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Plastic contamination of the food chain: A threat to human health?

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ABSTRACT

Macro-plastic pollution is found in terrestrial and marine environments and is degraded to micro-particles (MP) and nano-particles (NP) of plastic. These can enter the human food chain either by inhalation or by ingestion, particularly of shellfish and crustaceans. Absorption across the gastrointestinal tract is relatively low, especially for MPs, which appear to have little toxicity. However, NPs are more readily absorbed and may accumulate in the brain, liver and other tissues in aquatic species and other animals. Studies using nanoparticles of other materials suggest that toxicity could potentially affect the central nervous system and the reproductive system, although this would be unlikely unless exposure levels were very high and absorption was increased by physiological factors.

1. Introduction

Since the early 1950s, when the large-scale production of plastics began, some 8.3 billion (10^9) tonnes have been produced, of which three-quarters has now become waste [1]. Global annual production of plastic materials currently exceeds 320 million tonnes, 40% of which is single-use packaging. Much of this is not recycled and, since most plastics are non-biodegradable, they are to be found throughout the world, including the polar regions. They occur in the atmosphere as well as both the terrestrial and marine environments and it is within the latter that they have become most striking, being trapped and concentrated by circulating ocean currents (gyres) and then forming vast areas of plastic debris [2]. Disruption of the ecosystem will have an impact, either directly or indirectly, on the environment that human beings share with other creatures and could have long-term effects. Plastic pollution may therefore be a potential threat to human health, particularly if there is contamination of the food chain.

The most obvious plastic pollution arises from large (macro) items, including bottles, cartons, food wrappings, plastic straws and cosmetic products. However, this macroplastic can be further degraded. When photo-oxidised by UV light (sunlight) it becomes brittle; wind and wave action then produce plastic debris which contaminates the environment. Much of this is lost to the seas and oceans where it accumulates and extrapolations from current figures suggest that 250 million tonnes will be present by 2025. This degraded plastic material may be subdivided by size into microplastics (MPs; < 5 mm), found as fibres and fragments and nanoplastics (NPs; particles < 0.1 µm; 100 nm); both of which (plastic pollutants, PPs) are currently of concern as potential hazards to human health (Fig. 1). Plastic additives such as bisphenol A and phthalates, which are not chemically bound in plastic polymers, may also leach out and contaminate the marine environment – their potential effects on biosystems have been extensively reviewed and will not be discussed further [3]. Cadmium, lead, selenium and chromium (from the coloured pigments cadmium sulphoselenide and lead chromate) with bromine (probably from brominated flame retardants) also contaminate plastics [4] but this review will focus on PPs themselves.

For this review, literature searches were carried out using standard search engines, particularly Ovid Medline, and search terms 'plastic*' microplastic, nanoplastic, toxicity, food (human), nanoparticle, pollution.

2. Plastic types

Plastics are basically polymers, repeated units linked together as a chain. The chains may be cross linked or branched and the inclusion of other chemical monomers (as copolymers) may alter their physicochemical properties. Many plastics exist now that can be tailor-made to suit specific requirements. The most common types of plastic that the public will encounter, with a few examples of use, would be polyethylene (polythene; PE) in a low density form (LDPE; bin bags, film) and a high density construct (HDPE; shopping bags, bottle caps) or as a tetraphthalate (PET; bottles, food trays), polypropylene (PPL; rigid tubs, straws), polyvinyl chloride (PVC; pipes, door and window frames) and polystyrene, both rigid (PS; food pots, toys) and expanded (EPS; packaging, insulation) [5]. Other plastic varieties exist, some crystalline, some amorphous in a fluid matrix, but these are usually for

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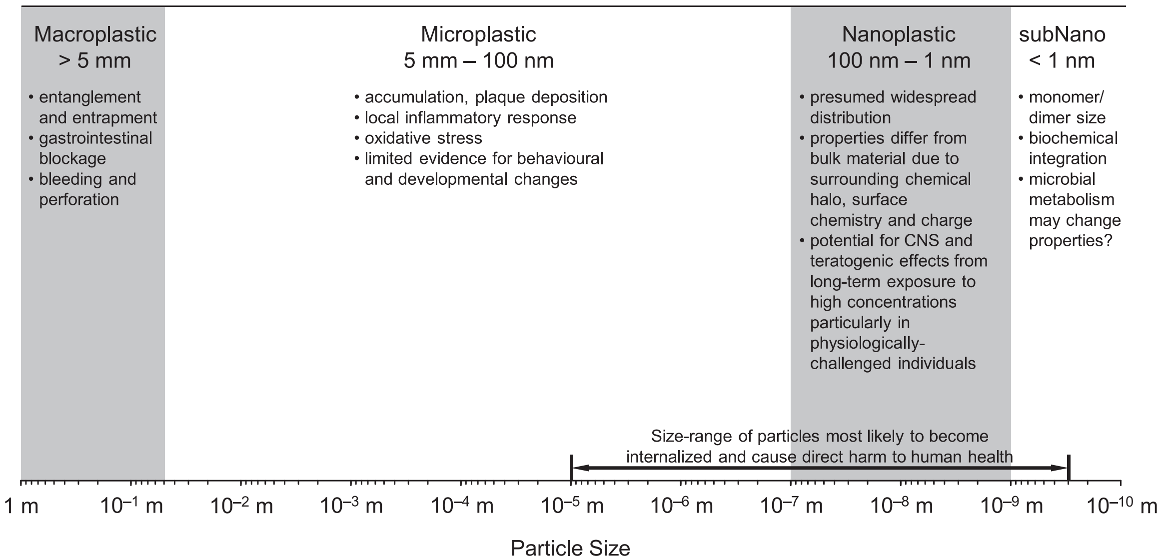

Fig. 1. Types of plastic in the environment.

specialist usage.

