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Environmental Impact of Microplastics: An Australian Scenario

ProSPER.Net Joint Research Project:
Development of Learning Materials for Understanding the Environmental Impact of Microplastics

Prepared by

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Description

Pollution of pristine environmental resources such as water, air, and soil by various anthropogenic activities is becoming a serious cause of concern worldwide. Besides many other sources of pollution, plastics especially microplastics, have emerged as a rapidly spreading environmental pollutant. Excessive use of plastics in various forms in industrial and/or household applications - and their further improper disposal and disintegration into microplastics - has led to water, soil, and air pollution. This has severely disturbed the ecological balance of marine, freshwater and terrestrial ecosystems. It's been predicted that by 2050 the ocean will have a greater mass of plastic in marine water than all aquatic species combined, which highlights an alarming situation if plastic pollution is not controlled. Considering this severity, we will shed a light on the current burning issue of microplastic pollution by addressing various aspects such as sources of plastics, their applications, pathways of plastic debris entering the environment, and their deteriorating impacts on both ecology and human health. Moreover, preventative and control measures are recommended to avoid the environmental damage caused by microplastics. Case studies specific to the Australian continent are also discussed to highlight the global issue of microplastic pollution. In short, this case study will give readers an insight into the global status of plastic pollution, political resolutions, upcoming research trends and environmental policies to help to maintain environmental sustainability by handling the danger of plastic pollution in a rational manner.

Learning objectives

- To understand plastic types, their properties, chemical structures, and applications
- To study the pathways of entry for plastics to environmental water, soil, air, and human bodies
- To understand the damaging impacts of microplastics on the environment
- To discuss preventative and control measures to curb plastic - especially microplastic -pollution, as well as future goals and challenges

Subjects covered

Microplastic pollution, environmental impacts, policies

Setting

Australian states and territories

Disclaimer

Sincere effort has been made to present accurate information for education purpose. All information in this case study was cited from the documents submitted on microplastic pollution and National Waste Policy of 2018 by the Ministry of Environment of the Government of Australia, and other researches on the similar topics. The author does not have any responsibility whatsoever in regards to the accuracy and/or comprehensiveness of the data provided.

Working Session 1. Introduction and Background of Plastics

In the 1920's plastic production was spread widely in manufacturing goods including items as diverse as manicure sets, trumpets, and fountain pens. The development of the GPO162, a functional telephone which was made from plastic, had a lasting impact on developing and designing telephone models for many decades.

One of the plastics industry's major successes was the discovery of Tupperware in 1949, by Earl S Tupper, where polyethylene was used to make economical, light weight food containers. Polyethylene allowed the lids of these containers to be re-sealable because of its elasticity and flexibility.

In 1980's with the advancement of polymer composites, a new generation of lower weight but strong structural material was produced. These composites were and are mixed with fibres. The lengthwise measurement and the material of the fibre determine the nature of the material. For example, glass fibre is flexible, but carbon fibres are inflexible.

Fig 1: Production of the most common artificial (plastic) and natural polymers, including some typical applications (***Source***: PlasticsEurope, 2016).

The fabrication of plastics brought about a major change in designing materials in the 20th century and allowed for new designs in many areas, from lightweight containers to life saving medical equipment.

The term 'plastic' defines a sub-category of the larger class of materials called polymers. Polymers are very large molecules that have characteristically long chain-like molecular architecture and therefore very high average molecular weights. They may consist of repeating identical units (homopolymers) or different sub-units in various possible sequences (copolymers). Those polymers that soften on heating, and can be moulded, are generally referred to as 'plastic' materials. These include both virgin plastic resin pellets (easily transported prior to manufacture of plastic objects) as well as the resins mixed (or blended) with numerous additives to enhance the performance of the material (Reisser et al. 2013). A more scientifically rigorous definition of plastic pieces might refer to nano (<1nm), micro (< 5mm), meso (<2.5cm), macro (<1m) and mega (>1m) size ranges (GESAMP, 2015). Many different types of plastic are produced globally, but the market is dominated by six classes of plastics: polyethylene (PE, both high and low density), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS, including expanded polystyrene - EPS), polyurethane (PUR), and polyethylene terephthalate (PET) (Lithner et al. 2011) (Figure 1).

