Quantification of Micro-plastics From Beaches of Long Island and Connecticut

By

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1. Abstract

Plastic debris in the oceans and on coastlines is of growing concern, with issues ranging from aesthetic to ecological. This research quantified micro- (0.5 – 5.0 mm) and macro-plastics (> 5.0 mm) in sediments collected from intertidal zones of eleven locations along the shores of Long Island and Connecticut. Shores surrounding the Long Island Sound estuary, ocean-facing beaches along the south shore of Long Island, and bays within Long Island were sampled. Three cores of ca. 265 cm$^3$ were collected at five points along the wrack line.

Recovered plastics included fragments, foam, fibers, beads, nurdles, and film. Foam constituted 94% of all plastic recovered. Ninety percent of all plastics were micro-plastics (< 5mm). In each of the four regions, eastern locations had the largest percentage of micro-plastics. The LIS-S region had the greatest density with 3.5 pieces of plastic per 10 g of sediment. The Bay region contained the lowest plastic density with 0.05 pieces of plastic per 10 g of sediment. Micro-plastic percentage increased along a West to East gradient. Understanding how plastics interact with the environment is a vital step in tackling the issue of plastic pollution.

2. Introduction

Since its creation in 1869, plastic has become one of the world’s most utilized materials. Wide scale production of plastics first began in the 1950's resulting in 5,800 metric tons of plastic produced as of 2015 (Geyer et al., 2017). The low cost, high strength, and universal use has made plastic a staple of modern society. The advent of plastic has benefited human health and safety, rapidly prolonged food shelf life, and has been revolutionary is modern building and manufacturing (Andrady et al. 2009). Unfortunately, the properties that make plastic so widespread in application, are also why it has become such a devastating pollutant. Plastic pollution has been documented on ocean floors (Wang et al., 2019), in Arctic ice (Obbard et al., 2014), on remote islands (Lavers et al., 2016), in wildlife tissue (Abbasi et al., 2018) and in human bodies (Prata, 2018). Either from poor disposal, intentional littering, or through accidental spill or release, plastics have made their way into every corner of our environment. It is estimated that 4.8 to 12.7 metric tons of plastic waste entered the ocean in the year 2010 alone (Jambeck et al., 2015).

Coastal plastic pollution has been documented on the coasts of Asia, Australia, Europe, North America, South America, and Antarctica (Ocean Conservancy, 2017). Not only is plastic debris aesthetically displeasing, plastic pollution impacts the health of wildlife. Plastic debris has been
documented in the stomachs of deceased marine turtles (Caron et al., 2018) and marine birds (Wood, 1997), as well as countless cases of marine mammal entanglements (NOAA, 2014). Lower trophic level organisms also experience complications with marine plastic debris. Micro-plastics, plastics smaller than 5 millimeters (Thompson et al., 2009), have been found to reduce the buoyancy of zooplankton fecal pellets, potentially disrupting pelagic-benthic coupling (Cole et al., 2016).

Not only do plastics cause physical harm, ingestion of plastic can cause disruption of the endocrine system of organisms (Rochman et al., 2014). Persistent organic pollutants such as DDD, DDE, and DDT adsorb onto plastics while in the marine environment (Ogata et al., 2009). Transfer of chemicals via plastics has been documented in seabirds as early as the 1980’s (Ryan et al., 1988).

The world’s oceans hold vast amounts of plastic pollution (Andrady, 2015); through winds (Moore, 2008) and water currents, plastics are transported to coastlines around the globe. This accumulation of plastics on coastlines has become a worldwide phenomenon. Currently, there are no studies of micro-plastic contamination on the coasts of Long Island and Connecticut. The goal of this study was to provide the first ever research into micro-plastic contamination on the shores of Long Island and Connecticut

3. Materials and Methods

![Sediment Sample Collection Locations](image-url)

*Figure 1. Sediment sample collection locations grouped by coastline type. Long Island Sound North (LIS-N), Long Island Sound South (LIS-S), Bay, and Ocean.*
Locations were preliminarily determined by approximate geographical spread across the coasts using Google Maps. Once the eleven locations were selected (Fig. 1), sediment cores of ca. 265 cm$^3$ were collected at five locations at each beach at the wrack line or the most recent high tide line using a garden bulb planter. The five collection locations at each beach were spread among stretches of sandy beach ranging from 300 to 4,200 meters in length. Samples were collected and transported in one gallon zip lock bags.

