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Emerging Issues of Environmental Concern

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Microplastics: Trouble in the Food Chain

Plastics in the environment

As the world's demand for plastic materials continues to grow, management of plastic waste will remain a global challenge. In 2014, global plastic production exceeded 311 million metric tons, a 4.0 per cent increase over 2013.[1] In 2010, out of 2.5 billion metric tons of solid waste generated by 192 countries, about 275 million tons consisted of plastic. It has been estimated that between 4.8 and 12.7 million tons ended up in the ocean as a result of inadequate solid waste management.[2]

Concern about visible plastic debris is increasing, while recent research reports the growing presence and abundance of microplastics in marine environments.[3-6] These small plastic pieces, between the size of a virus and an ant, now can be found worldwide: in the water of lakes and seas, in the sediments of rivers and deltas, and in the stomachs of various organisms ranging from zooplankton to whales. Microplastics have been detected in environments as remote as a Mongolian mountain lake and deep sea sediments deposited five kilometres below sea level.[7-9] One study estimated that, on average, every square kilometre of the world's oceans has 63,320 microplastic particles floating at the surface, with significant regional variations–for example, concentrations in East Asian seas are 27 times higher.[10,11] Marine organisms–including zooplankton, invertebrates, fishes, seabirds and whales–can be exposed to microplastics through direct ingestion of water and indirectly as predators in food webs.

Plastics that are originally manufactured in a particularly small size for specific applications are called primary microplastics. In the marine environment, plastic debris of every size can be mechanically broken down into smaller pieces by external forces such as UV radiation, wind, waves, or animals. This physical weathering produces secondary microplastics.[6,12]

Further breakdown of plastic into ever-smaller particles does not lead to a complete degradation into monomers. Instead, the original plastic polymer remains intact at microscopic scale unless the original polymer is converted into carbon dioxide, water, methane, hydrogen, ammonia, and other inorganic compounds, a process of biodegradation influenced by external conditions and the properties of the particular plastic polymer. This generally does not happen to plastics in the aquatic environment.

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Microplastics

The term 'microplastics' is widely used to describe plastic particles with the size ranging from 1 nanometre to 5 millimetre[22]

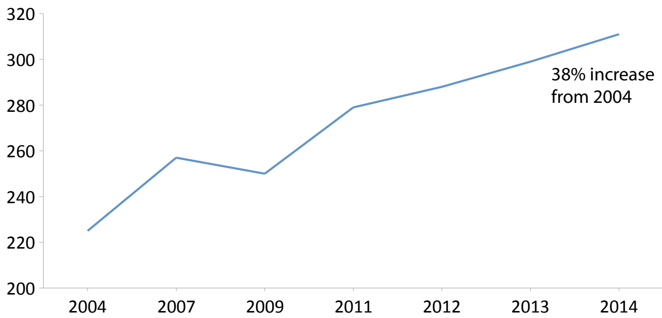
Monomer

Monomers are molecules capable of combining, by a process called polymerisation, to form a polymer. For example, the monomer ethylene (C_2H_4) is polymerised into a chain, using a catalyst, to form polyethylene $(C_2H_4)_n$

Polymer

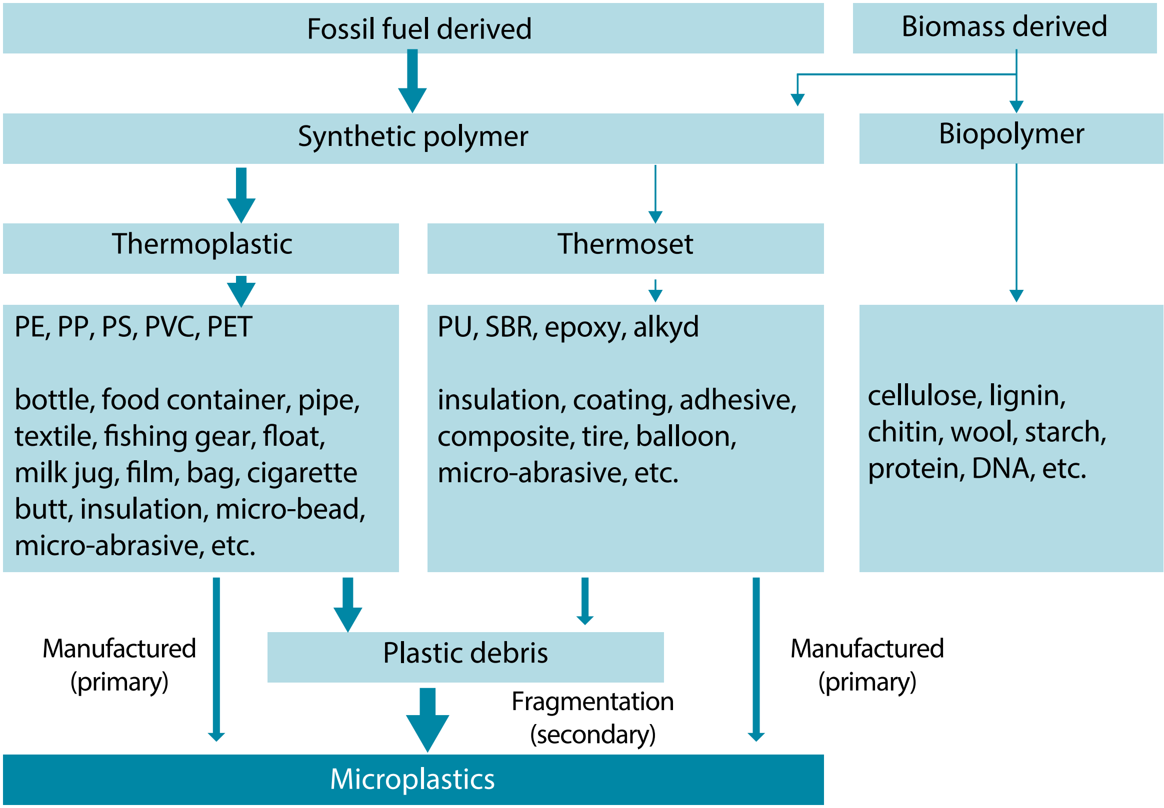
Polymers are large organic molecules composed of repeating carbon-based units or chains that occur naturally and can be synthesised. Common natural polymers include chiton (insect and crustacean exoskeleton), lignin (cell walls of plants), cellulose (cell walls of plants), and protein fibre (wool, silk)[6]

