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Plastic pollution: why is it a public health problem?

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Derived from petrochemicals,[1] plastics are composed of monomers that are sequenced into polymer chains. Since their commercial development in the 1930s and 1940s, the modern world has become hugely reliant on plastics. They have extensively replaced wood, metal, ceramics and glass in manufacture and construction. They are embedded in the economic system and our daily lives. There are many different types of plastic with different potentials to be reused or recycled (Box 1).[2]

There are many reasons for industry to move away from plastic use, not least is the fast-approaching peak of the economically and ecologically sustainable supply of petrochemicals.[3] However, even if this pillaging of finite resources can be ignored, the ecological and global health impacts of plastics cannot be.

Global plastic resin production has increased 620% since 1975 and much of this increase is used for packaging of other items.[4] Plastics have been considered disposable and consequentially plastic waste has grown.[1] In 2012, there were 280 million tons of plastic produced across the globe, and less than half of this was disposed of in landfill or recycled.[5] While some may still be in use, a large portion of the remainder becomes waste in the environment, with a substantial portion entering the ocean; the International Union for Conservation of Nature states that eight million tons of plastic accumulate in the ocean annually.[6]

Plastic waste can include particles from many sources, from raw plastic lost from the supply chain, packaging and carrier bags to synthetic clothing and cosmetic products. Once dispersed into the environment, it breaks into smaller pieces via photo-degradation or abrasion.[7] Such fragments are termed microplastics, defined as plastic particles smaller than 5mm. One of the worst culprits is the cosmetic microbead, which represents a significant proportion of micro-plastic debris within the oceans.[1,8] Microplastics alone account for 11% of the total ocean plastic pollution[9] and tens of thousands of microbeads are flushed down household drains per single use of microbead-containing product.[10] The rate microplastics enter the environment currently exceeds their removal. Plastic fragments make their way into food webs[5] as a result of ingestion or endocytosis by marine animals.[1]

Plastics do not generally biodegrade[7] and thus are a growing environmental, political and public concern.[4] Most plastics in the environment[5] ultimately end up in oceans via storm drains, rivers, sewage disposal and flooding. Once in the ocean, they float and converge into 'islands' or sink to the seabed.[1] While 10% of all waste is plastic, around 80% of waste that accumulates in the oceans and seabed is plastic.[7] Videos of 'plastic islands' in the oceans and flowing 'rivers of plastic' flood the media, and yet despite public outcry, seemingly little is being done about this crisis.

Plastic pollution, both macro and microplastic, is causing a significant adverse effect on marine ecology. The effects of the ingestion of plastics by marine life can be divided into physical and chemical aspects. Physical effects are incurred mostly from larger plastics and include blockage of the intestinal tract and subsequent starvation. Plastics have been found in most marine biota, from large marine mammals to tiny zooplankton. Zooplankton are a vital component of marine food webs as primary consumers and of ecological systems as the juvenile life-stage of many commercial species.[11] This not only increases microplastics in food webs but also affects the health of many vital species in marine ecology.

In Australia, there has been little investigation into the microplastics within the surrounding ocean, with most studies devoted to large plastic clean-ups from beaches.[8] Eriksen et al. (2013) examined plastic content from the coastal waters surrounding Australia, finding that most plastics were microplastics from cosmetics or polyethene and polypropylene particles from the break-up of larger objects.[8]

Box 1: Types of plastics.

Polyethylene Terephthalate (PET or PETE or Polyester)
- Commonly used in food and drink packages
- Commonly recycled
- Contains antimony, a possible carcinogen, but at levels lower than regulated values

High-density polyethylene
- Used in grocery bags, milk jugs, shampoo bottles, toys
- Most commonly recycled plastic
- Considered safe but some studies show it can leach chemicals that mimic oestrogen

Polyvinyl chloride (PVC)
- Used in credit cards, flooring, window and door frames, food wrapping, teething rings, toys
- Less than 1% is recycled and requires additional 'virgin' materials to do so
- Leaches multiple chemicals including Bisphenol A (phthalates, lead, mercury