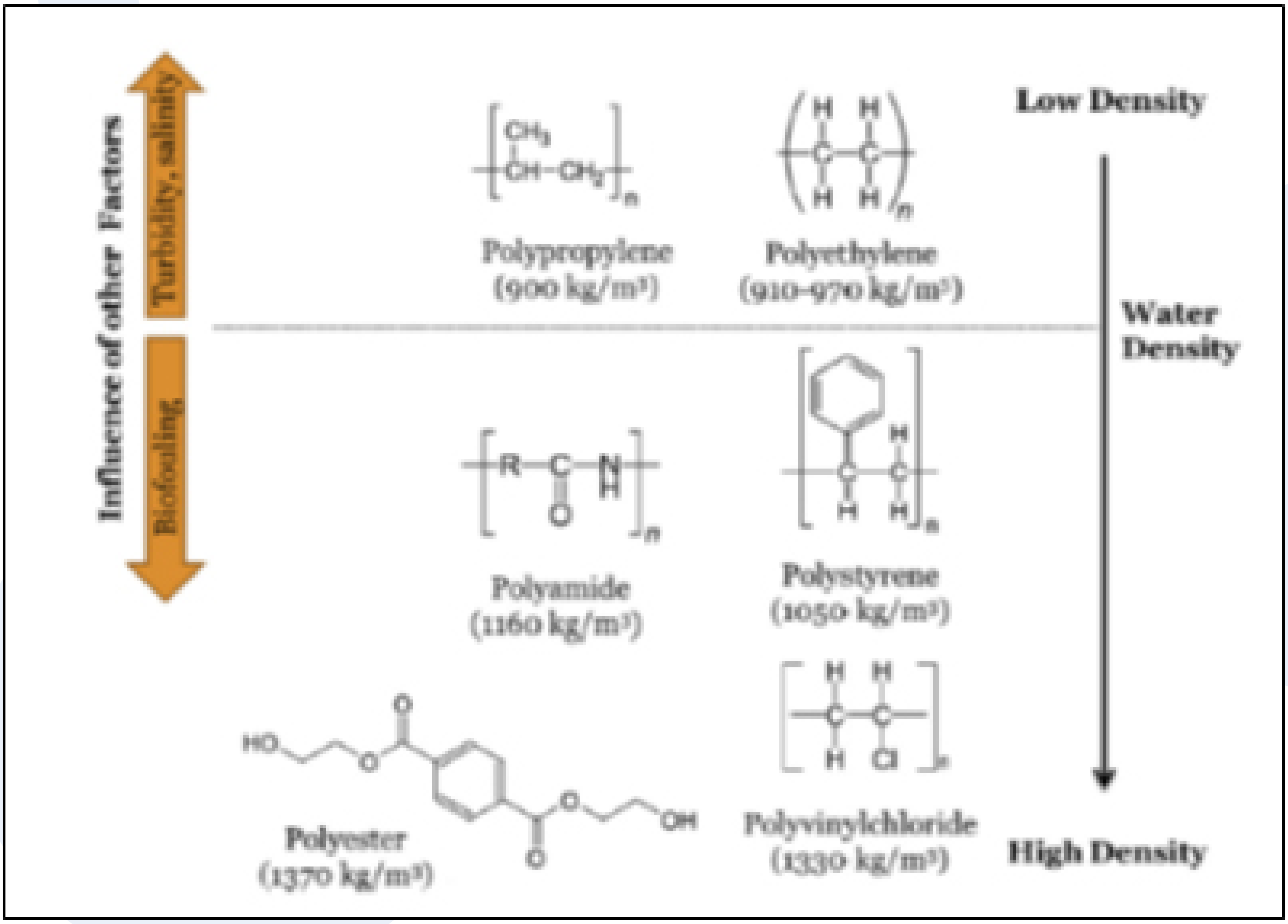
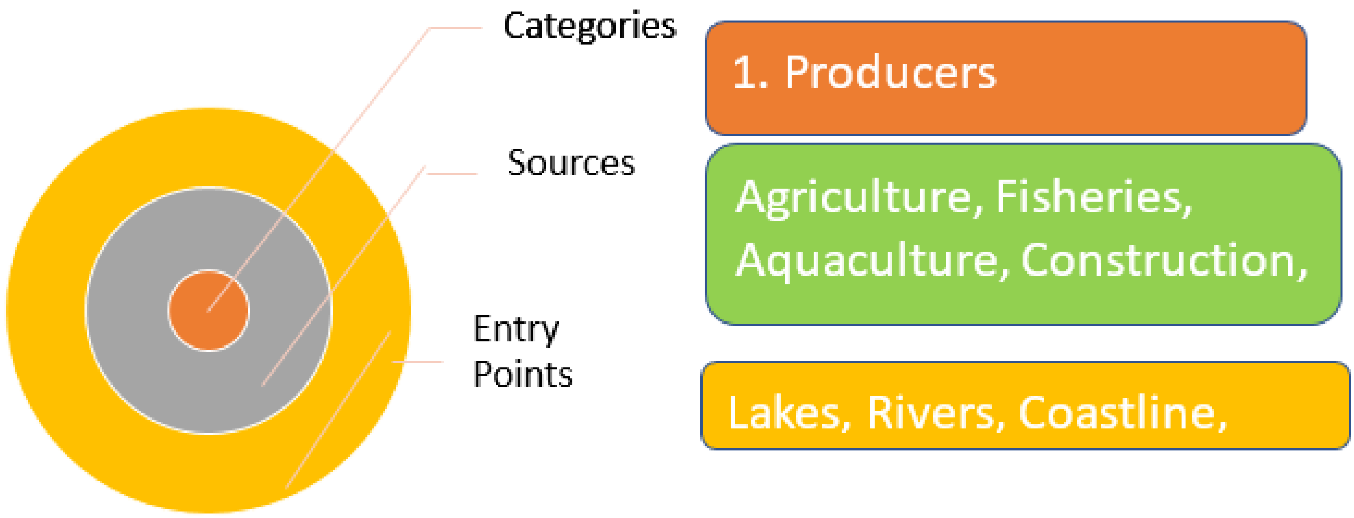


Fig. 2: Densities, structures, and expected distributions of different plastic polymers observed in water column with factors affecting buoyancy, and the direction of the change, are indicated with the arrows on the left (adapted from Anderson et al., 2016).

Sources and Potential Entry Pathways of Microplastics into the Environment

There are both primary and secondary sources of plastics present in the environment. The distinction is based on whether the particles were originally manufactured to be that size (primary) or whether they have resulted from the breakdown of larger items (secondary). Fragmentation and degradation plays a critical role in the formation of secondary microplastics, but the processes are not very well understood. There is evidence that microplastics are littered into the environment at all stages in the life cycle of a plastic product from producers to waste management. Micro- and nanoplastics can enter the marine environment via riverine systems, coastlines, directly at sea from vessels and platforms, or by wind-induced transport within the atmosphere. The category, sources, and entry points through which plastic enters the environment and causes severe pollution, is illustrated in Figure 3.