Sediments were then sieved and searched for micro- and macro-plastics. Plastics smaller than 0.5 mm were not considered due to difficulties with positive identification. Sieves of 4.76 mm, 2.00 mm, and 850 micrometer mesh sizes were used to fractionate the sample. Each size fraction was then searched for plastics with the naked eye. Any plastics caught in the sieves were collected using forceps and placed in a vial labeled with beach name and location on the beach, West, Central West, Central, Central East, and East. Sediments from all size fraction sieves were then density-separated in a NaCl solution containing 6 g of NaCl for every 100 mL of H$_2$O. Sediments in the solution were then stirred, visible plastics were removed from the surface of the solution with forceps and placed in labeled glass vials.

Plastics were counted and divided into $\leq 5$ mm and $> 5$ mm fractions, and by type. Plastic type was determined by common knowledge of plastics. Plastic type consisted of; fragments, foam, fibers, beads, nurdles, and film. Singular fibers were not counted due to high potential of contamination through fibers shedding from clothing or contamination by airborne fibers in the lab. Only clusters of fibers were recorded. Plastic size class was determined using a metric lab ruler. Plastics were then weighed on a top loading balance and photographed with a LEICA DFC dissecting microscope.

4. Results

4.1. Micro-plastic occurrence, characterization, and geographic distribution

All eleven beaches sampled were contaminated with plastic. A total of 1,598 plastic particles, totaling 3.75 g, were recovered and characterized. Identified plastics included microbeads, fibers, foam, fragments, nurdles, and film (Fig. 2). Across all samples, a total of 16 microbeads, 4 fibers, 1,503 foam pieces, 65 fragments, 6 nurdles, and 4 pieces of film were recovered (Fig 3). Foam was the most abundant pollutant recovered, contributing to 94.1% of all plastic recovered (Table 1).
Fig. 2. Plastic types recovered; A. Microbeads, B. Fiber cluster, C. Foam beads, D. Foam, E. Fragments, F. Film, G. Nurdles. Photos taken at 0.80 magnification. Scale bar=2 mm.

Figure 3. Count of all plastic types recovered, associated values represent plastic counts.
Plastic composition for all four regions was dominated by foam. At the LIS-S region plastic type composition was as follows; microbeads made up 0.8%, fibers, 0.2%, foam, 96%, fragments, 3%, nurdles, 0.3%, and film, 0.1%. For the LIS-N region, only microbeads, foam, and fragments were recovered (Fig. 4 & 5). Microbeads contributed to 3%, foam, 88%, and fragments 9%. At the Ocean region, film was the only plastic type that was not recovered. Microbeads contributed to 4%, fibers, 1%, foam, 76%, fragments, 18%, and nurdles, 1%. In the Bay region, only foam, fragments, and film were recovered. Foam contributed to 65% of the plastics recovered, fragments, 24%, and film, 12%. Of the plastics recovered, LIS-S beaches had the greatest occurrence of plastic debris with 1,473 pieces of plastic. LIS-N had 34, Ocean, 74, and Bay, 26 (Fig. 6).
Figure 5. Percentage of plastic types by region, highlighting the 60-100% range.

Figure 6. Total plastic counts from each of the four sample regions.
Moving east across the coastlines, in the LIS-N region, Rye and Long had counts of 11, and Hammonasset had 13. For LIS-S, Stehli had a plastic count of 95, Cedar, 27, and Third had 1,351. In the Ocean region, Jones had 46, Dune Road, 5, and Indian Wells had 23. The Eastern location in the Bay region, Foster, had 17 pieces of plastic, while the Western location, New Suffolk, had 9. A one-way ANOVA showed a difference in means ($F = 3.748$, $P = 0.001$). Of all the locations, Third was significantly more contaminated with plastics than all of the other ten locations (Tukey’s HSD $p < 0.004$ for pairwise comparisons) (Fig. 7).

