MARINE PLASTIC POLLUTION

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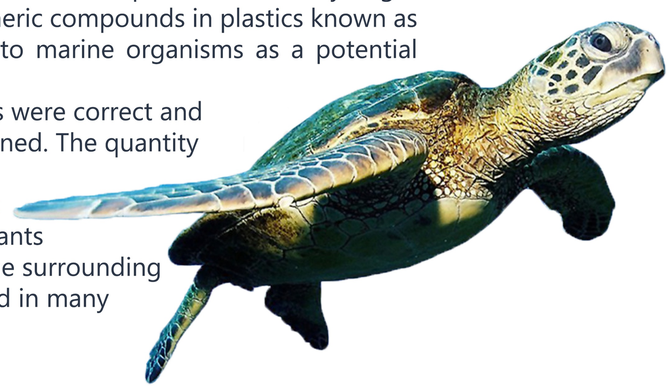
INTRODUCTION

Plastic touches all of our lives, from food packaging to computers and cars. But many of the plastics you touch in your daily life are used only once and thrown away and much of this plastic is ending up in the ocean. The handling of plastics on land will determine the future of our oceans for plastics impact nearly **700 species** in our ocean ranging from plankton to whales and corals.
It is estimated that more than **8 million metric tons** of plastic is entering our ocean every year [1] which means that in just a few years, we might end up with a pound of plastic for every three pounds of fish in the sea. Synthetic polymers have therefore made themselves a permanent part of the marine environment.
The first concerns about plastics in the marine environment emerged in the 1970s thanks to Edward Carpenter of the Woods Hole Oceanographic Institution who speculated that this problem was likely to get worse and that toxic, non-polymeric compounds in plastics known as plasticizers could be delivered to marine organisms as a potential side-effect.
Today, we know his speculations were correct and probably more so than he imagined. The quantity of plastics in ocean waters has increased enormously, and toxic plastic additives, as well as toxicants concentrated by plastics from the surrounding seawater have been documented in many marine species [1,2,3,4].



HOW DOES PLASTIC END UP IN THE OCEAN ?

In 1975, the estimated annual flux of litter of all materials to the ocean was 5.8 million metric tons (MT), based only on discharges from ocean vessels, military operations, and ship casualties. The discharge of plastic from at-sea vessels has since been banned, but losses still occur. Nowadays, it is however widely cited that **80% of marine debris originates from land** [2].

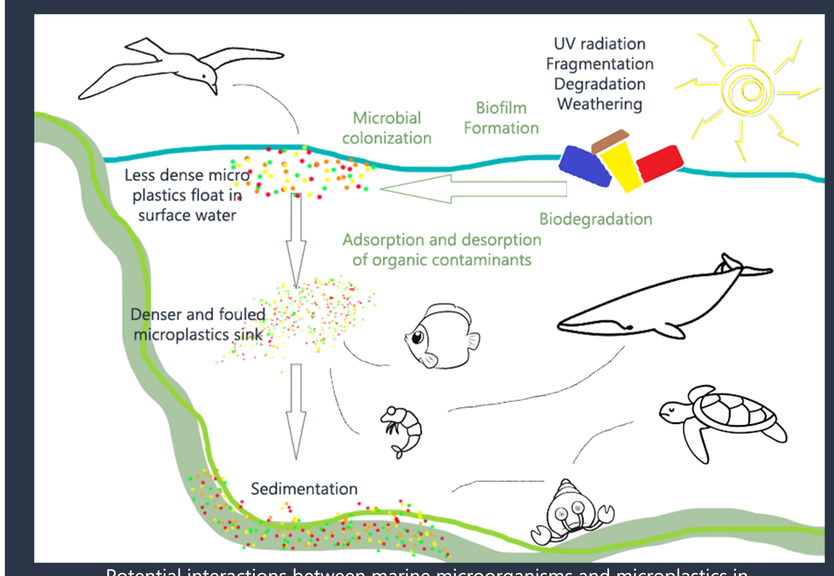
Three main sources allow plastics to enter the oceans from land [4] :

Rain and winds : In 2016, for the first time, more plastic packaging waste was recycled than landfilled in Europe. Unfortunately, in many countries, **landfill is still the first option**. When being transported, or when in open landfill, lightweight plastic is often blown away. It then eventually clutters around drains and enters rivers and the sea. Estimates of the mass of plastic waste carried by particular waterways range from <<1 kg per day (Hilo, HI) to 4.2 MT (4200 kg) per day (Danube River) [2].

Littering : Litter dropped on the street does not stay there ! Careless and improper waste disposal is also a big contributor – illegal dumping of waste adds greatly to the plastic surge in our seas.

Streams and storm drains : Many of the products daily are flushed down toilets : wet wipes, cotton buds and sanitary products. Microfibres are even released into waterways when using the washing machine. Industrial draining from costline factories also leads to large amount of plastic being released.

A FOCUS ON MICROPLASTICS



Potential interactions between marine microorganisms and microplastics in marine environment [3]

FRAGMENTATION PROCESS

Photo-oxidation of polymers is initiated by solar UV radiation or heat and helped by mechanical forces. High-energy UV-B (290–315 nm) and medium energy UV-A (315–400 nm) **solar wavelengths are particularly efficient** [3]. Oxidative chemical reactions involves :

- incorporation of oxygen-containing functionalities into the polymer molecules
- scission of long chain-like polymer molecules reducing the number-average molecular weight of the plastic material.