Global plastics production (metric tonnes)



Data source: PlasticsEurope (2015)

Schematic illustrating the relationship between primary materials source, synthetic and natural polymers, thermoplastic and thermoset plastics and their applications



Source: GESAMP (2015)[22], UNEP (2016)[6]

Exposure to UV radiation, oxygen, high temperatures, and microbial activity for an optimal duration can bio-degrade some types of plastic. Those made from polymers such as aliphatic polyesters, bacterial biopolymers, and some bio-derived polymers can be biodegradable in the natural environment. However, many plastics labelled as biodegradable–including single-use plastic shopping bags and take-away food containers–will breakdown completely only when subjected to prolonged temperatures above 50°C. These are the conditions produced in an industrial composter. Such conditions are rarely met in the marine environment.[5]

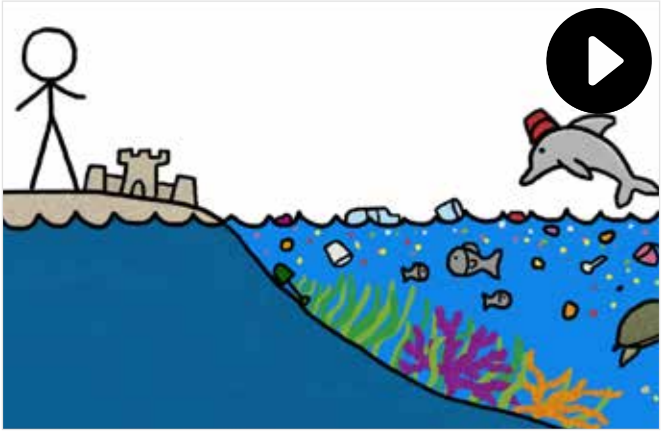
Biodegradable

Capable of being degraded by microorganisms such as bacteria and fungi. Biodegradation refers to a biological process of organic matter being completely or partially converted to water, carbon dioxide, methane, energy, and new biomass by microorganisms (UNEP 2015).

Chemical additives are often included during plastic manufacturing to generate or enhance certain properties. These properties often make the material more durable by introducing anti-microbial, flame retardant, UV resistance, rigidity, malleability, or waterproofing characteristics. Such enhanced plastic products include packaging materials, containers and bins, fishing nets, bottles, pipes, and furniture. After the product becomes waste, the chemical additives can potentially leach into marine organisms when they ingest the plastic and their systems attempt to digest. Potential adverse effects, at high enough concentrations, may include immunotoxicological responses, reproductive disruption, anomalous embryonic development, endocrine disruption, and altered gene expression.[13-17]

Photo Credit: Avemario/ Shutterstock.com

Video: Ocean Confetti!