For each of the four regions, micro-plastics encompassed the majority of the plastics (Fig. 2). In each region, micro-plastic percentages were greatest in beaches furthest east (Fig. 8). Micro-plastic percentages, from West to East, in the LIS-S region for Stehli, Cedar, and Third, were 89%, 89%, and 92%, respectively. Micro-plastics collected from the LIS-N beaches of Rye, Long Beach, and Hammonasset, constituted 73%, 73%, and 83%, respectively. Ocean beaches of Jones, Dune, and Indian Wells, were 70%, 80% and 100% respectively. Bay beaches of New Suffolk and Foster contained, 56% and 94% respectively (Fig. 8). On average, 92% of the plastic recovered from LIS-S were micro-plastics, 77% for LIS-N, 80% for Ocean, and 62% for Bay. The most abundant micro-
plastic type recovered, for each of the four regions, was foam. Foam micro-plastic contributed to 89% of all micro-plastics in the LIS-S region, 68% for LIS-N, 66% for Ocean, and 39% for the Bay region (Table 2).

**Table 2. Percentages of plastic type smaller than 5 millimeters in each sample region.**

<table>
<thead>
<tr>
<th>Percent Micro-plastic (&lt;5mm) by Region</th>
<th>LIS-S</th>
<th>LIS-N</th>
<th>Ocean</th>
<th>Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>0.8%</td>
<td>2.9%</td>
<td>4.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Foam</td>
<td>88.7%</td>
<td>67.6%</td>
<td>66.2%</td>
<td>38.5%</td>
</tr>
<tr>
<td>Fragment</td>
<td>1.8%</td>
<td>5.9%</td>
<td>8.1%</td>
<td>15.4%</td>
</tr>
<tr>
<td>Nurdle</td>
<td>0.3%</td>
<td>0.0%</td>
<td>1.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Film</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>7.7%</td>
</tr>
<tr>
<td>Total</td>
<td>91.7%</td>
<td>76.5%</td>
<td>79.7%</td>
<td>61.5%</td>
</tr>
</tbody>
</table>

**Micro-plastic Percentage by Beach**

![Bar chart showing the percentage of micro-plastics by beach](image)

**Figure 8. Percentage of micro-plastics (<5 mm) for each of the eleven sample beaches**

### 4.2. Plastic Mass

The LIS-S region had plastic mass density values were 0.58 \( mg \cdot g^{-1} \), 0.01 \( mg \cdot g^{-1} \), and 0.21 \( mg \cdot g^{-1} \) for Third Beach, Cedar, and Stehli respectively. For LIS-N, Rye had 0.01 \( mg \cdot g^{-1} \), Long Beach had 0.004 \( mg \cdot g^{-1} \), and Hammonasset had 0.002 \( mg \cdot g^{-1} \). For the Ocean
region, Jones had a 0.07 \( mg * g^{-1} \), Dune Road had 0.001 \( mg * g^{-1} \), and Indian Wells had 0.001 \( mg * g^{-1} \). Foster Memorial Beach, in the Bay region, had 0.01 \( mg * g^{-1} \) (Fig. 9).

\[ \text{Plastic Density (mg}\text{g}^{-1}\text{Sediment)} \]

![Bar graph showing plastic density (mg\text{g}^{-1}\text{Sediment}) for different locations.](image)

\text{Figure 9. Density of plastic in sediments of each sample location.}

4.3. Plastic Distribution From West to East

Locations were pooled by Zone; West, East, and Central. Zone groupings were made by relative longitude similarity. The West zone contained beaches; Rye, Stehli, and Jones, which fell between a longitude of -73.55 and -73.66. Central contained; Long and Cedar, falling between a latitude of -73.02 and -73.14. East contained; Hammonasset, Third, New Suffolk, Foster, Dune and Indian Wells which all fell between -72.13 and -72.56 degrees longitude. Micro-plastic percentages increased along a West to East gradient in these zones (Fig. 10). The percentage of micro plastic in the West zone was 82%, Central was 84%, and East was 92%. There was no significant difference between any of the zones (one-way ANOVA, \( F = 0.242, p=0.791 \)).
4.4. Linear regression of Macro- and Micro-plastics in Beach Sediments

