Microplastic: An emerging threat to marine environment and a new tool for POP monitoring

Shige Takada

(Tokyo University of Agriculture and Technology)
Topics

International Pellet Watch: new indicator of marine pollution

Detection of microplastics in seafood and potential transfer of microplastic-associated chemicals to seafood and human
International Pellet Watch
Global Monitoring of Persistent Organic Pollutants (POPs)
Using Beached Plastic Resin Pellets

Since 2005

Laboratory of Organic Geochemistry, Dr. Hideshige Takada,
Tokyo University of Agriculture and Technology,
Fuchu, Tokyo 183-8509, Japan

More than 50 pieces (~100 pieces) per one location
Plastic Resin Pellets
Resin pellets, industrial feedstock of user plastics, are spilled during transport and manufacturing and they are widely distributed in the ocean.

- Resin pellets are produced in an industrial plant.
- Resin pellets are transported by truck to a factory.
- Urban runoff carries resin pellets into a river.
- River water flows into the ocean, carrying resin pellets.
- Seabirds ingest resin pellets, leading to strandings on beaches.
Plastic resin pellets on high-tide line on our beaches

Sakumono Beach, Ghana
Plastics accumulate organic pollutants from seawater

PCBs

- Industrial products for a variety of uses including dielectric fluid, heat medium, and lubricants.
- Endocrine disrupting chemicals

DDTs

- DDT and its metabolites such as DDE and DDD.
- DDT was used as insecticides
- Endocrine disrupting chemicals

HCH

- Insecticide

Mato et al. (2001), ES&T

PAHs

Polyethylene (PE)

Polypropylene (PP)
Pellets accumulate POPs from seawater

PCBs
- Industrial products for a variety of uses including dielectric fluid, heat medium, and lubricants.
- Endocrine disrupting chemicals

DDTs
- DDT and its metabolites such as DDE and DDD.
- DDT was used as insecticides
- Endocrine disrupting chemicals

HCH

Plastics
- Concentration factor is estimated to be $\sim 10^5$ to $\sim 10^6$.

PAHs

Adsorption from ambient seawater
International Pellet Watch
Global Monitoring of Persistent Organic Pollutants (POPs)
Using Beached Plastic Resin Pellets

Since 2005

Laboratory of Organic Geochemistry, Dr. Hideshige Takada,
Tokyo University of Agriculture and Technology,
Fuchu, Tokyo 183-8509, Japan

More than 50 pieces (~ 100 pieces) per one location
Analysis for persistent organic pollutants (POPs)

- Feed the data back to the collaborators via e-mail
- Releasing the results on web  http://www.pelletwatch.org/
200 samples from 40 countries
Analytical Procedure of POPs, PAHs, sewage marker sterols, and triclosans in Pellets

Plastic Resin Pellets

Sorting
near-infrared spectroscopy (PlaScan-SH)

Yellowing PE pellets

Soaking Extraction
n-Hexane

5%H2O-deactivated silica gel column chromatography

25%DCM/Hexane

Fully activated silica gel column chromatography
(0.46 cm i.d. x 18cm)

Hexane

Alkanes Hopanones

PCBs, DDE

PAHs DDT, DDD

Sterols Triclosans

DCM

Acetylation

GC-MS

GC-ITMS

GC-MS, GC-ECD

GC-MS
Commercial PCBs mixtures were used in a wide variety of applications, including:

- Dielectric fluids in capacitors and transformers
- Heat transfer fluid
- Copying paper
- Carbonless copy paper
- Adhesives
- Sealant

PCBs were used from 1950s to early 1970s in industrialized countries.

Their usage was banned in 1970s.
Concentration of PCBs* in beached plastic resin pellet (ng/g-pellet)

*sum of concentrations of CB#66, 101, 110, 149, 118, 105, 153, 138, 128, 187, 180, 170, 206

Measured by Polaris Q (Thermo Fisher Scientific)
Mussel Watch: Traditional Monitoring of pollution in coastal waters

Mussel Watch
Monitoring methodology of coastal pollution using bivalves as sentinel organism

Coastal Water

Buoy

Wharf Wall

Organic micropollutants
- Hydrocarbons
- PCBs
- Pesticides

Uptake

Accumulation

Heavy Metals

MUSSEL
(Mytilus galloprovincialis)
Correlation of PCB concentrations between beached pellets and mussels

\[ r^2 = 0.77 \]

*Data on mussels: after Yamaguchi et al. 2000, Monirith et al. 2003, NOAA 2007*
IPW targets on legacy and emerging pollutants

Polychlorinated biphenyl (PCBs)

DDTs

Polycyclic aromatic hydrocarbons (PAHs)

Polybrominated diphenyl ethers (PBDEs)

Triclosan (TCS)
Topics

International Pellet Watch: new indicator of marine pollution

Detection of microplastics in seafood and potential transfer of microplastic-associated chemicals to seafood and human
International Pellet Watch tells us that marine plastics carry hazardous chemicals in marine environments.