3. Plastic contamination of ecosystems

3.1. Terrestrial

Initially, most contamination by plastics originates from terrestrial areas *via* human actions. Although there are a few natural plastic polymers such as latex (natural rubber) all the common plastics are solely human inventions. Land-based sources of plastic litter come from uncovered landfill sites, untreated sewage, wind-blown debris and rubbish jettisoned by human activities including bottles, plastic bags and boxes, road marking paints, footwear, car, bus and lorry tyres. These generally start as macroplastics which are subjected to slow environmental degradation releasing smaller particles that are more capable of moving around the ecosystem. Plastics buried within covered landfill sites will remain for many decades, posing potential problems for the future, although 'landfill mining', where debris is incinerated as fuel to provide energy, has been proposed.

3.2. Aquatic

Rivers are estimated to transport 70–80% of plastics that arrive in the oceans [6], most of this coming from manufacturing processes, agriculture and from waste water treatment plants which discharge their effluents into aquatic systems. Recent studies have focused on the release of fibres and MPs generated when clothes are washed - a standard 5 kg wash of polyester fabrics has been estimated as releasing up to 6,000,000 microfibres [7]. Over 95% of these plastic particles are retained in the biosolids from the treatment plant but this sludge is often used on agricultural land and the PPs are then scattered by the wind or transported by rainwater drainage back into the water systems.

Marine-source plastic litter comes from shipping, oil and gas platforms and fishing (discarded nets). For example, samples of sediments of the Ross Sea in Antarctica all contained plastics with particles ranging from 0.3 to 22 mm in length, mostly MP fibres of the styrene-butadiene copolymer (SBR; synthetic rubber) widely used in pneumatic tyres, probably from the Mario Zucchelli Base (Terra Nova Bay, Antarctica) [8]. This picture appears globally; plastic debris from sediments in five beaches on the Northern Adriatic coast was similar to other sites including those in Australia where about two thirds of the debris was MP filaments mostly from PE and PS [9].

Much marine debris is composed of MPs which have similar sizes and appearance to organisms such as zooplankton and can therefore be regarded as prey by marine life. As fish and shellfish are a major source of protein for many of the world's population, plastic particles may contaminate the human food supply. At the top of the piscine food chain, North Sea fish and Atlantic cod from Newfoundland had low particle counts [10,11] although most estuarine fish in a South American river had plastic debris inside the gut, suggesting that freshwater fish are more vulnerable to MP pollution [12]. The fish habitat is clearly a major factor in accumulating PPs. Sampling near the river Thames in London, UK, showed that up to 75% of European flounder, which are bottom feeders, had MPs in the gut as opposed to 20% of European smelt which are predators of other fish [13]. Zooplanktivorous fish such as anchovy, pilchard and herring had MP contamination (mostly PE) in the liver. Fish at the top of the food chain and living in the sea rather than rivers will therefore be less polluted. Generally, fish accumulate MPs in their gills, liver and gut, which may not be relevant to human consumption since these tissues are not usually consumed.

So far, PPs seem to be more readily internalised by filter feeders, probably because they are of the same order of magnitude as their preferred diet. Blue mussels exposed to NPs (30–100 nm) of PS showed intestinal uptake [14,15]; adsorption of NPs onto green algae and subsequent movement through the aquatic food chain *via* zooplankton to fish has also been demonstrated for PS [16,17]. Analysis of soft tissues from commercially grown blue mussels and the giant Pacific oyster gave MP levels of 36 ± 7 and 47 ± 16 particles/100 g wet weight, respectively [18]. Like other shellfish, these are eaten whole and it has been estimated that European shellfish consumers (presumably including Belgians enjoying 'Moules frites') could potentially ingest 11,000 microplastic particles/year although this seems much too high a figure for UK consumers [19]. Using the blue mussel as a test organism, 10 µm was the upper limit for translocation into the circulatory system – as mussels are generally eaten whole this gives the particle size relevant for human ingestion.

3.3. Aquatic 'Mats'

Small plastic particles have a high surface to volume ratio and readily adsorb other marine contaminants, such as the hydrophobic persistent organic pollutants (POPs), potentially concentrating them onto 'mats' of MPs [20]. These aggregations then act as 'sinks' for a range of chemicals which may cause toxicity responses such as endocrine disruption. Additionally, marine plastic debris has a negative visual impact, reducing tourism and commercial fishing and providing a