Across all sample beaches, micro-plastic abundance was about 5 times greater than macro-plastic abundance (Fig. 11) (p=<0.001, R-squared=0.998).
5. Discussion

This study provides the first data on micro-plastic contamination on the coasts of Long Island and Connecticut. Given general coastal plastic debris trends (Cannas et al., 2017, Eo et al., 2018, Stephen et al., 2018, Takunda et al., 2019, De Carvalho & Neto, 2016, Polasek, et al., 2017), it was expected these coasts would be contaminated. Further, foam plastic was found in the greatest abundance at each of the eleven locations. This suggests foam could possibly be the most commonly discharged plastic type or potentially has properties, such as high buoyancy, that facilitates transport and deposition at greater rates than other plastic types.

Similar plastic contamination trends have been found in the Yellow Sea in China. Zhou et al., (2018) found that 97% of micro-plastics recovered from coastlines were foam, similar to the 94% foam found on the coasts of Long Island and Connecticut. Similarly, Eo et al. (2018) found that 95% of plastics recovered from sediments on the coastline of South Korea were foam plastics. Eo et al. (2018) quantified plastics down to 0.2 mm in size, suggesting foam abundances are similar even in smaller size fractions of micro-plastics.

Thompson et al. (2004), found average micro-plastic (~0.2 mm) density in beach sediments in the United Kingdom to be 8 micro-plastics per kg⁻¹ of beach sediment, while in Singapore, Ng and Obbard, (2006), found there to be 3 micro-plastics (~0.3 mm) per kg⁻¹ of beach sediment. Converting the results from this study, beaches of Long Island and Connecticut contain about 0.0037 micro-plastics kg⁻¹ of sediments. Thompson et al. (2004), also found that micro-plastic abundances vary between beach sediments (8 particles per kg⁻¹ of sediment) and subtidal sediments (86 particles per kg⁻¹ of sediment) suggesting plastic abundances vary throughout the tidal zone of beaches leading to potential underestimates from this study. Smaller scale sampling for micro-plastics distribution across the intertidal zone, rather than geographic range, has great potential to provide very interesting results.

The large disparity in plastic density between the coast of Connecticut and the north shore of Long Island has opened the door to research into why these coasts, located on the same body of water, differ so greatly in plastic contamination. The north shore of Long Island was 56 times more contaminated with plastics than the Connecticut coast. It is possible that water currents (NOAA, 2003) and wind patterns could be depositing plastics on the Long Island coast at higher rates than Connecticut. Deposition by human activity could potentially be a factor as well, although this
requires local research of beachgoers in the Long Island and Connecticut region, it could provide vital data to help explain the disparity between coasts.

Another finding that will require more research relates to the distribution of micro-plastic percentages which seemed to increase from west to east. Before looking into potential reason as to why micro-plastics become more prevalent moving West to East, repeated studies are needed to add more data to this new, highly variable dataset.

Future studies into micro-plastics in beach sediments should include repeated sampling and identification of smaller plastics. This study failed to repeatedly samples beaches, and without some of the technologies in other micro-plastic studies (Claessens et al., 2011), identification of plastics smaller than 0.5 mm was not possible. To further understand the distribution of micro-plastic contaminants on beaches, sampling outside of the wrack line would provide valuable data that could provide a more complete image of plastics in beach sediments.

If we are to see environments free of plastics, the supply of plastic into natural systems needs to cease. Weather by consumer choice, policy implementation, or a change in the market, we need to begin changing our habits. The outcomes of plastic pollution on wildlife, the environment, and humans, mentioned throughout this paper, is just the beginning of our understanding about plastic pollution. What we do know is disheartening but what we do not yet know may be even more frightening.

6. Acknowledgments

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