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Video Link: https://www.youtube.com/watch?v=qVoFeELi_vQ

Video: What really happens to the plastic you throw away

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Video Link: https://www.youtube.com/watch?v=_6xlNyWPpB8

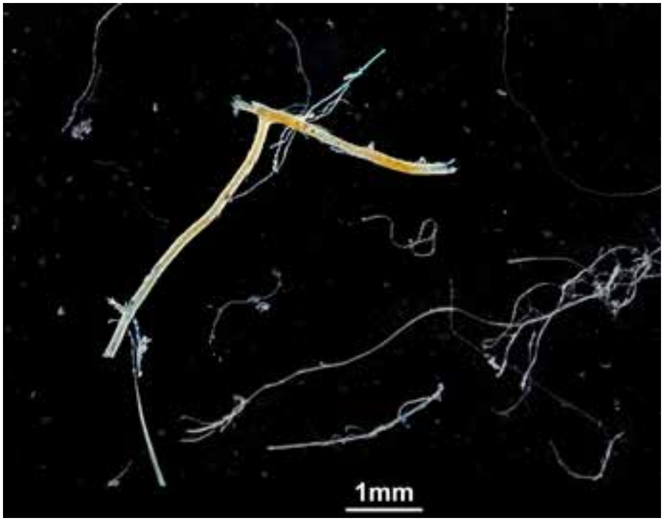
Photo Credit: Sascha Corti/ Shutterstock.com

Common sources of microplastics

In the late 1990s, cosmetic and personal care manufacturers began to market 'microbeads' as abrasives in skin cleansers, toothpaste, shaving cream, and similar products. Researchers monitoring water quality began to find microbeads in public water reservoirs and natural environments by the mid 2000s. Investigators were able to trace the particles to the personal hygiene use in communities upstream of rivers, lakes, and seas.[18-20] Following public awareness campaigns widely supported by consumers, some producers responded by agreeing to remove the material from their goods.[21] The microbead issue has attracted considerable international attention and generated significant actions to address the pollution, particularly in Europe and North America. However, similar particles are still being introduced into water systems in other regions. Without appropriate wastewater treatment to capture particles of that size, microplastic will remain an important pollutant given extensive use of primary microplastics in industry and the generation of secondary microplastics in many sectors.[22]

For instance, an abrasive application was designed as an alternative to stripping paint with toxic chemicals: primary microplastics are commonly used for surface blasting to remove rust, paint, and other unwanted surface coverings on buildings, cars, ships, and aircraft.[22,23] While the abrasives are used repeatedly, they eventually break down to unsuitable size and are discarded. During their useful life, these plastic materials can become highly contaminated with heavy metals from the surface covering, such as cadmium, chromium, and lead.[19,24]

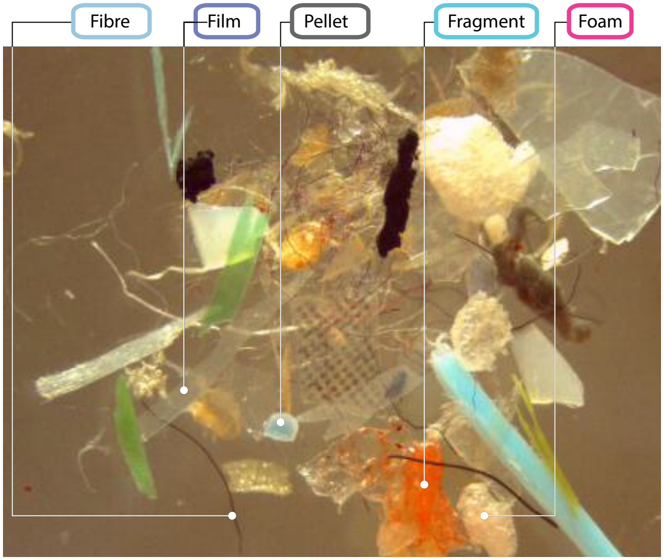
Growing evidence suggests that fibres from synthetic fabrics are a significant source of secondary microplastics commonly found in wastewater and in the aquatic environment.[25-28] The world's consumption of synthetic fibres as clothing and textiles for domestic and industrial uses exceeded 55 million tonnes in 2013, or 61 per cent of the global consumption of all fibres.[12] This reveals a sharp increase from 35.8 million tonnes



Mcroplastic filaments found in the deep-sea sediments[9]
Photo Credit: Courtesy of the Natural History Museum, London

Microplastics collected from a sandy shoreline in Europe (Wright *et al.* 2013)[45]
Photo Credit: This image was published in Current Biology, Vol.23, Wright *et al.* 2013, Copyright Elsevier (2013)

Different types of microplastics found in the Francisco Bay



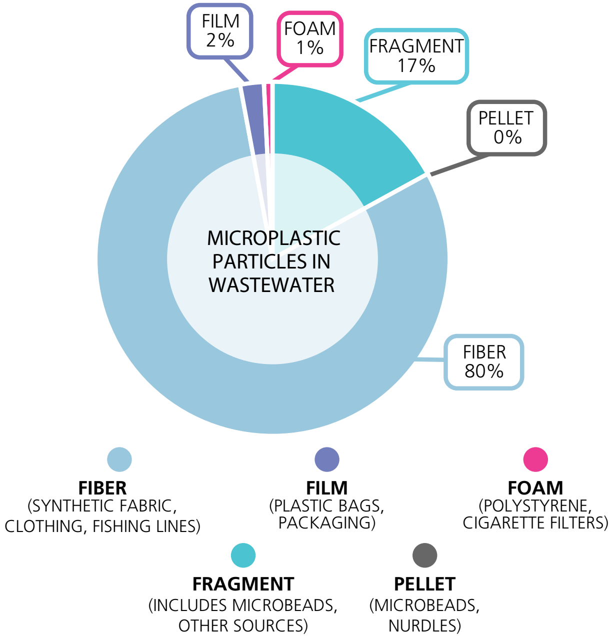


Photo Credit: Sherri A. Mason/State University of New York at Fredonia
Source: San Francisco Estuary Institute (2015)[43]

in 2009.[29] Plastic fibres–polyester, acrylic, and polyamides–are shed from garments through mechanical abrasion in washing machines and then drained with the effluent water.