(a)



(b)

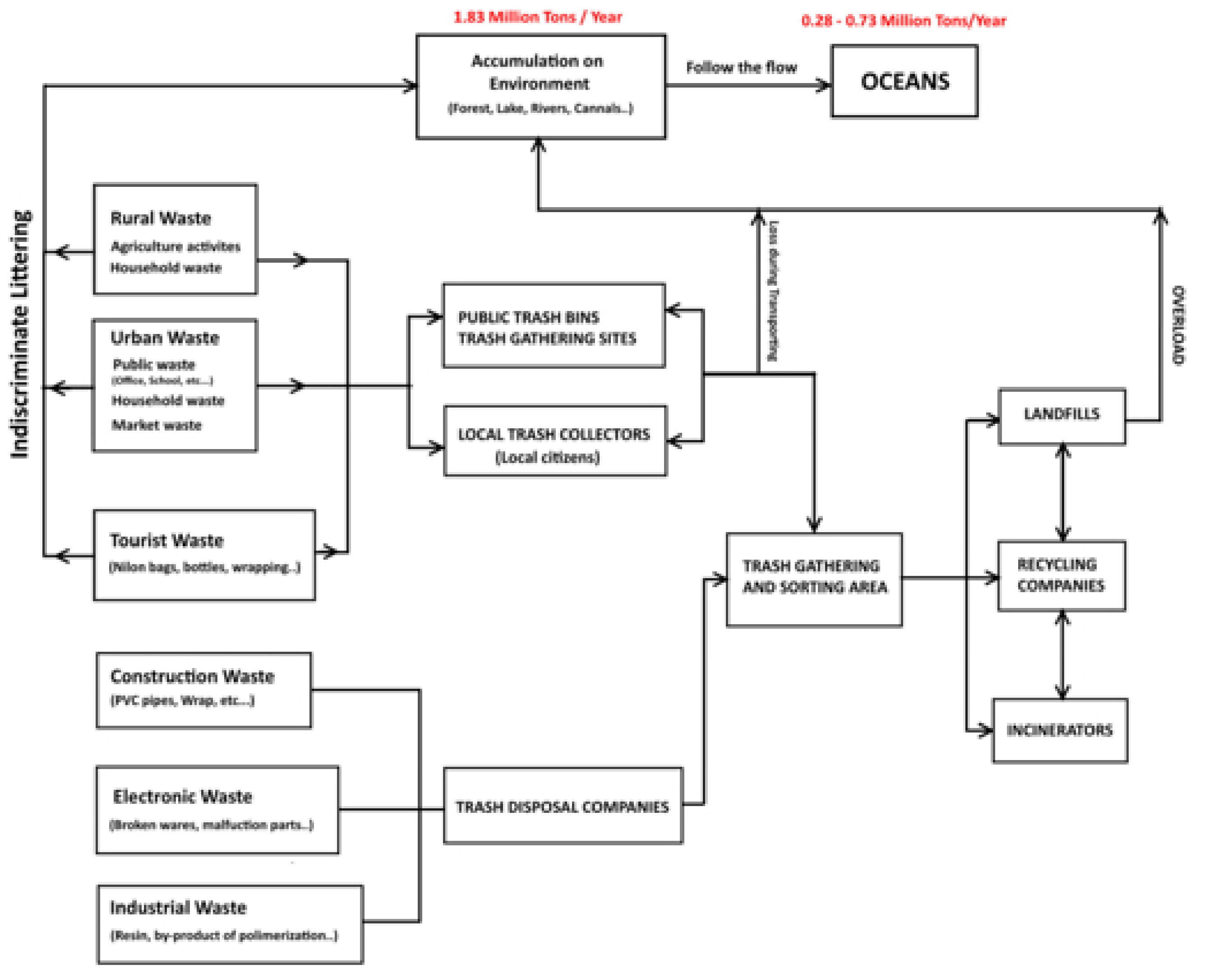


Fig. 3: (a) Sources and potential entry points of mega to nanoplastics and (b) potential routes of plastic wastes into an environment in detail.

Working Session 2: Potential Impacts of Microplastics Pollution on Environment and Ecology

Potential Impacts of Microplastic Pollution on Marine Ecosystems

Plastic pollution is universally distributed and is present throughout the marine environment due to its properties of buoyancy and durability. Some researchers have claimed that synthetic polymers are a hazardous waste present throughout all marine environments. Due to the process of photodegradation and weathering, plastics get degraded into smaller and smaller fragments like microplastics and nanoplastics and disperse throughout the ocean. These can then enter into the subtropical gyres. Plastic accumulation is seen in closed bays, gulfs, and seas which are often thickly populated coastlines and watersheds. Tiny particles of plastics are found in sea water which are eaten by the marine animals and end up in human food.

