Please refer to the following paper by Law and Thompson, 2014 for question 1-6

OCEANS

Microplastics in the seas

Concern is rising about widespread contamination of the marine environment by microplastics

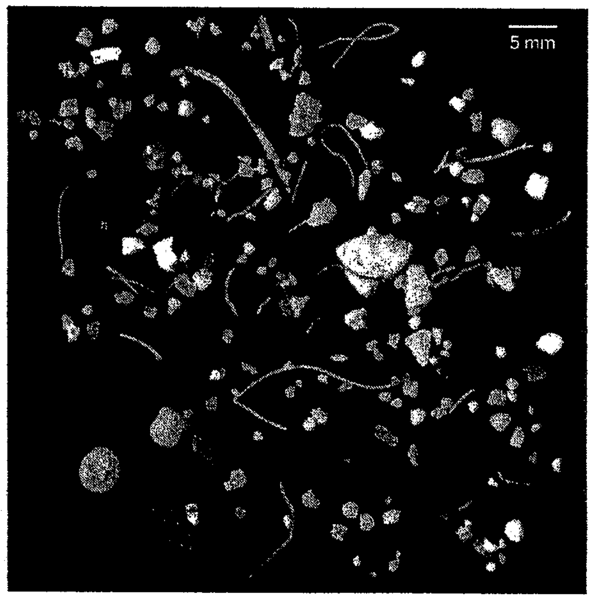
By **Kara Lavender Law**[1] *and* **Richard C. Thompson**[2]

Plastic debris in the marine environment is more than just an unsightly problem. Images of beach litter and large floating debris may first come to mind, but much recent concern about plastic pollution has focused on microplastic particles too small to be easily detected by eye (see the figure). Microplastics are likely the most numerically abundant items of plastic debris in the ocean today, and quantities will inevitably increase, in part because large, single plastic items ultimately degrade into millions of microplastic pieces. Microplastics are of environmental concern because their size (millimeters or smaller) renders them accessible to a wide range of organisms at least as small as zooplankton, with potential for physical and toxicological harm.

Since its introduction in the published literature in 2004 (*1*), the term microplastic has been widely used to describe plastic fragments in the marine environment. Typically considered to be smaller than 5 mm in diameter, microplastics are ill defined by size, with ranges that vary between studies. In most open-water studies, microplastics are measured with plankton nets, and particles smaller than the net mesh (typically ~0.33 mm) can evade capture. In marine sediment, bulk sampling can retain particles of all sizes; however, efficient identification is a serious challenge in quantifying microplastic loads, especially with decreasing size. Spectroscopic analysis has identified individual fragments of common plastics as small as 20 μm in diameter.

The sources of microplastic include fragmentation of larger items entering by rivers, runoff, tides, winds, and catastrophic events, together with at-sea sources, including lost cargo and fishing and aquaculture gear. There are also direct inputs of microplastics as micrometer-sized particles, such as cosmetic beads and clothing fibers that pass through wastewater treatment into the environment. Although the sources are well known, knowledge of their relative contribution and geographic distribution is limited.

Once in the ocean, floating microplastics are transported passively by complex two- and three-dimensional physical flows, resulting in very large variability in surface concentrations that makes detection of long-term trends difficult even in the heavily sampled western North Atlantic (*2*) and eastern North Pacific Oceans (*3*). Oceanographic models [including (*4*)] and environmental observations find very high concentrations (up to 10^6 pieces km^{-2}) of floating microplastic in subtropical ocean gyres, far from land-based sources. In these gyres, converging surface currents trap and retain floating debris. Similarly high concentrations have been observed in enclosed basins such as the Mediterranean Sea (*5*).



Microplastics everywhere. Microplastics collected from seawater, shorelines, or marine sediments are typically defined as particles with a diameter of 5 mm or less. Sources include larger deteriorating plastic items, as well as microbeads used in the cosmetics industry. The microplastics in the photo were collected in the North Pacific subtropical gyre with a surface plankton net.