The Norwegian Environment Agency found that emission of microplastic in wastewater from washing synthetic clothing is an order of magnitude higher than that from the personal care products and cosmetics.[12] Experiments show that more than 1,900 microplastic fibres are released from a single synthetic garment in just one wash by a laundry machine.[30] Their microscopic size and buoyancy allows these microplastic pollutants to pass through both the coarse (larger than 6 millimetre) and fine (1.5-6 millimetre) screen filters that are most commonly used in wastewater treatment facilities. They then end up in sludge or in natural water bodies that receive the effluent. Researchers estimate that about 10 per cent of synthetic fibres present in the wastewater can pass undetected through the treatment facility.[31]

Another source of microplastic pollution is the plastic debris from mechanical abrasion of car tyres on pavement that is washed by rain, snow melt, and street cleaning into natural and municipal drainage systems.[6] On-going research focuses on potential sources of microplastics. One monitoring and sampling investigation, conducted over many months of 2014 and 2015, suggests that atmospheric fallout delivers microplastics to whole landscapes, and to any closely associated marine environments. The study sampled an urban site and a suburban site in the region of Paris, France, and found fibres made up most of the microplastic deposition, that deposition at the urban site notably exceeded the suburban site, and that nearly 30 per cent of the fibres were synthetic, specifically made from hydrocarbons.[32]

Plasticized food chains

Numerous studies in recent years have provided more evidence on the presence, distribution, and starting sources of microplastic. However, the current stage of knowledge does not provide a definitive explanation of how microplastic contaminants interact chemically and physiologically with various organisms at different trophic levels. Ultimately, the risks microplastics pose to human health through consumption of contaminated food need to be considered, but these are still difficult to determine. Researchers are attempting to answer these questions with focus on specific areas. First is the level of exposure.

In a recent study, a quarter of the marine fish sampled from markets in Indonesia and California, USA, were found to have plastic debris and fibres from textiles in their guts.[33] Besides seafood, emerging evidence shows that the microplastics, especially synthetic fibres, have been detected in a variety of foods, including drinking water, beer, honey, sugar, and table salt.[34-36] The presence of microplastic in foodstuffs could potentially increase direct exposure of plastic-associated chemicals to humans and may present an attributable risk to human health. However, on the basis of current evidence, the risk to human health appears to be no more significant than via other exposure routes.[6]

Many chemicals of concern, such as heavy metals and persistant organic pollutants (POPs) are present in the marine environment, and are taken up by marine organisms. Research has shown that harmful and persistent substances both bioaccumulate over time and biomagnify as predators eat prey, especially in species high in lipids (oils and fats). Depending on how much an organism consumes and how high it is on the food chain, each assumes some of the chemical burden of the prey and of the environment.[37] In this manner seafood can become contaminated, particularly in higher-level predators such as tuna and swordfish, causing concern for human health, in some circumstances.[38]

Many POPs are hydrophobic, meaning they are repelled by water. When these chemicals encounter plastics in lakes and oceans, they are absorbed into the plastic surface. The degree of adsorption varies widely depending on different characteristics of the POP and its host, as well as other environmental variables. However, plastic resin pellets collected from the oceans and beaches have been found to contain POPs at orders of magnitude higher concentrations than the water.[39]

Heavy metals

Heavy metals normally occur in nature and are essential to life, but can become toxic through accumulation in organisms. Arsenic, cadmium, chromium, copper, nickel, lead and mercury are the most common heavy metals which can pollute the environment. Sources of heavy metals include mining, industrial production, untreated sewage sludge and diffuse sources