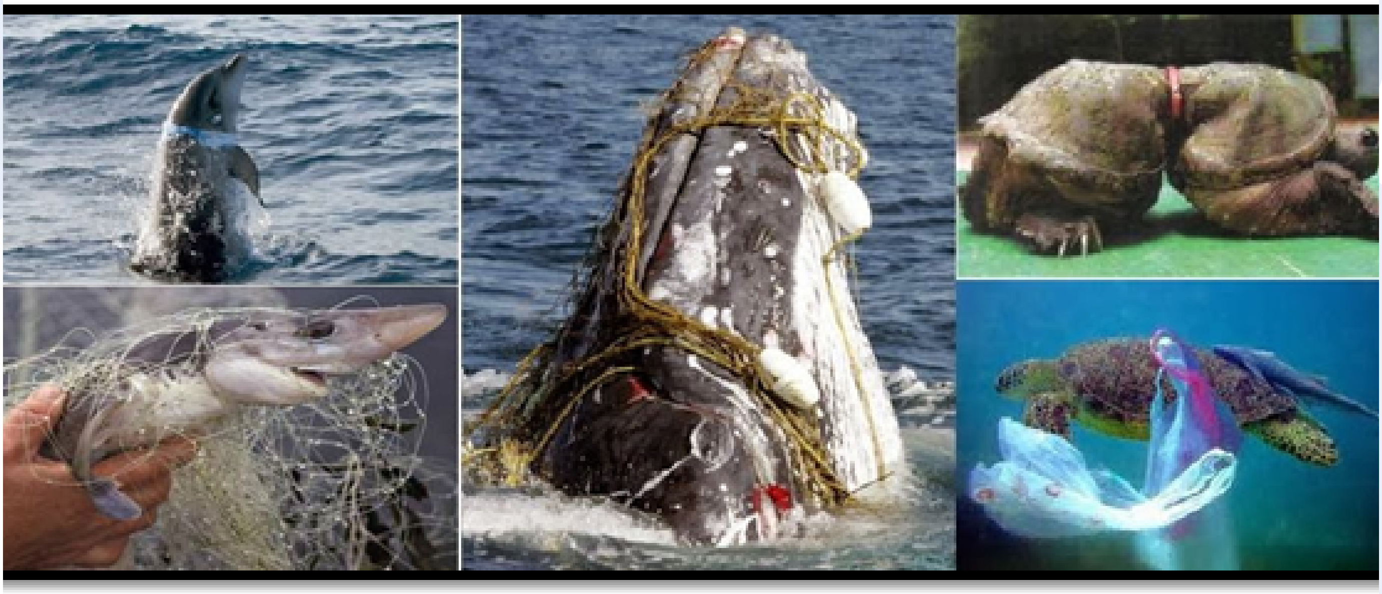


Fig 4: Plastic debris threatening the life of marine animals.

The plastic contamination in the Australian marine environment is subjected to:

- Beach litter that records the existence of large plastic objects.
- Illegal discarding
- Tourism related litter
- Land-based surveys of marine mega fauna impacted by marine debris
- Inferences based on plastic pollution reports from New Zealand.

The hazards with microplastics in the marine environment are:

- Physical effects
- Bioaccumulation
- Desorption and toxicity of pollutants
- Leaching and toxicity of additives and monomers
- Transport of invasive species

Potential Impacts of Microplastic Pollution on Freshwater Ecosystem

It is estimated that between 1.15 and 2.41 million tonnes of plastic waste currently enters the ocean every year from rivers (Lebreton et al., 2017). Microplastics in freshwater have been severely understudied in general compared to marine systems, and therefore, the presence and effects of mega to nanoplastics in freshwater ecosystems remains largely unknown (Anderson et al., 2016). Only a few local studies have reported on levels of plastic contamination in freshwater systems worldwide (Wagner et al., 2014). Such freshwater studies generally focus on micro-plastics contaminating sediment and waters of lakes and rivers. A few studies have demonstrated the presence of microplastics in freshwater systems which might be a reason to raise concern about the presence of microplastic in drinking water since human populations are highly dependent on freshwater systems for drinking water supply and food resources (Eerkes-Medrano et al., 2015). For example a study on beach sediments from Lake Garda in Italy revealed an abundance of 1,108 ± 983 microplastic particles/m^2 at the north shore of the lake which is used for drinking water supply (Imhof et al., 2013). Most of the plastic particles were identified as secondary microplastics, most likely originating from post-consumer products, whereas detected fibers were found to originate from lakeside sources such as fishing gear and ropes.

Microplastics are finding their way in drinking water. Drinking water treatments are unable to remove these types of particles. For example, sedimentation techniques rely on particles such as clay, slit, and natural organic matter which settles at the bottom of the tank. But many particles are less dense than water, hence they float in the water and cannot be removed.

Potential Impacts of Microplastic Pollution on Terrestrial Ecosystem

Understanding the impacts of plastic pollution on terrestrial ecosystems is still in its infancy stage (E.L-Ng et al. 2018). Plastic loading rates in many agro-ecosystems could be high due to primary (manufactured) micro and nanoplastics (eg., waterborne paints, medical applications, electronics, coatings, adhesives) or indirectly as secondary microplastics or nanoplastics generated as breakdown of larger plastic debris (Duis and Coors, 2016). Of the microplastics that pass through wastewater treatment plants, 95% of microplastics are estimated to be retained in biosolids (Ziajharomi et al. 2016). As both treated wastewater and biosolids are getting used in agriculture for irrigation and fertilizers, the microplastic loading on agricultural land is likely to be high (Mohapatra et al., 2016). In Europe, it is estimated that approximately 63,000 to 430,000 tonnes of microplastic entre agro-ecosystems annually through biosolids alone, while estimates for North America range from 44,000 to 300,000 tonnes annually (Nizzetto et al. 2016). The Australian and New Zealand Biosolids Partnership (2016) have estimated that between 2,800 to 19,000 tons of microplastics are applied to Australian agro-ecosystems each year through biosolids. Besides biosolids, composts derived from non-source-separated residential waste or mixed municipal solid waste, as well as source-separated garden organic waste, are also sources of plastic pollution in agro-ecosystems.