In coastal sediments around the world, microplastics also appear to be ubiquitous, with quantities typically ranging from 2 to 30 particles per 250 ml of sediment (*6*). Arctic sea ice is the most recently identified reservoir of microplastics (*7*). With the exception of localized spills, the relationship between microplastic concentration and its sources is poorly understood because of complex transport mechanisms and unknown fragmentation rates.

Because of their size, microplastics may have different effects from larger items of debris. For example, floating microplastics in open ocean gyres provide habitats for diverse communities of microorganisms, with assemblages that differ from those in surrounding seawater and that vary with polymer type (*8*). Furthermore, microplastics may be ingested by many diverse organisms, and some animals such as mussels can retain particles after ingestion (*9*); ingestion of small quantities of microplastics can disrupt physiological processes in marine worms, compromising their ability to store energy (*10*).

Plastic debris readily accumulates harmful chemicals such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) from seawater worldwide (*11*), increasing their concentration by orders of magnitude. This process is reversible, with microplastics releasing contaminants upon ingestion (*12*) and laboratory evidence of uptake in marine worms (*13*) and fish (*14*). Transfer depends on the polymer, contaminant, and conditions in the organism, particularly pH and temperature. These interactions are specific but not yet fully predictable (*15*). There is also concern that plastic debris might release monomers and potentially toxic additives such as plasticizers, flame retardants, and antimicrobial agents that are incorporated into plastics during manufacture.

This emerging evidence of harm comes primarily from laboratory studies. It is unclear whether microplastics in the environment transport chemicals to biota in concentrations high enough to cause substantial damage. The potential for harm from microplastics could increase with decreasing particle size, but size distributions and generation and degradation rates are essentially unknown, and the resulting effects on natural populations are difficult to ascertain. Nevertheless, ingestion of microplastics by mammals, fish, birds, and invertebrates is now well documented. Although quantities can be low, the widespread incidence in some natural populations together with evidence of potentially harmful effects is cause for concern.

Major questions remain about the risks from microplastics to marine organisms and ecosystems, as well as to food safety and public health. Research is urgently needed on the behavior of different polymers in the environment, including fragmentation, chemical release, degradation, transport, and accumulation; the rate at which organisms encounter microplastics, based on particle size and degradation time; and the physical, chemical, and interactive risks to organisms from these encounters, including possible magnification with increasing trophic level (biomagnification).

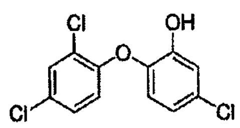
Given the concerns over microplastics, the temptation may be to "clean up the mess," but substantial removal of microplastic debris from the environment is not feasible. Identification and elimination of some of the major inputs of plastic waste is a more promising route, as is reduced consumption and the recognition of plastic waste as a resource. With the rapidly increasing human population, the need for greater resource efficiency could have a secondary benefit in reducing the quantities of debris entering the environment. ■

REFERENCES

1. R. C. Thompson *et al.*, *Science* **304**, 838 (2004).
2. K. L. Law *et al.*, *Science* **329**, 1185 (2010).
3. K. L. Law *et al.*, *Environ. Sci. Technol.* **48**, 4732 (2014).
4. N. Maximenko, J. Hafner, P. Niiler, *Mar. Pollut. Bull.* **65**, 51 (2012).
5. A. Collignon *et al.*, *Mar. Pollut. Bull.* **64**, 861 (2012).
6. M. A. Browne *et al.*, *Environ. Sci. Technol.* **45**, 9175 (2011).
7. R. W. Obbard *et al.*, *Earth's Future*, (2014); http://onlinelibrary.wiley.com/doi/10.1002/2014EF000240/abstract.10.1002/2014EF000240.
8. E. R. Zettler, T. J. Mincer, L. A. Amaral-Zettler, *Environ. Sci. Technol.* **47**, 7137 (2013).
9. M. A. Browne, A. Dissanayake, T. S. Galloway, D. M. Lowe, R. C. Thompson, *Environ. Sci. Technol.* **42**, 5026 (2008).
10. S. L. Wright, D. Rowe, R. C. Thompson, T. S. Galloway, *Curr. Biol.* **23**, R1031 (2013).
11. Y. Ogata *et al.*, *Mar. Pollut. Bull.* **58**, 1437 (2009).
12. E. L. Teuten *et al.*, *Phil. Trans. R. Soc. B* **364**, 2027 (2009).
13. M. A. Browne, S. J. Niven, T. S. Galloway, S. J. Rowland, R. C. Thompson, *Curr. Biol.* **23**, 2388 (2013).
14. C. M. Rochman *et al.*, *Nat. Sci. Rep.* **3**, 3263 (2013).
15. A. Bakir, S. J. Rowland, R. C. Thompson, *Environ. Pollut.* **185**, 16 (2014).