Persistent organic pollutants

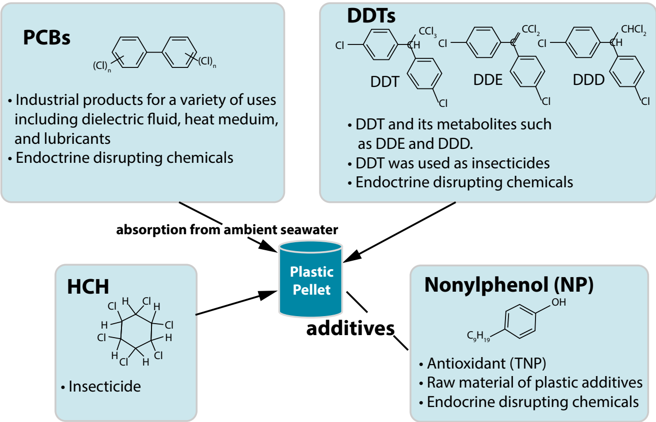
Persistent organic pollutants (POPs) are chemical substances that remain in the environment, are transported over large distances, bioaccumulate through the food web, and pose a risk of causing adverse effects to the environment and human health. POPs include pesticides such as DDT, industrial chemicals such as polychlorinated biphenyls (PCB) and unintentionally generated chemicals such as polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF)

Bioaccumulate

The accumulation of a substance, such as a toxic chemical, in various tissues of a living organism. Bioaccumulation takes place within an organism when the rate of intake of a substance is greater than the rate of excretion or metabolic transformation of that substance

Usually, when microplastics and the contaminants they sequester are detected in seafood, they are in the animal's stomach. Except for shellfish, humans tend to remove and discard the stomach of the seafood they consume. The risk of chemical contaminants being transferred to humans would then depend on: i) the retention time of the particles in the fish gut, ii) the rate and degree to which contaminants are released from the plastic and cross the gut wall, iii) the degree to which fine particles might be translocated from stomach to other tissues of animals, and iv) the degree to which chemical contaminants can transfer from the consumed seafood to human body.[22,40] At present scientists only have results from laboratory feeding studies using non-commercial fish species to examine contaminant transfer and accumulation in the tissues and that note any altered predatory behaviour. A number of these experiments with a range of marine species show that microplastics are able to translocate from stomach to other organs such as liver and hepatopancreas.[41,42] Currently there is insufficient evidence to assess the potential for transfer of these contaminants to the fish flesh, and hence be made available to predators, including humans.[6,40]

Different types of microplastics found in the Francisco Bay



Courtesy of International Pellet Watch (2016)[44]

Plastic resin pellets

Plastic resin pellets are the raw material for the manufacturing process of plastic items

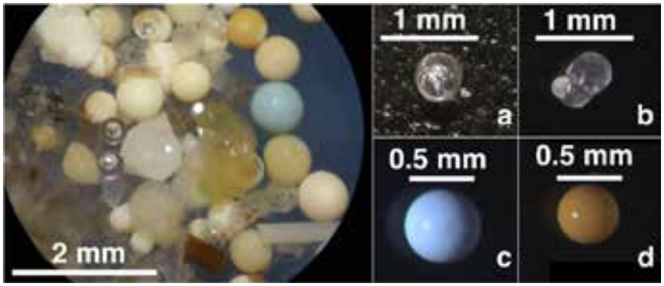
Biomagnify

The increasing concentration of a substance, such as a toxic chemical, in the tissues of organisms at successively higher levels in a food chain. As a result of biomagnification, organisms at the top of the food chain generally suffer greater harm from a persistent toxin or pollutant than those at lower levels.

Video: Are microplastics in our water becoming a macroproblem?

© National Geographic
Video Link: https://www.youtube.com/watch?v=ZHCgA-n5wRw
Photo Credit: Coprid/ Shutterstock.com

Microplastic typically found along the Rhine River



Opaque spherules, fragments and fibres;
(a/b) transparent spherules with gas bubbles, polymethylmethacrylate;
(c/d) opaque spherules, polystyrene

Source: Mani *et al.* (2015)[26]

Addressing the issue at the source

While more research to investigate the physiological, biological, and chemical interactions between microplastic and organisms is underway, it is imperative to continue with the effort by all stakeholders to reduce new influx of plastic into the environment. Concerted efforts have been made by various stakeholders to tackle the issue of microplastics at the source including governments, private sector and NGOs. The Netherlands intends to become the first country to be free of microbeads in cosmetics by the end of 2016. Member companies of the Dutch Cosmetics Association are working towards removing microbeads from their products. By 2017, 80 per cent of the companies are expected to have completed the transition to a microbead-free product line. In December 2015, the United States passed a law that prohibits the sale and distribution of cosmetic products containing plastic microbeads with a phase-out period until 1 July 2017 when the bead manufacturing will be completely banned. The legislation also preempts state laws and regulations related to microbeads, which helps close some loopholes, such as banning only non-biodegradable plastic microbeads. Other countries such as Australia, Canada, and the United Kingdom are following suit.

As a front runner in raising awareness of the issue and campaigning against the use of microbeads, the Beat the Microbead initiative has so far attracted more than 79 NGOs from 35 countries and 59 companies in the cosmetic industry to join the effort. A smartphone App developed by the initiative has been used by consumers around the world to scan the bar code to check for the presence of microbeads in personal care products available in the market.

The European Union through its project, MERMAIDS, works to address the issue of microplastic fibres released through textile washing processes into the European waters. The project is investigating different technologies that can capture released fibres in the washing process, or prevent the breakage of fibres from garments through innovative textile or detergent additives.