Plant-microbe-plastic response has been studied for agro-ecosystems where organismal-level response to micro and nanoplastics was reported on earthworms *Lumbricus terrestris* exposed to 28% PE microplastics (w/w in dry plant litter) and above showed growth inhibition (Huerta Lwanga et al. 2016). Studies on algae showed that nanoplastics adsorbed on the cell wall of microalgae such as *Scenedesmus*, *Chlorella* indicated that nanopolysterenes interfered with algal photosynthesis due to increased water turbidity and light scattering, coverage of algal cell surface with microplastics, or immobilization of algae at concentration of around 1.5 $mg.1^{-1}$ and above (Nolte et al. 2017a). To assess the soil microbiome response to micro-nano plastics, a pot trial experiment with 67.5 and 337.5 $kg.ha^{-1}$ plastic mulch residue (20mm x 20mm) was conducted (Wang et al. 2016) at constant moisture content. Soil microbial biomass, enzyme activities (dehydrogenase and fluorescein diacetate hydrolysis), and functional diversity (community level physiological profile) tended to decrease with increasing concentrations of plastic mulch residue. Uptake of microplastics by plants is not expected. The high molecular weight or large size of plastic particles prevents their penetration through the cellulose-rich plant cell wall. In contrast, nanoplastics have been shown to entre plant cells (E-L. Ng et al. 2018). There are no studies on translocation and storage of nanoplastics in plants; similarly there is no data on the toxicity of nanoplastics in plants (E-L. Ng et al. 2018). General observations on toxicity of carbon nanoparticles that may have relevance to future studies using nanoplastics are: (1) phytotoxicity tests such as germination, root elongation, and growth measures across studies indicate that the sensitivity depends on the plant species and the physiochemical properties of the engineered carbon nanoparticles; (2) cell damage occurs through genotoxicity and cytotoxicity (Shen et al. 2010); and (3) interactions between different types of engineered carbon nanoparticles with pesticides can increase or decrease the uptake of pesticides in different crops (Torre-Roche et al. 2013).

So far, studies on the ecological impact of plastic in soil are mostly at the organismal level, or on the soil microbiome. But, impact studies at higher levels of biological organization are difficult (Browne et al. 2015), suggesting that existing knowledge of ecological linkages, where known, and population models, where the linkages are unknown, can be used to deduce such impacts. Currently, only one laboratory study explored such an ecological linkage. The study showed that the *L.terrestris* had lower biomass under the exposure of 7% microplastic (w/w in dry plant litter) while the burrows occurred in significantly higher numbers and burrow walls were denser compared to the control without exposure to microplastics, however the burrow length was similar across all treatments during the 14 day experiment (Huerta Lwanga et al. 2017). These results indicate soil porosity may increase as a result of earthworm-microplastic interaction. Additionally, microplastics may also have a direct effect on soil porosity, as both synthetic water soluble and gel-forming polymers are used as soil conditioners to improve water infiltration, water retention, and soil stabilization.

Millions of plastic items are being disposed of in both marine and terrestrial environments. Plastic pollution poses a threat to plants and animals, including humans. In landfills, the decomposition of plastics takes up to 1,000 years, leaching potentially toxic substances into the soil and water during this time. The impact of microplastics in the soil sediments could cause negative long-term effects on ecosystems. Most plastics end up in soil or water where they disintegrate into microplastics, and these microplastics can further break down into smaller particles, referred to as nanoparticles or nanoplastics (< 0.1μm). These particles can potentially enter the food chain and produce hazardous health effects.

Sewage is an important factor which assists in the distribution of microplastics. 80% to 90% of plastic particles that enter the environment do so through sewage systems. Sewage in the form of sludge is applied to the fields as fertilizers, and due to this thousands of microplastics end up each year in the soil. These microplastics can be found even in tap water. Futhermore, microplastics interact with soil fauna which affects the soil functions. For example, earthworms make their burrows differently due to the presence of microplastics in the soil, which affects the earthworms functioning and lowers the soil condition (Machado et al. 2017).

Chlorinated plastics can release harmful chemicals in the soil as they break down, which can then move into underground water or any other surrounding water sources within an ecosystem. This causes potentially harmful effects on any species that drink water. When plastic particles break down, they take on new physical and chemical properties which elevate the risk of noxious effect on organisms. Additives like phthalates and Bisphenol A (BPA) leaches out of plastic particles. These additives cause hormonal effects and disrupt the hormone system of vertebrates and invertebrates alike. The minute particles causes skin irritation and can quickly cross the blood barrier or the placenta.

Potential Impacts of Microplastic Pollution on Human Health

There is mounting evidence of the occurrence of plastic particles in marine organisms that are part of the human food chain, and this also represents a potential threat to human health via biomagnification. A possible exposure pathway of humans to microplastic is represented by diet, especially since there are studies available that demonstrate the presence of microplastic in commercially important fishes, shrimps, and mussels (Devriese et al. 2015; Romeo et al. 2015; Van Cauwenberghe and Janssen 2014). Microscopic fibers ranging from 200-1500 μm have been found in mussels (average 3.5 fibres/10 g mussel) from Belgian stores which was in the same range as wild caught mussels in the same study (De Witte et al. 2014). Furthermore, synthetic fibers were reported in 63% of commercially important brown shrimp caught in the Southern North Sea and Channel area (Devriese et al. 2015).

