# Missing Plastic? Investigating the distribution and transfer of ocean plastics through trophic levels

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## Abstract

An estimated 9.5 to 25 millions tons of plastic will enter the world's oceans annually by 2025. As a result, there is a growing importance to improve our understanding of the relationship between plastic pollution and marine species. Despite a globally acknowledged plastic crisis, researchers have struggled to detect the expected increases in marine plastic debris in sea surfaces sparking discussions about "missing plastics" and final sinks.

The redistribution of different polymer types in the world's oceans is aptly illustrated by debris collected from the beaches of Cornwall. Density studies suggest the likely destination of heavier polymers is degradation to microplastics and subsequent burial in deep sea sediments. Microplastics have been found in the stomachs of fish destined for human consumption; links between the polymers identified in fish and the feeding habits of the fish are hypothesised.

## The plastic problem

The word plastic is usually used to refer to the numerous organic synthetic polymers that have become ubiquitous in daily life. Their durability and energy-efficiency of production have led to an exponential increase in their production since the 1940s. Adequate methods for the disposal of plastics have not yet been identified and as a result increasing amounts of plastic are finding their way into the worlds oceans.

Despite resistance to biodegradation, the degradation of large plastic items into microplastics is relatively rapid. Microplastics can easily enter the food chain, either by direct consumption by a species or by bioaccumulation through trophic levels.[2]

Through degradation, many plastics have been shown to leach compounds harmful to the health of aquatic organisms as well as to humans. Some hormone-like compounds, such as bisphenol A (BPA), have been linked to the development of cancers in humans.

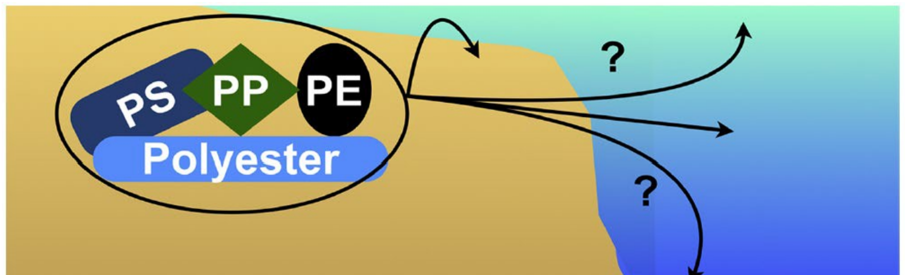



**Figure 1.** Identifying the final sinks of polymers escaping into the ocean is a growing concern for researchers.

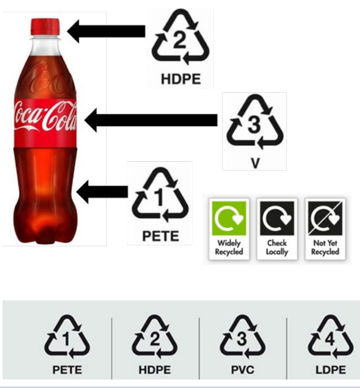



**Figure 2.** Resin Identifier Codes (RIC) used to identify the polymer used to produce an item. Polymers cannot typically be co-recycled leading to time and energy consuming separation.

## Case Study: Lego Lost At Sea

On February 13th, 1997, 62 containers fell off the cargo ship Tokio Express when it was hit by a rogue wave 20 miles off the Cornish Coast.[1]


One of the containers held nearly five million pieces of Lego, much of it sea-themed. In the years since the spill, Lego has continued to wash up on Cornish beaches. Collecting the pieces has become a hobby for many Cornish beach cleaners.

Every year, 160 million containers are shipped worldwide. It is estimated that of these between two and three thousand are washed overboard.

It takes 3 years for plastic debris to be washed across the Atlantic ocean. In the 23 years since the spill, the plastic could have travelled 85,000 miles, more than three and a half times the Earth's circumference. There could be Lego from Tokio Express on any beach on Earth.

## The prevalence of plastic on beaches by polymer

The origin of beach plastic found on beaches cannot be determined and it should not be assumed that all plastic has been washed up. A typical beach clean (1h) yielded over 3kg of mixed plastics. These were classified by Resin Identification Code and weighed.[3] Figure 3 reflects the large amounts of rope and fishing line (nylon, 7) typically found.