Starting in 1992, with the goal to minimise the impact of pellet leakage into the environment, the Operation Clean Sweep initiative has become even more relevant as the issue of microplastic has become a global challenge. It is an example of industry-driven effort with the aim to prevent raw plastic materials such as plastic pellets, flakes, and powder from entering the waste stream. Targeting different segments of the plastic industry including supplier, manufacturer, and transport operators, the initiative aims to achieve a zero loss of these materials through better containment, reclamation, and proper disposal.

Further engagement of other relevant industries that use primary microplastics in their industrial processes or indirectly generate secondary microplastics is crucial. Textile industries may have an important role to play in research and development for synthetic textiles that shed fewer fibres, or simply minimise the use of synthetic material in their products. Involvement of the producers of washing machines

Video: Operation Clean Sweep

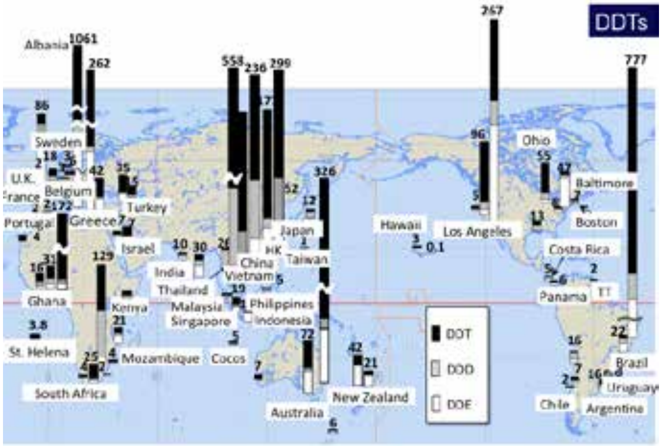
Video Link: https://www.youtube.com/watch?v=54QQ8t8TePY
Photo Credit: XXLPhoto/ Shutterstock.com

is necessary for the enhancement of filtering capacity to effectively capture microscopic fibres from drain water. The shipyard, aviation, and automobile industries are key in the reduction of microplastic leakage through the effective containment and appropriate disposal of spent abrasive blasting materials and generated dust.

Recognizing the environmental and economic impacts of plastics in the marine environment, in June 2014 the United Nations Environment Assembly, represented by over 163 countries, adopted a resolution on marine plastic debris and microplastics to address the issue through legislation, improved waste management, efficient use and sound management of plastics, enforcement of international agreements, and education. The G7 summit in June 2015 expressed their commitment to address the land-based and sea-based sources of marine litter by improving waste management, searching for sustainable solutions to reduce or prevent microplastic pollution, and promoting best practices throughout the plastic value chain. In September 2015, world leaders agreed on a specific target to "prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution" by 2025 (SDG Target 14.1) of the Sustainable Development Goals (SDGs). However, indicators to be used for monitoring progress towards the target are currently under development among governments and stakeholders.

Photo Credit: UN Photo/Martine Perret

Concentration of DDTs in plastic resin pellets collected from beaches around the world



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Concentration of PCBs in plastic resin pellets collected from beaches around the world

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References

1. PlasticsEurope (2015). Plastics - the Facts 2015. http://www.plasticseurope.org/Document/plastics---the-facts-2015.aspx

2. Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R. and Law, K.L. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768-771. http://science.sciencemag.org/content/347/6223/768.full-text.pdf+html

3. UNEP (2011). UNEP Year Book 2011: Emerging issues in our global environment. United Nations Environment Programme, Nairobi. http://www.unep.org/yearbook/2011

4. UNEP (2014). UNEP Year Book 2014: Emerging issues in our global environment. United Nations Environment Programme, Nairobi. http://www.unep.org/yearbook/2014

5. UNEP (2015). Biodegradable Plastics and Marine Litter: Misconceptions, concerns and impacts on marine environments. United Nations Environment Programme, Nairobi. http://www.unep.org/gpa/documents/publications/BiodegradablePlastics.pdf

6. UNEP (2016). Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change. United Nations Environment Programme, Nairobi.

7. Free, C.M., Jensen, O.P., Mason, S.A., Eriksen, M., Williamson, N.J. and Boldgiv, B., (2014). High-levels of microplastic pollution in a large, remote, mountain lake. Marine Pollution Bulletin, 85(1), 156-163. http://www.sciencedirect.com/science/article/pii/S0025326X14003622

8. Van Cauwenberghe, L., Vanreusel, A., Mees, J. and Janssen, C.R. (2013). Microplastic pollution in deep-sea sediments. Environmental Pollution, 182, 495-499. http://www.sciencedirect.com/science/article/pii/S0269749113004387

