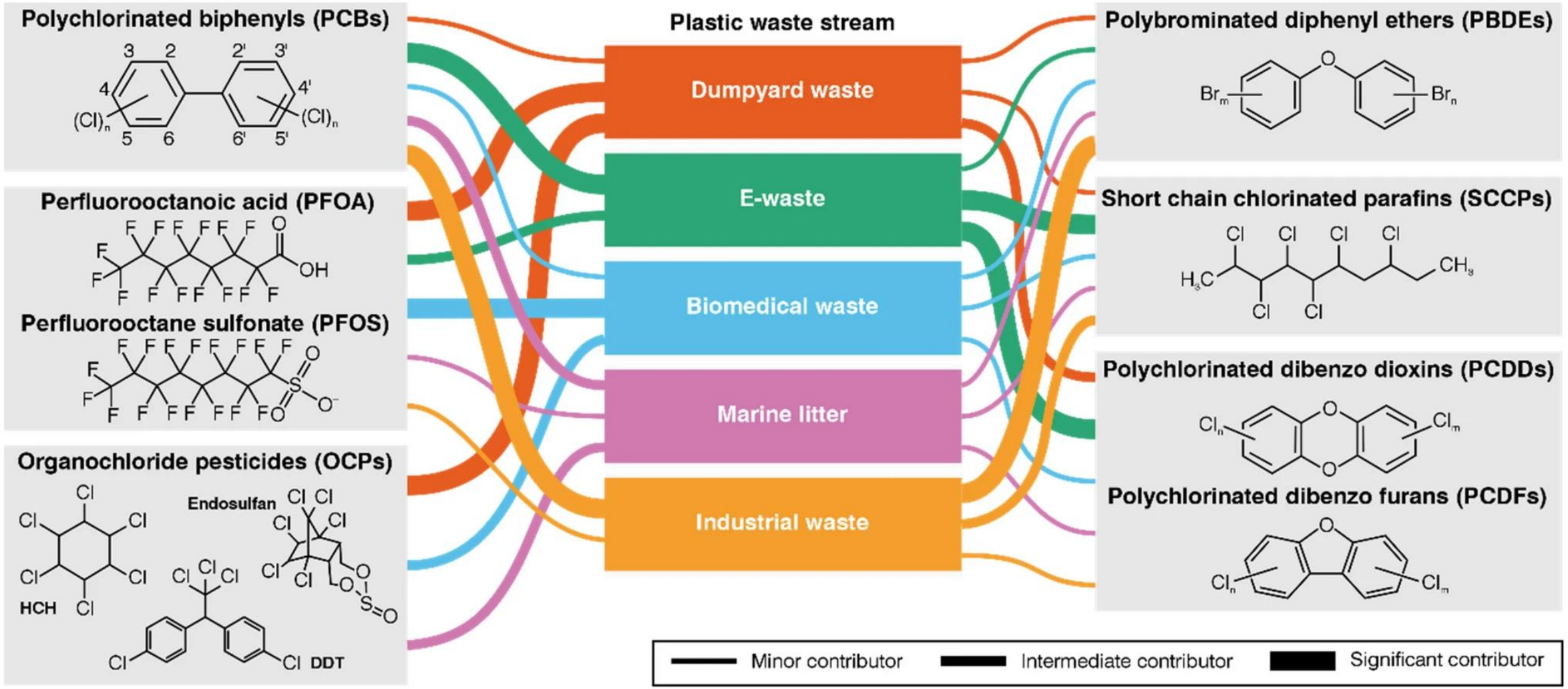


Li *et al*. 2024

Science to Support Public Policy & Global Monitoring
Global Plastic Observation System Model (GPOS)

Bank *et al*. (2021) *Environmental Science & Technology*

INDIA CASE STUDY:
Contribution and pathways of legacy and emerging POPs



Chakraborty et al. 2022

New UN Treaty on Plastics (INC 5.4) & UN Chemicals & Waste Panel

- **There is no legislation that is holistic and addresses the 'entire pollution lifecycle,' which includes production, consumption, and waste.**

- **Better chemical policy alignment is needed and financing details need to be refined.**

- **Lessons can be learned from other environmental conventions (Basel, Rotterdam, Stockholm, Minamata). Update UN approach (an old system needs to be updated to address 21st century global problems).**

- **Plastic production is one of the primary engines of climate change with 99% being made from fossil fuels.**