Low-density polyethylene
- Used for food wrapping, grocery bags, waste disposal bags, bubble wrap, disposable drinking cups
- Difficult to recycle
- Considered safe but may leach oestrogen-mimicking chemicals

Polypropylene
- Used in medication bottles, yoghurt/margarine pots, condiment bottles, sanitary pad liners
- Uncommonly recycled, frequently found in landfill
- Considered safe but some studies demonstrate potential to exacerbate asthma or act as an endocrine disrupter

Polystyrene
- Disposable foam cups, packaging, take-away food containers
- Not widely recycled
- Considered toxic - styrene is probably carcinogenic

Others
- Used in baby bottles, dental sealants, light fixtures, many more
- Generally difficult to recycle
- Potential to leak BPA and endocrine disruptors

The public health implications of plastics and plastic pollution

While once considered inert, unreacted monomers and other harmful substances can be found within plastics. Some plastics may be chemically harmful, either directly toxic themselves or because they absorb and carry other pollutants.[5] Chemical effects include damage to the heart, nervous system, reproductive system and potential cancers.[12] Monomers and other substances in plastics can mimic the effects of oestrogen in living organisms. The *United Nation's Globally Harmonised System of Classification and Labelling of Chemicals* considers such elements to be in some way hazardous in more than half of plastics produced; some have even been observed accumulating in blood.[5] Pesticides and organic toxins are found on plastic particles at harmful concentrations – 100 times more than found in sediments and a million times more than in seawater.[5]

Seafood, alcohol and plastic-bottled water are the greatest sources of microplastic ingestion in humans.[13] While the investigation of the toxic effects of microplastics in food webs is complex and ongoing,[14] evidence suggests that ingestion of these microplastics in humans may be associated with infertility, obesity and suspected endocrine dysfunction including oestrogen mimicking, which in women has been associated with breast cancer.[12] While difficulty lies in separating the comparative exposure from pollution and food webs and exposure via food packaging,[14] it could be argued that this separation is a moot point should significant human health effects begin to unfold.

Human health risks from plastics stem from their component monomers such as bisphenol A (BPA), additives such as plasticizers, or a combination of the two.[15] While there is very limited information about the long-term human health effects of plastics, research has demonstrated high levels of (BPA) in women and young infants[16] and this may cause alterations in neurological white matter in children.[17] These findings require more long-term research. BPA is both a plastic monomer component and an additive to many varieties of plastic. Ingestion is the commonest route of exposure via plastic packaging, particularly re-usable plastic packaging where repeated washing and storage results in polymer breakdown. Studies have determined that around 95% of humans have detectable serum and urinary levels of BPA. The overall health risks of BPA are still under debate and are by no means fully comprehended; it is currently classified as an oestrogen mimic and endocrine disruptor in that it is known to bind to oestrogen receptors. Current reference doses of BPA, it is argued, are unsuitable for assessing the risk. It has also been argued that owing to the endocrine-system effects, any level of exposure is unacceptably harmful.[14] Animal studies have noted the effects of BPA to include: increased postnatal growth, early sexual maturation (in females), sex hormone imbalances in both males and females, decreased fertility in males, prostatic hyperplasia, alterations in immune system function, hyperactivity and more.[15] BPA is also the compound of interest when considering pollution-related microplastic infiltration of the food web. Replacement phenols for BPA such as BPF and BPS may be just as harmful to human health and research into alternative safe materials is required.[18]

The healthcare system utilises an abundance of plastics owing to their inexpensive production and single-use sterile nature.[15] Medical devices such as those used in dialysis, blood transfusion and extra-corporeal membrane oxygenation (ECMO) contain phthalates. These compounds can also be ingested from food contaminated from plastic packaging. Despite being rapidly metabolised, health concerns associated with phthalates include endocrine disruption and malformations of the male reproductive system in animals. Human studies have also drawn an association between serum phthalate levels, increased waist circumference and insulin resistance.[15] The human health risks of phthalates remain under some scientific debate; however, there is evidence from longitudinal birth cohort studies in animals that peri-natal phthalate exposure can impair brain development and there is emerging evidence that phthalate exposure increases the risk of learning and attention deficits in children.[19]

While the risks and impacts of plastic-related toxin exposure need further investigation, more extensive and integrated safe recycling and disposal of plastics must increase significantly on a global scale to prevent potential harms.