9. Woodall, L.C., Sanchez-Vidal, A., Canals, M., Paterson, G.L.J, Coppock, R., Sleight, V., Calafat, A., Rogers, A.D., Narayanaswamy, B.E. and Thompson, R.C. (2014). The deep sea is a major sink for microplastic debris. Royal Society Open Science, 1, 140317. http://rsos.royalsocietypublishing.org/content/royopensci/1/4/140317.full.pdf

10. Eriksen, M., Lebreton, L.C., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G. and Reisser, J. (2014). Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. PLoS one, 9(12), e111913. http://journals.plos.org/plosone/article/asset?id=10.1371%2Fjournal.pone.0111913.PDF

11. Isobe, A., Uchida, K., Tokai, T., and Iwasaki, S. (2015). East Asian seas: A hot spot of pelagic microplastics. Marine Pollution Bulletin, 101(2), 618-623. http://www.sciencedirect.com/science/article/pii/S0025326X15301168

12. NEA (2014). Sources of microplastics to the marine environment. Norwegian Environment Agency. http://www.miljodirektoratet.no/Documents/publikasjoner/M321/M321.pdf

13. Avio, C.G., Gorbi, S., Milan, M., Benedetti, M., Fattorini, D., d'Errico, G., Pauletto, M., Bargelloni, L. and Regoli, F. (2015). Pollutants bioavailability and toxicological risk from microplastics to marine mussels. Environmental Pollution, 198, 211-222.

14. Li, H., Getzinger, G.J., Ferguson, P.L., Orihuela, B., Zhu, M. and Rittschof, D. (2015). Effects of Toxic Leachates from Commercial Plastics on Larval Survival and Settlement of the Barnacle Amphibalanus amphitrite. Environmental Science & Technology, 50(2), 924–931. http://pubs.acs.org/doi/abs/10.1021/acs.est.5b02781

15. Nobre, C.R., Santana, M.F.M., Maluf, A., Cortez, F.S., Cesar, A., Pereira, C.D. and Turra, A. (2015). Assessment of microplastic toxicity to embryonic development of the sea urchin Lytechinus variegatus (Echinodermata: Echinoidea). Marine Pollution Bulletin, 92(1–2), 99–104.

16. Rochman, C.M., Kurobe, T., Flores, I. and Teh, S.J. (2014). Early warning signs of endocrine disruption in adult fish from the ingestion of polyethylene with and without sorbed chemical pollutants from the marine environment. Science of The Total Environment, 493, 656–661. http://www.sciencedirect.com/science/article/pii/S0048969714009073

17. Sussarellu, R., Suquet, M., Thomas, Y., Lambert, C., Fabioux, C., Pernet, M.E.J., Le Goïc, N., Quillien, V., Mingant, C., Epelboin, Y., Corporeau, C., Guyomarch, J., Robbens, J., Paul-Pont, I., Soudant, P., and Huvet, A. (2016). Oyster reproduction is affected by exposure to polystyrene microplastics. Proceedings of the National Academy of Sciences, 113(9), 2430–2435. http://www.pnas.org/content/113/9/2430.full.pdf

18. Browne, M.A., Galloway, T. and Thompson, R. (2007). Microplastic – an emerging contaminant of potential concern? Integrated Environmental Assessment and Management, 3(4), 559–561. https://www.researchgate.net/publication/5800734_Microplastic_-_An_Emerging_Contaminant_of_Potential_Concern

19. Derraik, J.G.B. (2002). The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin, 44, 842–852. http://www.sciencedirect.com/science/article/pii/S0025326X02002205

20. Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W., McGonigle, D. and Russell, A.E. (2004). Lost at sea: where is all the plastic? Science, 304(5672), 838. http://science.sciencemag.org/content/304/5672/838

21. Plastic Soup Foundation (2016). International campaign against microbeads in cosmetics. http://beatthemicrobead.org/en/results

22. GESAMP (2015). Sources, fate and effects of microplastics in the marine environment: a global assessment. (Kershaw, P. J., ed.). IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. Rep. Stud. GESAMP No. 90. http://www.gesamp.org/data/gesamp/files/media/Publications/Reports_and_studies_90/gallery_2230/object_2500_large.pdf

23. Cole M., Lindeque P., Halsband C. and Galloway T.S. 2011. Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin, 62(12), 2588-2597. http://www.sciencedirect.com/science/article/pii/S0025326X11005133

24. Gregory, M.R. (1996). Plastic 'scrubbers' in hand cleansers: a further (and minor)source for marine pollution identified. Marine Pollution Bulletin, 32(12), 867–871. http://www.sciencedirect.com/science/article/pii/S0025326X96000471

25. Desforges, J.P.W, Galbraith, M. and Ross, P.S. (2015). Ingestion of Microplastics by Zooplankton in the Northeast Pacific Ocean. Archives of Environmental Contamination and Toxicology, 69(3), 320-330. http://link.springer.com/article/10.1007/s00244-015-0172-5