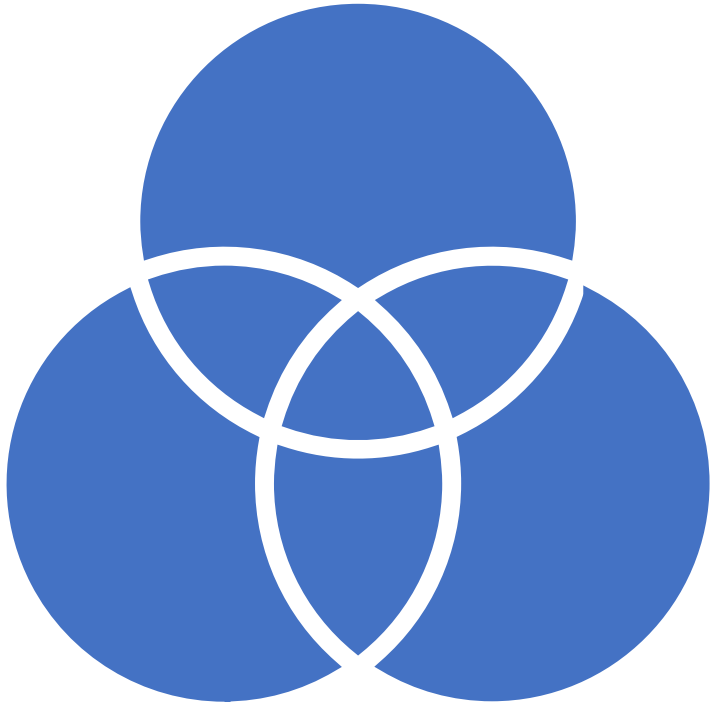
- **Preventing discharge and creating a safe, circular economy is critical to avoid a ten-fold increase in ocean MPs by 2100 (Bermúdez et al. 2025).**

- **Several Countries do not know how to properly consider scientific advice.**

Synthesis

- Microplastic generation and fate and transport is complex with many pathways.

- Public and policy awareness is high. Push for consensus. Solutions require multiple approaches and a wide array of stakeholders. Continued focus is needed on ‘upstream’ pollution and ensuring **production of plastic is included in public policy**.



- Biohazard and chemical risks can not be overlooked. **Remove chemicals from plastic!**

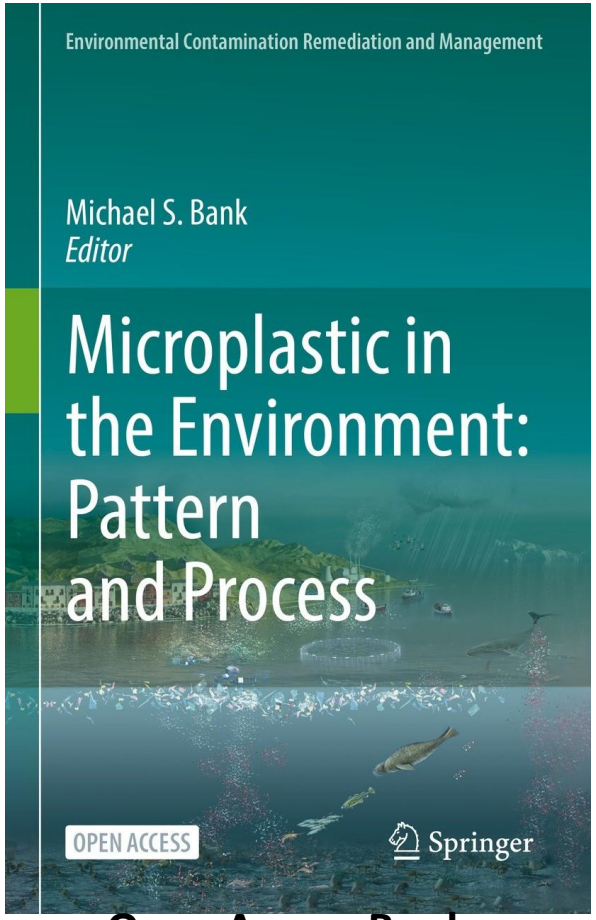
- **Identify Critical Human Health Pathways.**

Microplastic Research Prioritization, Outlook, & *Further Information….*

IDENTIFY MAJOR EMISSION POINT SOURCES INTO THE ATMOSPHERE, LITHOSPHERE, HYDROSPHERE, AND BIOSPHERE. **UNDERSTAND FLUXES AND IDENTIFY MICROPLASTIC HOT SPOTS, INCORPORATE SUSTAINABLE FOOD SYSTEMS**

DEVELOP GLOBAL MASS BALANCE MODELS AND VALIDATE MODELING STUDIES WITH OBSERVATIONS TO SUPPORT POLICY. ESTABLISH LINKAGES WITH BASEL CONVENTION AND UNEA. **MACHINE LEARNING ADVANCES** WILL BE IMPORTANT. COMPLEX SYSTEMS AND RESILIENCE MODELING WILL ALSO BE IMPORTANT

ANALYTICAL CHEMISTRY, **MICROPLASTIC-ANTIBIOTIC RESISTANCE CONNECTION, HUMAN HEALTH RISK ASSESSMENT STUDIES** (BISPHENOLS) & EPIGENETICS . UNDERSTAND HIDDEN COSTS OF PLASTIC ALTERNATIVES



Open Access Book

Questions & Collaborations - Michael.Bank@hi.no