Marine microplastics carry chemicals of concern from plastic additives even after fragmentation

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Researchers analyzed additive-derived chemicals in floating microplastics and larger plastic debris collected from coastal, offshore, riverine, and seafloor environments around Japan. They detected a wide range of chemicals, including antioxidants, plasticizers, ultraviolet stabilizers, and flame retardants, and identified Irgafos 168-related compounds, the plasticizer DEHP, and the flame retardant HBCD as chemicals of particular concern. These chemicals showed distinct environmental behaviors, including leaching from plastics, sorption from surrounding water and particles, and persistence during fragmentation and transport in marine environments. The findings show that fragmentation into microplastics does not necessarily reduce concerns about chemicals and highlight the need to consider the environmental fate of plastic-associated chemicals in risk assessment and management.

1. Background

Plastic pollution is not only a marine litter issue; it is also closely linked to resource circulation and chemical management. Plastic products contain a wide range of additives, including antioxidants, plasticizers, ultraviolet stabilizers, and flame retardants. Some of these chemicals are regulated or managed due to concerns about their effects on human health and ecosystems.

Once plastics enter the environment, exposure to sunlight and waves can cause degradation and fragmentation. Larger plastic debris may break down into microplastics, generally defined as plastic particles smaller than 5 millimeters. These smaller particles can disperse more widely in the marine environment. Fragmentation also increases the surface area of plastics relative to their mass, potentially affecting both the leaching of chemicals from plastics and the sorption of chemicals from surrounding water and particles.

2. Methods

A research team led by Go Suzuki of the National Institute for Environmental Studies, Japan, in collaboration with the Tokyo University of Marine Science and Technology and Nagasaki University, analyzed additive-derived chemicals in floating microplastics and larger plastic debris collected from coastal, offshore, riverine, and seafloor environments around Japan.

Floating microplastics were collected from five marine areas: Tokyo Bay, the Genkai Sea, Pacific coastal waters, waters off Hokkaido, and Japan Sea coastal waters. Larger plastic debris, including bags, ropes, nets, and hard fragments, was recovered from offshore and coastal areas across Japan, as well as from a river drainage pump station in Tokyo. The researchers identified the polymer types of the samples and analyzed extracted chemicals using gas chromatography–mass spectrometry.

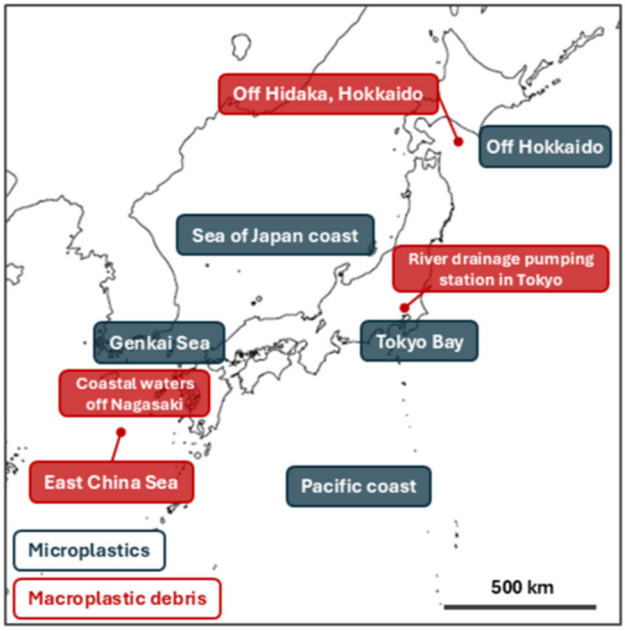

Figure1. Sampling areas and collection locations for microplastics and larger plastic debris around Japan.

Blue labels indicate marine areas where floating microplastics were collected from surface waters. Red labels indicate locations or regions where larger plastic debris was recovered from riverine, coastal, and seafloor environments.

3. Results and discussion

A wide range of chemicals were detected in both microplastics and larger plastic debris, including antioxidants, plasticizers, ultraviolet stabilizers, flame retardants, and polycyclic aromatic hydrocarbons. Based on detection frequency, concentration, and regulatory or management relevance, the researchers focused on three groups of chemicals: Irgafos 168-related compounds, di(2-ethylhexyl) phthalate (DEHP), and hexabromocyclododecane (HBCD).

Irgafos 168 is an antioxidant used to reduce oxidative degradation in plastics such as polyethylene and polypropylene. The distribution of Irgafos 168 and its oxidation products differed by polymer type and particle size. The observed patterns were consistent with leaching and transformation from within the plastic matrix.