26. Mani, T., Hauk, A., Walter, U. and Burkhardt-Holm, P. (2015). Microplastics profile along the Rhine river. Scientific Reports, 5, 17988. http://www.nature.com/articles/srep17988

27. Mathalon, A. and Hill, P. (2014). Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia. Marine Pollution Bulletin, 81(1), 69–79. http://www.sciencedirect.com/science/article/pii/S0025326X14001143

28. Zhao, S., Zhu, L., Wang, T. and Li, D. (2014). Suspended microplastics in the surface water of the Yangtze Estuary System, China: First observations on occurrence, distribution. Marine Pollution Bulletin, 86, 562-568. http://www.sciencedirect.com/science/article/pii/S0025326X14004123

29. FAO and ICAC, (2011). A summary of the world apparel fiber consumption survey 2005-2008. Food and Agriculture Organisation of the United Nations and International Cotton Advisory Committee. http://www.fao.org/fileadmin/templates/est/COMM_MARKETS_MONITORING/Cotton/Documents/World_Apparel_Fiber_Consumption_Survey_2011_-_Summary_English.pdf

30. Browne M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T. and Thompson, R. (2011). Accumulation of microplastic on shorelines woldwide: sources and sinks. Environmental Science & Technology, 45(21), 9175–9179. http://pubs.acs.org/doi/abs/10.1021/es201811s

31. EU (2015). Newsletters 2 Life+ project Mermaids. European Union. http://life-mermaids.eu/en/newsletter-2-life-mermaids/

32. Dris, R., Gasperi, J., Saad, M., Mirande, C. and Tassin, B. (2016). Synthetic fibers in atmospheric fallout: A source of microplastics in the environment? Marine pollution bulletin, 104(1-2), 290-293. 6

33. Rochman, C.M., Tahir, A., Williams, S.L., Baxa, D.V., Lam, R., Miller, J.T., Teh, F.C., Werorilangi, S. and Teh, S.J. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. Scientific Reports, 5, 14340. http://www.nature.com/articles/srep14340

34. Liebezeit, G. and Liebezeit, E. (2013). Non-pollen particulates in honey and sugar. Food Additives & Contaminants: Part A, 30(12), 2136-2140.

35. Liebezeit, G. and Liebezeit, E. (2014). Synthetic particles as contaminants in German beers. Food Additives & Contaminants: Part A, 31(9), 1574-1578.

36. Yang, D. H. (2015). Microplastic Pollution in Table Salts from China. Environmental Science & Technology, 49, 13622-13627. http://pubs.acs.org/doi/abs/10.1021/acs.est.5b03163

37. Mizukawa, K., Takada, H., Takeuchi, I., Ikemoto, T., Omori, K. and Tsuchiya, K. (2009). Bioconcentration and biomagnification of polybrominated diphenyl ethers (PBDEs) through lower-trophic-level coastal marine food web. Marine Pollution Bulletin, 58(8), 1217–1224. http://www.sciencedirect.com/science/article/pii/S0025326X09001210

38. Gassel, M., Harwani, S., Park, J. S. and Jahn, A. (2013). Detection of nonylphenol and persistent organic pollutants in fish from the North Pacific Central Gyre. Marine Pollution Bulletin, 73(1), 231-242.

39. Takada, S. (2013). International Pellet Watch: Studies of the magnitude and spatial variation of chemical risks associated with environmental plastics. In Gabrys, J., Hawkins, G. and Michael, M. (eds.), Accumulation: The Material Politics of Plastic. Routledge, New York.

40. Galloway, T.S. (2015). Micro- and Nano-plastics and Human Health. In M. Bergmann, L. Gutow, M. Klages (Eds.), Marine anthropogenic litter. Springer, Berlin. http://link.springer.com/chapter/10.1007%2F978-3-319-16510-3_13

41. Avio, C.G., Gorbi, S. and Regoli, F. (2015). Experimental development of a new protocol for extraction and characterization of microplastics in fish tissues: First observations in commercial species from Adriatic Sea. Marine Environmental Research, 111, 18–26.

42. Brennecke, D., Ferreira, E.C., Costa, T.M., Appel, D., da Gama, B.A. and Lenz, M., (2015). Ingested microplastics (> 100µm) are translocated to organs of the tropical fiddler crab Uca rapax. Marine pollution bulletin, 96(1), 491-495. http://www.sciencedirect.com/science/article/pii/S0025326X15002581

43. San Francisco Estuary Institute (2015). Microplastic Contamination in San Francisco Bay - Fact Sheet. http://www.sfei.org/sites/default/files/biblio_files/MicroplasticFacts.pdf

44. International Pellet Watch (2016). Pollutants in pellet. http://www.pelletwatch.org/index.html

45. Wright, S.L., Rowe, D., Thompson, R.C. and Galloway, T.S. (2013). Microplastic ingestion decreases energy reserves in marine worms. Current Biology, 23(23), R031-R1033. http://www.cell.com/current-biology/abstract/S0960-9822(13)01343-2