Concentration of PCBs* in beached plastic resin pellet (ng/g-pellet)
Sorption of chemicals occurs not only on pellets but on fragments.
Facilitated Leaching of Additive-Derived PBDEs from Plastic by Seabirds’ Stomach Oil and Accumulation in Tissues

Kosuke Tanaka, Hideshige Takada, Rei Yamashita, Kaoruko Mizukawa, Masa-aki Fukuwaka, and Yutaka Watanuki

†Laboratory of Organic Geochemistry, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan
‡Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Hokkaido 085-0802, Japan
§Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido 041-8611, Japan

Supporting Information

ABSTRACT: Our previous study suggested the transfer of polybrominated diphenyl ether (PBDE) flame retardants from ingested plastics to seabirds’ tissues. To understand how the PBDEs are transferred, we studied leaching from plastics into digestive fluids. We hypothesized that stomach oil, which is present in the digestive tract of birds in the order Procellariiformes, acts as an organic solvent, facilitating the leaching of hydrophobic chemicals. Pieces of plastic compounded with deca-BDE were soaked in several leaching solutions. Trace amounts were leached into distilled water, seawater, and acidic pepsin solution. In contrast, over 20 times as much material was leached into stomach oil, and over 50 times as much into fish oil (a major component of stomach oil). Analysis of abdominal adipose, liver tissue, and ingested plastics from 18 wild seabirds collected from the North Pacific Ocean showed the occurrence of deca-BDE or hexa-BDEs in both the tissues and the ingested plastics in three of the birds, suggesting transfer from the plastic to the tissues. In birds with BDE209 in their tissues, the dominance of BDE207 over other nona-BDE isomers suggested biological debromination at the meta position. Model calculation of PBDE exposure to birds based on the results of the leaching experiments combined with field observations suggested the dominance of plastic-mediated internal exposure to BDE209 over exposure via prey.
Transfer of chemicals from ingested plastics to biological tissue has been confirmed.

Biological effects concerned:
- e.g., endocrine disruption
- reproductive failure
- decline of species
Plastics are fragmented into smaller particles (i.e. microplastics) and various sizes of marine plastics are ingested by various sizes of marine organisms.
Microplastics in lower-trophic-level organisms

Microplastics in bivalves cultured for human consumption

Lisbeth Van Cauwenbergh, Colin R. Janssen

Ghent University, Laboratory of Environmental Toxicology and Aquatic Ecology, Jozef Plateaustraat 22, 9000 Ghent, Belgium

Ingestion of Microplastics by Zooplankton in the Northeast Pacific Ocean

Jean-Pierre W. Desforges, Moira Galbraith, Peter S. Ross

Fig. 1. Microplastics detected in the acid digested Mytilus edulis and Crassostrea gigas. A. Red particle recovered from Mytilus edulis; B. Green sphere detected in the soft tissue of Crassostrea gigas. (Scale bar: 50 μm) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. The feeding appendage anatomy of a N. cristatus and b E. pacifica suggest that the sizes of ingested microplastic particles were within the physical limits of mouth gape and handling capacity of setae. The average microplastic particle size detected in this study is shown in relation to the size of setae for both zooplankton species.

~ μm

~ μm
Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption

Chelsea M. Rochman, Akbar Tahir, Susan L. Willia, Jeffrey T. Miller, Foo-Ching Teh, Shinta Werorilang

Figure 3. Types of anthropogenic debris in market fish products sampled from Indonesia and the United States. The pie charts above show the percentage of each type (i.e. plastic fragments, fibers, plastic film, plastic foam and plastic monofilament) of anthropogenic debris found across all fish sampled from Indonesia (top) and the United States (bottom). Images show examples of each type of debris found. Scale bars on all pictures are set at 500μm.
Method

Dissection

Stomach contents

Hydrolysis with KOH

Identification of polymer type by using FTIR
Collecting microplastics in seawater of Tokyo Bay
Collecting microplastics in seawater of Tokyo Bay
Microplastics in seawater of Tokyo Bay
Invasion of plastics and associated chemicals to ecosystem
Marine organisms are exposed to hazardous chemicals through their natural prey and microplastics.
Plastic waste inputs to the sea will increase by a factor of **10 in coming 20 years**, if no action will be taken.

Jamebeck et al. (2015), Science
Marine organisms are exposed to hazardous chemicals through their natural prey and microplastics.

PCBs

Human

Cl
\[\text{Cl} \quad \text{Cl} \quad \text{Cl} \quad \text{Cl} \]

Cl
\[\text{Cl} \quad \text{Cl} \quad \text{Cl} \quad \text{Cl} \]

PCBs
Conclusion

Plastic resin pellets are a promising indicator of legacy and emerging hydrophobic pollutants.

Microplastics carry POPs to seafood

Questions

Importance of microplastic-associated path of POPs to food chain

We should know

• Concentrations of POPs in microplastics and their variations
• Concentrations of POPs in natural prey (e.g., plankton)
• Amounts of microplastics in the organisms
• Retention time of microplastics in the organisms
• Leaching rate of POPs from microplastics to digestive fluid