There are also studies that reported non-marine sources of microplastic in the food chain. For example nineteen honey samples were analyzed for colored fibres and fragments of colored material was found in all of the samples (Liebezeit and Liebezeit 2013). Fiber counts ranged from 40/kg up to 660/kg of honey and fragments ranged from 0 – 38/kg of honey. Sources were identified as introduction of particles during the processing of honey and/or particles were introduced by the bees into the hive. The honey samples originated mostly from Germany, but also from France, Italy, Spain, and Mexico. Five commercial sugars were analyzed as well and in all refined samples fibers (mean 217 ± 123/kg of sugar) and fragments (32 ± 7/kg of sugar) were found. Unrefined cane sugar was found to contain 560 fibers and 540 fragments per kilogram of sugar. Furthermore, a total of 24 German beer brands were analyzed in a study for microplastic fibres, fragments, and granular material (Liebezeit and Liebezeit 2014). Contamination was found in all samples with fiber counts ranging from 2 to 79 fibers /L, 12 – 109 fragments/L and 2 – 66 granules/L. Potential sources of the contamination include natural and synthetic fibers in clothing that become airborne, materials that were used during the production process, and bottles that might have been already contaminated or became contaminated during the cleaning process. A study on 15 different table salts in China demonstrated the presence of microplastics in these samples as well (Yang et al. 2015). The amount of microplastics ranged from 550 – 681 particles/ kg in sea salts, 43 – 364 particles/kg in lake salts and 7 – 204 particles/kg in rock/well salts. Sea salts were found to be significantly more contaminated with microplastics than other salts which underline the contamination of marine products. In sea salts particles measuring less than 200 μm were detected to be the predominant type of microplastic, accounting for 55% of the particles, with PET as the most abundant polymer type followed by PE and cellophane.

The risk of microplastic transfer from the gastrointestinal tract in humans and other mammals to other tissues is very real. Hussain et al. (2001) showed that PE particles could transfer from the gut to lymph and circulatory system in humans. PS particles up to 240 nm was shown to be taken up by the placenta in a human ex vivo study (Wick et al. 2010). Nanosize particles of PS also decreased cell contractility of human muscle cells and resulted in cellular damage of human blood vessels (Berntsen et al. 2010; Fröhlich et al. 2010). Further effects related to the plastic polymer itself are not described, however knowledge can probably be extracted from the field of medical transplants using polymer materials of different types.

Another concern in regard of exposure of microplastics and microfibers to humans are plastic-associated chemicals (PACs) such as bisphenol A and phthalates. These compounds are well-known as endocrine disruptors and interfere with the hormone system. In one population-based human study, levels of BPA and several phthalate metabolites were associated with lipid infiltration of the vascular wall and therefore suggest that these chemicals play a role in atherosclerosis (Lind and Lind 2011). Furthermore BPA was reported to be positively associated with cardio vascular disease and prevalent myocardial infarction in a cross sectional analysis of 1,455 adults (Lind and Lind 2012).

Socio-Economical Aspects of Microplastic Pollution

Plastic pollution is a global concern where presence of various forms of plastics ranging from macro fractions to nanoplastics has been reported in various ecosystems and environmental regimes. The socio-economic status of a region can severely be affected by the pollution, e.g. fisheries have been one of the major livelihood businesses in coastal regions of various parts of the world, but majority of the coastal areas have been are experiencing severe pollution. Plastics contribute a significant amount to coastal pollution due to the dumping of solid wastes. This has considerably damaged marine ecosystems, thus affecting commercial coastal and marine fisheries (Islam and Tanaka, 2004) and coastal tourism (Watkins et al. 2015), thus impacting livelihoods of the local communities. Microplastics ingestion has been reported by many laboratory and field studies, but its movement across the food chain and its toxic impacts on the entire ecosystem are still being investigated to a great extent and pose a significant concern. (Cole et al. 2011) For example, Horton et al. (2017) reported that terrestrial pollution poses a greater threat to ecosystems and human life than that of marine pollution, as the annual disposal or dumping of plastic on the land 'is estimated at 4–23 times that released to oceans (page no: 128).'

Working Session 3: Why does Australia need to have National Waste Policy for Plastics/ Microplastics?

Plastic pollution is a shared responsibility and we can all do our bit to reduce its impacts. Worldwide, the impact of plastic shopping bags has received significant attention, and there have been many attempts to reduce their use. Policy intervention plays a very important and necessary role in achieving targets. Over the years many international agencies *viz.* United Nations Environment Program (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO), The Oceans Compact, United Nations - Oceans (UN-Oceans), United States EPA (Environmental Protection Agency), Global Partnership on Marine Litter, Online Marine Litter Network, Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA), and the Global Partnership on Waste Management and Environment Management Group have played a very important role in combating plastic pollution. Since 1972 major global players have been formulating and implementing various regulations and treaties such as the London Convention (1972) on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, the International Convention for the Prevention of Pollution from Ships (1973/1978); the United Nations Convention on the Law of the Sea/MARPOL (Part VIII, Section 2, Articles 117-120); the Convention for the Protection of the Marine Environment of the North-East Atlantic/The OSPAR (1992); the Marine Strategy Framework Directive (Directive 2008/56/EC); the EU Strategy (2018) for Plastics in the Circular Economy; and the UN Sustainable Development Goals (2030) (EC, 2018; EMUN, 2017 and Eunomia, 2016).

Figure 5 explains the strategic plan that needs to be followed by Australia to work together at the national and international level in curbing global plastic pollution. More than thirty countries have implemented voluntary or regulatory approaches to reduce the use of lightweight plastic bags. Countries such as Bangladesh, South Africa, China, Ethiopia, Eritrea, France, Italy, Kenya, Morocco, and Tanzania have all banned plastic bag use. England, Ireland, Wales, Denmark, and Germany have used point-of sales charges to reduce plastic bag use. Though there is no national plastic bag ban or charge in the USA, over 100 local counties and municipalities have plastic bag bans or charges, and California has a state-wide ban on plastic bags. Internationally, France passed legislation in 2016 to reduce the environmental impacts of single use plastic tableware (plates, cups, and cutlery). The legislation comes into effect in 2020, and will require disposable tableware to be compostable at home, and composed of at least 50% biologically-sourced material (The State of Victoria Department of Environment, Land, Water and Planning, 2017).

Fig. 5: Strategic action plans towards plastic free environment.