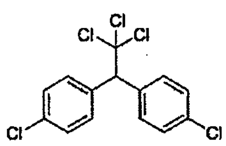
Reference: Law, K.L., Thompson, R.C., "Microplastics in the seas." Science, 2014, 345, (6193), 144 - 145

Triclosan



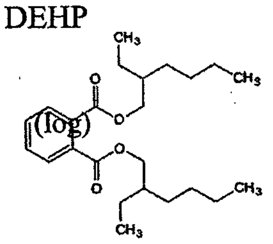
MW = 290
pKa = 7.9
logKow = 4.8
Boiling point = 120°C
Melting point = 56°C

DDT



MW = 354.5
pKa = 16[a]
logKow = 6.9
Boiling point = 185°C
Melting point = 108.5°C

DEHP



MW = 390.6
pKa = 4.2–5.1[b]
logKow = 7.6
Boiling point = 385°C
Melting point = −55°C

[a] William H et al. (1976), *Accounts of Chemical Research, 9(1), 19-25*

[b] Hopf N.B. et al. (2014), *Toxicology letters, 224(1),*

MW: molecular weight
log Kow: octanol/water partition coefficient

※ 注意：請於試卷內之「非選擇題作答區」作答，並應註明作答之題號。

1. Microplastics are typically defined as particles with a diameter. (6 points)
a) < 0.33 mm
b) < 0.005 m
c) < 20 mm
d) < 0.02 mm
e) 10^{-6} km

2. Which one below is NOT the source of microplastics in the seas. (6 points)
a) cosmetic beads
b) clothing fibers
c) larger deteriorating plastic items
d) marine worms and fish

3. Which one below is NOT the concern of microplastics. (6 points)
a) Microplastics accumulates persistent contaminants such as PCBs.
b) Microplastics might release toxic additive such as antimicrobial agents used in the household.
c) Microplastics has been found ubiquitous around the world including coastal sediments and seas.
d) Microplastics undergo biomagnification and become larger in size throughout times.

4. Which one below could be the concentration unit for trace contaminants such as DDT or PBDEs in the aquatic environments. (6 points)
a) 10 μg/L
b) 10 pieces/km^2
c) 10 particles/mL
d) 10 kg/mL
e) 10 particles/L

5a. DDT is the insecticide, triclosan is one of the commonly used antimicrobial agent, and DEHP is the plasticizer. All of them have the potential to be incorporated into plastics during manufacture and being released later with the plastic debris. Once released to the environment, which one would have the lowest potential to be sorbed onto the sediments according to the information given in the table. (6 points)
a) Triclosan
b) DEHP
c) DDT

5b. Please explain your choice for 5a. (5 points)

6. Using the information given in the table, which one (Triclosan, DEHP or DDT) could be potentially more toxic and of greater concern to marine mammals. <u>Please explain your reasoning in detail.</u> (10 points)

7. Please explain the following terms and their environmental concerns. (25 points)
   a) Environmental justice
   b) Low impact development
   c) Volatile organic compounds
   d) Temperature inversion
   e) Nonpoint source of water pollution

8. Water and energy are two major components in the global search for sustainable development. Please explain the meaning of water-energy nexus. (10 points)

9. Please draw a schematic of nitrogen cycle, consisting of the 4 major steps. (10 points)

10. What is the bioaccumulation/biomagnification of mercury and its environmental implication? (10 points)

試題隨卷繳回