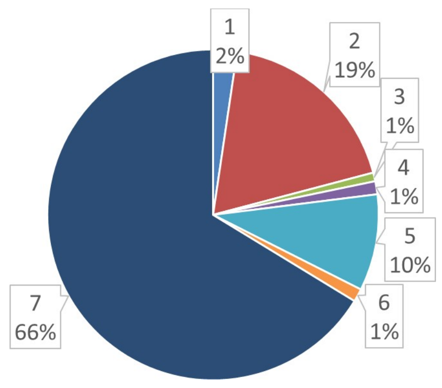
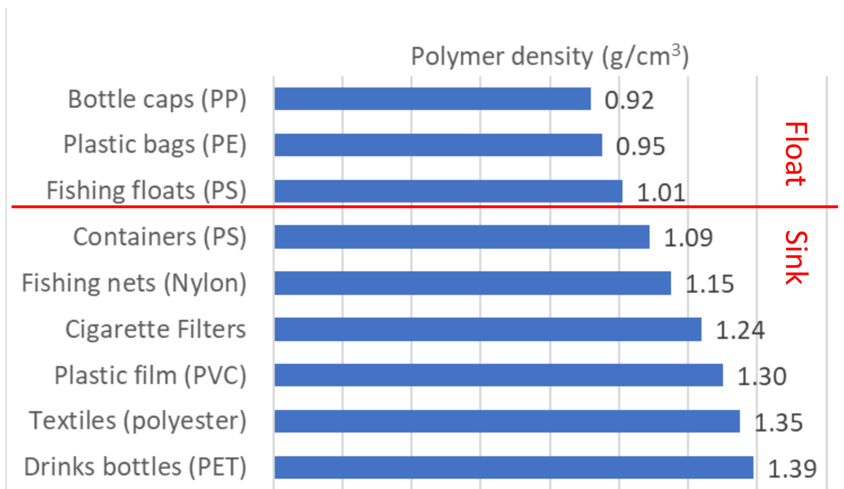



**Figure 3.** Analysis of plastics found on a typical beach clean. Plastics were identified by eye or by origin. Percentages were determined by mass. Clean time: 1h; total mass: 3.12kg; clean location: Hayle Sands, Cornwall, UK.




The density of different plastic items was identified by floating prepared samples of plastic in varying concentrations of ethanol/water and salt/water mixtures. The typical density of sea water is 1.02-1.03g/cm$^3$, thus those objects below the red line would be expected to sink in the ocean.

**Figure 5.** Density of plastic items. Method: Samples of approximately 0.2g were cut and placed in a beaker of water. Those that floated (d < 1.0g/cm$^3$) were removed, dried and placed in ethanol (25cm$^3$). Water was added to the ethanol until the plastic floated. Those that sank (d < 1.0g/cm$^3$) were dried and placed in water (25cm$^3$) and salt (NaCl) was added until the plastic floated. The mass of water/salt added was used to determine the density of solution and thus the density of the plastic.

## Investigating microplastics in fish stocks

The presence of microplastics in fish destined for human consumption is of a growing concern.[4] Samples of four species of fish were dissected and evidence of plastic contamination was explored.

| Species | Fish Mass | Plastics found |
|---|---|---|
| Mackerel | 310g<br>253g | 1 (PP)<br>- |
| Bream | 292g | - |
| Sea Bass | 311g | 1 (PP) |
| Rainbow trout | 346g | - |


**Figure 4.** Searching for microplastics in fish stocks. All fish were line-caught in Cornish coastal waters and purchased from local providers, except rainbow trout which was farmed in fresh water. Method: Incision was made from the anus to the gill covers along the ventral side. The intestinal tract (oesophagus, stomach, pyloric ceca and intestines) was located, removed and rinsed through with water. The tract was then opened and rinsed with further water. The combined washings were filtered using a Bucnher filter and dried on the filter paper. Samples were inspected under a microscope.

Two of the fish were found to contain microplastic. Each piece was a thread, less that 1mm in length and relatively inflexible, leading to their identification as polypropylene (PP).