Of these, it is the latter that drastically affects the useful properties of the polymer. Even at less than one percent oxidation, very substantial loss in mechanical strength can occur.

The basic mechanism of light-induced degradation for the two plastics used in highest volume and therefore most numerous in marine debris, PE and PP, is well known. It is a free-radical reaction initiated by UV radiation or heat and propagated via hydrogen abstraction. As peroxide products can themselves dissociate readily into radicals, the reaction sequence is autocatalytic.

$$RH \rightarrow R\bullet, H\bullet$$
$$R\bullet + O_2 \rightarrow ROO\bullet$$
$$ROO\bullet + RH \rightarrow ROOH + R\bullet$$

At the same time, settlement of the biomass on floating plastic called **biofouling** occurs, letting plastic particules sink and sediment. However litter in sediment persist for a long time, as degradation rates lower due to low ambient temperature, lack of light and dioxygen [1,3].

Microplastics (plastics under 5 mm) comprise a very heterogeneous assemblage of particles usually subdivided as [1] :

- 'primary' microplastics, produced either for indirect use as precursors (nurdles or virgin resin pellets) for the production of polymer consumer products, or for direct use as in cosmetics
- 'secondary' microplastics, resulting from the breakdown of larger plastic material into smaller fragments up to the nano scale. Some 'degradable' plastics are even designed to fragment quickly into small particles, however, the resulting material does not necessarily biodegrade.

WHY IS IT CONCERNING ?

There are three main concerns whith microplastics [1,4]:

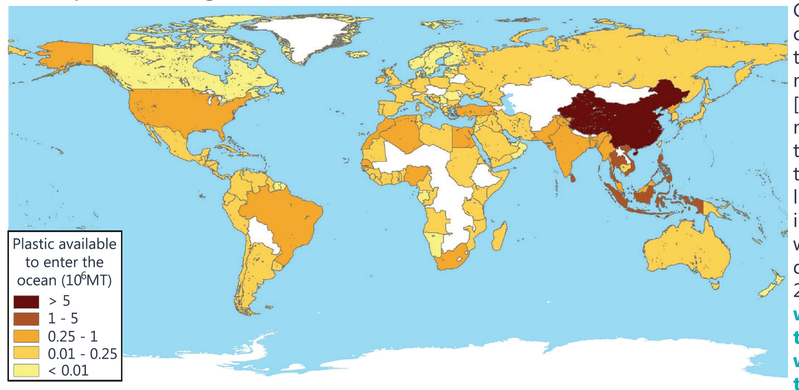
- They introduce **persistent organic pollutants** (POPs) into marine foodwebs : microplastics contain biolo gically active plasticizers called 'additives' such as Bisphenol A (BPA) and di-butyl phthalates used to give tensile strength or flexibility.
- Plastic particles also tend to **adsorb and accumulate toxic materials from the surrounding seawater** such as polychlorinated biphenyls (PCBs) or heavy metals.
- They provide raft **substrates for bacteria and algae** and transport them to new areas. The invasion of these species can be detrimental to littoral, intertidal and shoreline ecosystems.

The smaller the particle, the more efficient these mechanisms are [2].

Research shows that most invertebrates and myctophid fish consume microscopic plastic particles which can even pass through cell membranes [1]. These species are an essential trophic link in many oceanic ecosystems, therefore introducing rippling effects in the whole foodweb. The most common of which is digestive organs malfunctions, often leading to starvation.

Other harmful effects reported are :

- adsorption of nanoplastics in the organism's skin
- lowered steroid hormone level
- delayed ovulation and reproductive failure
- delayed growth and death.



Global map with each country shaded according to the estimated mass of mismanaged plastic waste [millions of metric tons] generated in 2010 by populations living within 50 km of the coast. Only the 192 costlines countries are taken into account. Mismanaged waste is the sum of inadequately managed waste plus 2% littering. **The top 20 waste-producing countries' mismanaged plastic waste encompass 83% of the total** in 2010 [2].

POSSIBLE MANAGEMENT STRATEGIES

Total annual waste generation is mostly a function of population size. However, the percentage of mismanaged waste is also important when assessing the largest contributors. Sixteen of the top 20 producers are middle-income countries, where fast economic growth is occurring but waste management infrastructure is lacking (the average mismanaged waste fraction is 68%). Only two of the top 20 countries have mismanaged fractions <15%. If there were a 50% increase in **adequate disposal of waste** (i.e. 50% less mismanagement) in the 20 top-ranked countries, the global mass of mismanaged plastic waste would decrease 41% by 2025 [2,4].

Alternatively, **reduced waste generation and plastic use** would also decrease the amount of mismanaged plastic waste. If per capita waste generation were reduced to the 2010 average (1.7 kg/day) in the 91 coastal countries that exceed it, and the percent plastic in the waste stream were capped at 11% (the 192-country average in 2010), a 26% decrease would be achieved by 2025 [2].

Aside from reducing, reusing, and recycling plastic waste, two more solutions should be considered : **energy recovery** and **molecular redesign** [2,4]. The first consists in producing energy with the plastics we can't yet recycle : if all landfilled plastic were convert in energy in the US, 14 million houses could be powered each year. Research on the latter focuses on the microbial activity and biofilm development on plastic surfaces in the marine environment. Adaptation to new sources of carbon can create new features of microorganisms' enzymes and provide numerous biotechnological opportunities.

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