Working Session 4: Areas of Future Research

Knowledge on the adverse effects of concentrations of various plastic types, particle forms, and particle sizes are lacking for all species. It is known that plastics are ingested, that chemicals can sorb to particles and desorb within species, and that biological effects can occur. However, it is currently not possible to assess the risk of macro – nanoplastics since the reported studies do not present dose-response relationships. The most prevalent polymer types found in the environment are PP, PE, and different polymers in the shape of fibers, so it is therefore recommended to prioritize these in effects studies. There are indications that smaller size particles are more hazardous; they can more easily enter the food web, they have a larger capacity to sorb or incorporate pollutants, and larger particles will eventually fragment to smaller particles. The goals must therefore be to generate relevant dose response relationships and adverse effect concentrations with emphasis on exposure to the dominant size fractions and forms of PP, PE, and PS particles and synthetic fibers from clothes (polyesters, polyamide). Tests should be done on ecologically and economically relevant marine and freshwater species (both invertebrates and fish) under standardized conditions. In such tests it is also critical to develop standardized methods for expressing plastics doses, taking particle form, polymer type, and size distribution into consideration. Preferably, the doses should be expressed in the same way as in field measurements and it would be helpful if field surveys report on abundance, weight, and type of plastics. This would greatly facilitate the possibility to perform actual risk assessments, putting critical effect levels in relation to actual exposure levels. Any toxicity testing should be designed so effects of plastics and effects of plastics-associated chemicals can be distinguished. The testing would generate new knowledge regarding mechanisms of the toxicity of plastics and associated additives and adsorbed chemicals. Crucial in this research is the issue of bioavailability of plastic associated chemicals in living organisms. Therefore, mechanisms that influence desorption in the gastrointestinal tract of both sorbed and incorporated chemicals, and the extent of chemical uptake, should be studied. The relative role of organ accumulation of plastics-associated chemicals to the total load of chemicals from the surrounding environment including diet should also be quantified.

Besides effects testing, a standardized global qualitative and quantitative biomonitoring program focusing on temporal and geographical variation of occurrence of microplastics in freshwater and marine ecosystems on all trophic levels should be implemented. These data will be crucial in understanding point sources, trends, and microplastic dynamics regarding fate and behavior. They will also be crucial in the assessment of potential risks and to guide plastics management strategies. Another area of focus is studies on occurrence of microplastics in the terrestrial environment with emphasis on synthetic fibers and agricultural areas using sewage sludge as fertilizers.

The question of whether microplastics will fragment into nanoplastics in significant amounts remains to be answered. Therefore it is crucial to direct research resources towards elucidation of occurrence of nanoplastics in freshwater and marine ecosystems. Further, laboratory studies on fragmentation processes from micro- to nanoplastic should be performed, as should uptake toxicity studies of nanoplastics in relevant organisms.

Human exposure to microplastics is not well studied. Putative exposure pathways include microplastics entering lungs via air, or entering the gastrointestinal tract via water and food. None of these pathways have been quantified. Therefore it is crucial to assess and quantify the exposure pathways to microplastics for humans. The effects of microplastics on humans are to a great extent unknown, although knowledge from the pharmaceutical field should be carefully reviewed. Therefore, a systematic assessment of microplastics toxicity on human should be carried out. Typically, for effects assessment this would entail extrapolation of effects found in experimental animal studies and from occupational settings. Exposure scenarios and actual measurements of microplastics exposure are also needed. Put together, generation of this kind of research data should facilitate human risk assessment of microplastics of different sizes, forms, and polymer types. The risk assessment should also include effects of microplastics-associated additives and also effects of nanoplastics if there is a potential human exposure of this particle size class.

In addition, plastics need to be considered as resourceful entity for regeneration purposes. For example, there are several instances where waste plastics are getting used for road development and energy generation. More such applications must be implemented for ‘best from waste’ resources.

Take Home Message

Plastics make up an important part of human lives and well being. Owing to their unmatchable properties including strength, low weight, durability and cost-effectiveness, plastics and their products are used extensively for packaging, transport, healthcare, construction, electronics, and several other industries. Consequently, global plastic production has seen rapid growth in last few decades. Unfortunately, this has led to the generation of huge amounts of plastic waste and debris, which pose a serious threat to the biosphere. Plastics get accumulated through various ways, such as biofouling or accumulation of microorganisms, plants or algae onto the plastic debris which makes them heavier and this makes the debris eventually sink at the base of the sea. Various types of plastics and plastic wastes are known to cause serious negative implications to marine, fresh water, and terrestrial ecosystems as well as to human health. Plastic waste management has become a serious challenge in contemporary times and necessitates effective approaches to tackle this problem; one potent way might be via integrating any physical, chemical, biological, and/or technological approaches with regulatory interventions. Through this paper, we have proposed some promising approaches to make our planet plastic-free, including mainly through innovation, technological advents and collaborative efforts for providing better alternatives, creating public awareness, and developing governmental policies. However, more comprehensive and in-depth studies are needed not only for detailed assessment of the hazardous effects that each type of plastic exerts on life forms, but also for developing better environmental-friendly but cost-effective alternatives.

Discussion Questions

Q1. Microplastics are considered as a growing environmental and community concern. Discuss.

Q2. Which are the current and emerging challenges associated with microplastic pollution management at global level?

Q3. Comment on the statement: ‘We all have a role to play in managing microplastic pollution’.

Q4. Discuss the role of policy frameworks and programmes to curb microplastics pollution at both the national and international level.

Q5. How can microplastic pollution impact the socio-econoimc status of any state or nation?