## Polymer degradation study

To simulate the varying conditions in which polymers may degrade, samples of HDPE were stirred in saltwater with sand, in the presence or absence of UV light. After14 days, aliquots of water were removed and filtered. Analysis using a microscope showed the presence of thread-like microplastics in both samples. The sample stirred under UV light showed significant discolouration, suggesting the likely leaching of chemicals into the water.

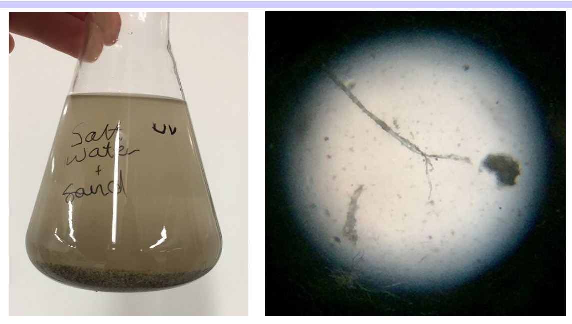



**Figure 6.** Plastic degradation model study. The presence or absence of UV light was designed to simulate degradation on the water surface vs degradation in deep water. Method: HDPE sample (2.0g) cut and placed in 100ml of saltwater with 25g sand. One sample was wrapped in foil while the other was left below a UV lamp. Stir time: 14 days. Samples filtered and analysed by microscope.

## Implications and future work

Determining the origins and fate of ocean plastic is a significant and important challenge. These studies have illustrated a series of important implications which will be the focus of ongoing investigations.

Firstly, different plastics occupy different sections of the water column, based on their varying densities. The relative quantities of different plastics found on beaches does not reflect the distribution of plastics being produced and entering the ocean. Density studies have shown that the likely fate for higher density polymers is most likely the ocean floor. Further studies of sediments for the identification of microplastics will aim to confirm the fate of heavier resins.

Simple degradation studies have shown that the varying conditions within the water column will significantly alter the rate and manner of degradation of plastics. The effect of temperature has not yet been considered but would be an important factor to consider.

The uptake of microplastics into fish stocks is alarming but not unexpected.[4] To our knowledge, no investigation linking the type of plastic found in fish and the section of the water column in which they feed has been conducted. Further investigation will focus on dissection of different species of fish (e.g. surface vs bottom feeders) with the hope of identifying trends in the types of plastics taken up at different parts of the sea column.

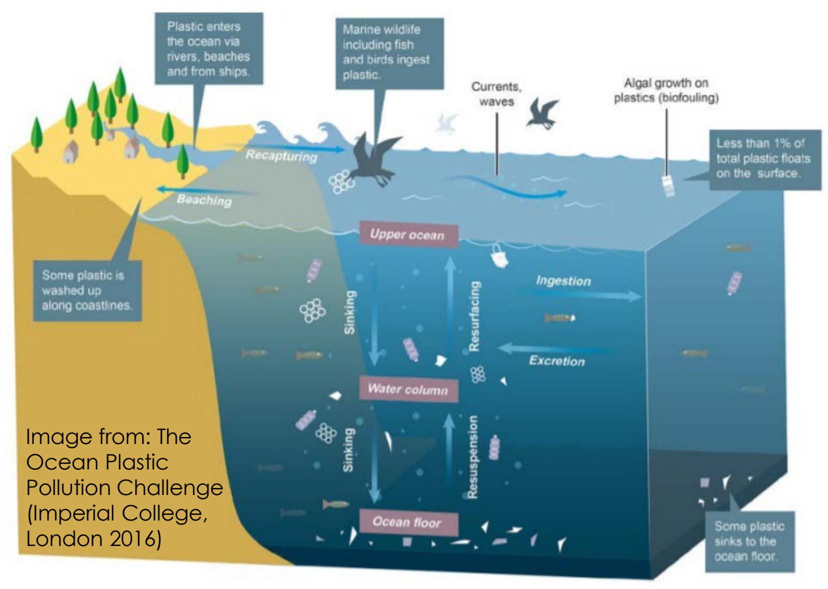



Image from: The Ocean Plastic Pollution Challenge (Imperial College, London 2016)

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## Acknowledgements

The authors wish to thank our teacher, Dr Gower for his support and Camborne Science and International Academy for the opportunity to take part in ISYF 2020.

In particular, we wish to thank the staff and students of HCI for organizing such an inspiring event.