DEHP is a plasticizer historically used primarily in flexible polyvinyl chloride products. It was widely detected in both microplastics and larger plastic debris. In some samples, concentrations exceeded 1,000 micrograms per gram (equivalent to 0.1% by weight). DEHP concentrations were higher in floating microplastics than in larger plastic debris recovered from the seafloor in both polyethylene and polypropylene samples. The results suggest that, in addition to chemicals remaining within plastics, DEHP present in surrounding water, suspended particles, and organic matter may be sorbed to microplastics from the surrounding environment.

HBCD is a brominated flame retardant that has been used in materials such as expanded polystyrene. Because it is persistent, bioaccumulative, and capable of long-range environmental transport, HBCD is regulated as a persistent organic pollutant. The researchers detected HBCD at concentrations of 110–590 micrograms per gram in microplastics collected from the Genkai Sea, Pacific coastal waters, and Japan Sea coastal waters. The findings indicate that fragmented plastic particles containing HBCD can remain mobile in the marine environment and may act as secondary sources of exposure.

The study shows that fragmentation does not necessarily remove chemical concerns associated with plastics that have entered the marine environment. Chemicals may leach from plastic matrices, may be sorbed to fragmented particles from the surrounding environment, or may remain in those particles during transport. Product-based chemical controls alone may not fully capture these processes after plastics enter the environment.

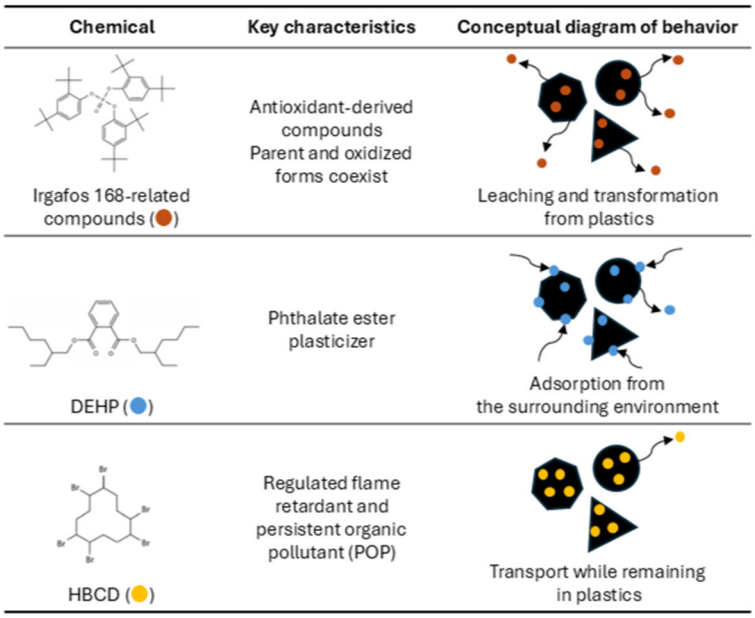

Figure2. Additive-specific pathways in marine-leaked plastics.

Conceptual illustration of the distinct environmental behavior of three substances highlighted in the study. Irgafos 168-related compounds are affected mainly by leaching and transformation from within the plastic matrices. DEHP may be sorbed to microplastics from the surrounding environment. HBCD can remain in fragmented particles during marine transport. The dots are schematic and do not quantitatively represent chemical concentrations or particle numbers.

4. Future perspectives

Further research is needed to determine how much of the chemicals associated with microplastics are taken up by organisms and whether they contribute to ecological effects. It is also important to identify the sources and release pathways of plastics containing chemicals of concern and to apply this knowledge to leakage prevention, selective collection, and appropriate treatment.

These findings provide a scientific basis for connecting measures to address marine plastic pollution with chemical management. They may also contribute to discussions on the international legally binding instrument on plastic pollution currently under negotiation.

This research was featured as the Supplemental Cover Art for Environmental Science & Technology, Vol.60, Issue 27. The cover image is available on the journal's issue webpage.

(https://pubs.acs.org/toc/esthag/60/27) (Opens in a new window)

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This study also partly utilized trawl samples obtained through a research project on marine debris floating on the ocean surface and settled on the seafloor in offshore waters around Japan, commissioned by the Ministry of the Environment, Japan.

6. Published article

【Title】

Priority Plastic Additives of Environmental Concern in Marine-leaked Micro- and Macroplastics: Occurrence, Distribution, and Management Implications

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Figure3. Supplemental Cover Art for the article in Environmental Science & Technology.

Supplemental Cover Art selected for the article "Priority Plastic Additives of Environmental Concern in Marine-leaked Micro- and Macroplastics:
Occurrence, Distribution, and Management Implications" in Environmental Science & Technology, Vol. 60, Issue 27.

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