References

Anderson JC, Bradley J, Park b et al (2016) Microplastics in aquatic environments: Implications for Canadian ecosystems. Environ Pollut 218 : 269-280

Australian and New Zealand Biosolids Partnership (2016) Australian Biosolids Statistics. http://www.biosolids.com.au/guidelines/australian-bio-solids-statistics/ Accessed date: 17 April 2018

Berntsen P, Park CY, Rothen-Rutishauser B et al (2010) Biomechanical effects of environmental and engineered particles on human airway smooth muscle cells. J Royal Soc Interface 7:S331-S340

Cole M, Lindeque P, Halsband C et al (2011) Microplastics as contaminants in the marine environment: A review. Mar Pollut Bull 62. 2588–2597

De Witte B, Devriese L, Bekaert K, et al (2014) Quality assessment of the blue mussel (mytilusedulis): Comparison between commercial and wild types. Mar Pollut Bull 85:146155

Devriese LI, van der Meulen MD, Maes T, Bekaert et al (2015) Microplastic contamination in brown shrimp (crangoncrangon, linnaeus 1758) from coastal waters of the southern north sea and channel area. Mar Pollut Bull 98:179-187

Duis K, Coors A (2016) Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. Environ Sci 28:1-25

Eerkes-Medrano D, Thompson RC, Aldridge DC (2015) Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritization of research needs. Water Res 75:63-82

E.-L. Ng, Huerta Lwanga E, Eldrige SM, et al (2018) An overview of microplastic and nanoplastic in agroecosystem. Sci Total Environ 627: 1377-1388.

Fröhlich E, Kueznik T, Samberger C et al (2010) Size-dependent effects of nanoparticles on the activity of cytochrome p450 isoenzymes. Toxicol Appl Pharm 242:326-332

Horton AA, Walton A, Spurgeon DJ et al (2017) Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities. Sci Total Environ 586:127-141

References

Huerta Lwanga E, Gertsen H, Gooren H et al (2016) Microplastic in terrestrial ecosystems: implications for Lumbricus terrestris (Oligachaeta, Lumbricidae) Environ Sci Technol 50: 2685-2691

Hussain N, Jaitley V, Florence AT (2001) Recent advances in the understanding of uptake of microparticulates across the gastrointestinal lymphatics. Adv Drug Delivery Rev 50:107-142

Imhof HK, Ivleva NP, Schmid J et al (2013) Contamination of beach sediments of a subalpine lake with microplastic particles. Curr Biol 23:R867-R868

Islam MS and Tanaka M (2004) Impacts of pollution on coastal and marine ecosystems includingcoastal and marine fisheries and approach for management: A review and synthesis. Marine Pollut Bull 48:624–649

Lebreton Laurent CM, van der Zwet J, DamsteegJW et al (2017) River plastic emissions to the world's oceans.Nature Communications. 8:15611

Liebezeit G, Liebezeit E (2013) Non-pollen particulates in honey and sugar. Food Addit Contam A 30:21362140

Liebezeit G, Liebezeit E (2014) Synthetic particles as contaminants in german beers. Food Addit Contam A 31:1574-1578

Lind PM, Lind L (2011) Circulating levels of bisphenola and phthalates are related to carotid atherosclerosis in the elderly. Atherosclerosis 218:207-213

Lind L, Lind PM (2012) Can persistent organic pollutants and plastic-associated chemicals cause cardiovascular disease? J Intern Med 271:537-553

Machado AA de Souza et al (2017) Microplastics as an emerging threat to terrestrial ecosystems, Global Change Biol DOI: 10.1111/gcb.14020

Mohapatra DO, Cledon M, Brar SK et al (2016) Application of wastewater and biosolids in soil: occurrence and fate of emerging contaminants. Water Air soil Pollut 227

Nizzetto L, Futter M, Langaas S (2016) Are agriculture soil dumps for microplastics of urban origin? Environ Sci Technol 50: 10777-10779

References

Nolte TM, Hartmann NB, Klejin JM (2017a) The toxicity of plastic nanoparticles to green algae as influenced by surface modification, medium hardness and cellular adsorption. Aquat Toxicol 183:11-20

PlasticsEurope (2015) Plastics - the facts 2014/2015. Retrieved from

Romeo T, Pietro B, Peda C et al (2015) First evidence of presence of plastic debris in stomach of large pelagic fish in the mediterranean sea. Mar Pollut Bull 95:358-361

Shen CX, Zhang QF, Li J et al (2010) Induction of programmed cell death in Arabidopsis and rice by single-wall carbon ananotubes. Am J Bot 97: 1602-1609

The State of Victoria Department of Environment, Land, Water and Planning (2017) Reducing the impacts of plastic on the Victorian environment. Retrieved from www.delwp.vic.gov.au Accessed date: 17 April 2018

Torre-Roche RD, Hawthorne J, Deng Y et al (2013) Multiwalled carbon nanotubes and C60 fullerenes differentially impact the accumulation of weathered pesticides in four agricultural plants. Environ Sci Technol 47

Van Cauwenberghe L, Janssen CR (2014) Microplastics in bivalves cultured for human consumption. Environ Pollut 193:65-70

Wang W, Ndungu AW, Li Z et al (2017) Microplastics pollution in inland freshwaters of China: A case study in urban surface waters of Wuhan, China. Sci Total Environ 575:1369–1374

Wick P, Malek A, Meili D et al (2010) Barrier capacity of human placenta for nanosized materials. Environ Health Persp 118:432-436

Watkins E, ten Brink P, Withana S et al (2015) Marine litter: socio-economic study. Scoping Report. London, Brussels

Yang DQ, Shi HH, Li L et al (2015) Microplastic pollution in table salts from china. Environ Sci Technol 49:13622-13627

Ziajahromi S, Neale PA, Leusch DDL (2016) Wastewater treatment plant effluent as a source of microplastics: review of fate, chemical interactions and potential risks to aquatic organisms. Water Sci Technolo 74: 2253-2269