Additional to chemical effects, plastics disrupt ocean ecosystems with an indirect effect on human health. For instance, alongside climate-change-related ocean warming, plastic pollution is having a direct effect on coral reefs. Corals feed on zooplankton and similar small species, thereby ingesting microplastics. Plastic-related health damage to coral reefs contributes to their declining health in an already increasingly hostile environment.[12] Coral reefs are essential coastal structures, not only functioning as vital components of food webs and ecosystems but also providing natural physical barriers to storms and cyclones. This compounds the impacts of greenhouse gas emissions and other anthropogenic effects on the oceans; 87% worldwide of coral reefs have some level of degradation.[20]

Responding to the plastics pandemic

The most immediate concerns are poorly managed macro-plastic waste and microplastics that pollute the environment. This is an area where immediately beneficial action is possible. Management of other plastics in major industries and infrastructure will need longer-term planning and management.

We need to both remove existing and prevent new contamination. Prevention is partially addressed by the slogan: reduce, refuse, reuse, repurpose and recycle. This focuses on what individuals can do to divert pollution from the environment. Other sources of microplastics such as cosmetic beads and clothing also have relatively straightforward solutions but require legislative change as well as consumer information. The more complex issue of our societies' reliance on plastic needs discussion, policy development and decisions about production, use and waste management.

Australia must urgently develop a plastic pollution policy that focuses both on supporting and encouraging individual action and a broader system in response by industry groups.

What individuals can do immediately, while insufficient, is useful; in 2016–17 in Australia, a mere 12% of generated plastics were recycled.[21] This low yield is often due to poor public understanding regarding the suitability of different plastics for recycling.[22] Consequentially, within a broad policy response, advocacy and education are fundamental to addressing plastic pollution.

Individual action can occur at the personal, household and community level. Community-based social marketing is an approach that provides evidenced-based strategies that governments, usually local, can use to lead such action on waste reduction and recycling.[23] The site [Authors, please specify which site you are referring to] also has community discussion fora and resources to share ideas and seek advice.

To promote awareness and normalise sustainable waste management practices, social initiatives such as 'Plastic-free July' encourage people to reduce their single-use plastic purchases and find novel ways to reduce plastic pollution.[24] Additionally, local governments and agencies hold public events to assist with marine clean-ups. Such initiatives build on public education and advocacy, fostering a sense of individual responsibility for plastic pollution reduction.[25]

Clean-up of the plastics already in the environment is a mammoth task that, while beginning with such projects as 'The Ocean Cleanup',[26] can never be completed while production and improper disposal continue. In addition, after collection, the waste still needs further disposal. An alternative to recycling and incineration is using microbes to degrade plastics enzymatically. There are several bacterial species known to degrade polymers, including soil-based strains of staphylococcus and pseudomonas,[27] however, the solid nature of plastics means that bioavailability is low. This means that biodegradation is slow and this solution on any large scale would be challenging. An alternative to biodegradation may be co-metabolic biotransformation[28] to stimulate indigenous microbes with degrader properties;[29] however, more research is required to ascertain feasibility.[28]

This is a serious environmental crisis that has both direct and indirect adverse effects on the public's health. The public health profession's role is education and advocacy through policy development, and campaigning for governments, industry and individuals to take the necessary preventive and protective actions. Further, we need to adopt the concept of ecosystem stewardship that is emerging within the eco-social and planetary health domains. This is an action-based framework for the development of ecological sustainability, including reducing the vulnerability of communities to expected changes, fostering resilience and responding to trajectories where possible.[30]

It is imperative that management strategies are developed and implemented now, for if plastic pollution rates continue as they are, it is likely there will be 33 billion tons of plastic present globally by 2050.[5] Inaction is arguably an action in and of itself and one that could be catastrophic for the health of the planet and all its inhabitants. *Natural disasters or calamities cannot be avoided, but man-made blunders can be stopped or terminated.*[31]

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