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Microplastic pollution in the surface waters of the Laurentian Great Lakes



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ABSTRACT

Neuston samples were collected at 21 stations during an ~700 nautical mile (~1300 km) expedition in July 2012 in the Laurentian Great Lakes of the United States using a 333 μm mesh manta trawl and analyzed for plastic debris. Although the average abundance was approximately 43,000 microplastic particles/ km^2 , station 20, downstream from two major cities, contained over 466,000 particles/ km^2 , greater than all other stations combined. SEM analysis determined nearly 20% of particles less than 1 mm, which were initially identified as microplastic by visual observation, were aluminum silicate from coal ash. Many microplastic particles were multi-colored spheres, which were compared to, and are suspected to be, microbeads from consumer products containing microplastic particles of similar size, shape, texture and composition. The presence of microplastics and coal ash in these surface samples, which were most abundant where lake currents converge, are likely from nearby urban effluent and coal burning power plants.

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1. Introduction

Plastic pollution is the dominant type of anthropogenic debris found throughout the marine environment (Barnes et al., 2009; Gregory and Ryan, 1997). Floating plastic debris, including microplastics, have been reported in the subtropical gyres since the early 1970s in the North Atlantic (Carpenter and Smith, 1972; Colton et al., 1974; Law et al., 2010), North Pacific (Day et al., 1990; Moore et al., 2001), South Pacific (Eriksen et al., 2013), and outside the subtropical gyres in near shore environments (Thompson et al., 2004; Thiel et al., 2013; Dubaish and Liebezeit, 2013).

These plastic debris can be found in high densities and can have far ranging impact on marine ecosystems. Though other types of debris are found in the marine environment, such as glass floats,

bottles and light tubes, metal cans and derelict traps, and nets and line, 60–80% is estimated to be petroleum-based plastic (Derraik, 2002; Thompson et al., 2004; Browne et al., 2010, 2011). Plastic marine pollution has the potential to transport non-native species beyond their historical geographic range (Astudillo et al., 2009; Barnes and Fraser, 2003; Bravo et al., 2011; Gregory, 2009; Webb et al., 2009). A wide range of marine life are impacted by plastic pollution through entanglement or ingestion, including marine mammals, birds and reptiles (Laist, 1987; van Franeker et al., 2011), as well as through the persistent organic pollutants that sorb onto the plastic (Mato et al., 2001; Teuten et al., 2007, 2009; Rios et al., 2010). The Convention on Biological Diversity summarized there are currently 663 species of marine life that are known to be impacted by marine debris (Convention on Biological Diversity, 2012).

Plastic pollution may enter waterways through drainage systems, sewage treatment overflow during high-volume rain events (EPA, 2007; Browne et al., 2010; Browne et al., 2011), or can blow off beaches or developed structures, like docks and piers (Ryan et al., 2009). Microplastics may form on land by UV degradation and fragmentation (Andrady, 2003; Thompson et al., 2004; Cole et al., 2011) or road abrasion of larger plastic items through damage by vehicles and transport along concrete pathways, but may also enter the aquatic environment through direct release (Browne

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et al., 2010). Polyethylene and polypropylene microbeads, used in many consumer facial cleansers, have been identified as potential contributors to marine pollution (Gregory, 1996; Fendall and Sewell, 2009). Textile laundering facilities are also potential sources of microplastic fibers (Browne et al., 2011), and microplastic particles from sandblasting media have been suspected to pollute the marine environment since the early 1990s (Zitko and Hanlon, 1991).

Despite the ubiquitous nature of plastic pollution within the open-waters of the world's oceans, data describing microplastic abundance in the Laurentian Great Lakes has been limited to beach surveys (Zbyszewski and Corcoran, 2011). Given that the watersheds surrounding the Great Lakes are heavily urbanized (including the cities of Chicago, Milwaukee, Detroit, Cleveland and Buffalo in the United States, and Toronto in Canada), flow into the St. Lawrence River and ultimately to the North Atlantic Ocean, the lakes represent an important, potential upstream source of plastic pollution into the North Atlantic Gyre. We report here the first open-water survey for plastic pollution within the Laurentian Great Lakes system.

2. Materials and methods

To explore the presence and distribution of plastic pollution in the Laurentian Great Lakes, an expedition aboard the U.S. Brig Niagara was jointly organized between the 5 Gyres Institute⁶ and SUNY Fredonia. The 3-week expedition began on 11 July 2012 from Munising, Michigan, sailed Lakes Superior, Huron and Erie before ending on 31 July 2012 in Erie, Pennsylvania. Five samples were collected in Lake Superior, while 8 samples each were collected in lakes Huron and Erie. The sea state on the Beaufort Scale remained between 1 and 3 for all sample sites. The 21 sample sites were not equidistant, but samples were each 60 min long, timed using a stopwatch, and the tow speed was kept to 2.0 knots. All samples were preserved with 70% isopropyl alcohol.

Samples were collected using a manta trawl with a rectangular opening 16 cm high by 61 cm wide, and a 3 m long 333 μ m net with a 30 \times 10 cm² collecting bag. The net was towed along the surface on the downwind side of the vessel using a spinnaker pole to position the towline outside of the ship's wake. The area sampled was calculated by using the onboard knotmeter, which measures the number of nautical miles traveled over a defined distance, to measure the actual length of sea surface trawled in the 60-min period. The tow length multiplied by the width of the trawl provided the area sampled, allowing particle abundance per square kilometer to be calculated.

The samples were later rinsed in salt water, which floated most of the plastic to the surface for removal. Using a dissecting microscope, plastic was removed from preserved natural material, and then sorted by rinsing through Tyler sieves into 3 size classes: 0.355–0.999 mm, 1.00–4.749 mm, >4.75 mm. Individual pieces of plastic were divided into categories; fragment, foamed polystyrene, line, pellet, film; and then counted.

To understand the surface characteristics and chemical composition of the micro-particles initially sieved from the Great Lakes samples, all particles within the 0.355–0.999 mm size class for each of the 21 samples were examined using scanning electron microscopy (SEM). Samples were spread on double-sided carbon tape, coated with a thin film of evaporated carbon, and then imaged using a Hitachi SU70 field emission SEM operating at 20 keV in backscatter mode. Qualitative elemental composition of particles was confirmed using an Oxford INCA Energy Dispersive X-ray Spectroscopy system (EDS). As SEM analysis showed the development of very healthy biofilms on the surface of collected

particles a small fraction of sample 21 was soaked in 2 M hydrochloric acid for a period of 24 h, sieved, rinsed with deionized water and dried prior to SEM analysis in order to image particle surfaces in absence of this biofouling.

3. Results

Of the 21 net tows, all samples except one, sample 13, contained plastic (Fig. 1, Table 1). The initial visual analysis separated natural debris from material suspected to be plastic. The SEM/EDS system was used for microscopic and elemental analysis of particles from all samples <1 mm. Particles >1 mm were more easily identified as plastic, and therefore excluded from SEM/EDS analysis.

Several particles <1 mm were suspected to be paint from the vessel based on the red color and laminate nature. SEM/EDS analyses confirmed that suspected paint fragments were not polymeric and had a nearly identical elemental fingerprint to samples taken from the vessel. It was concluded that these were paint chips from the vessel and they were excluded from plastic particle counts.

SEM/EDS analysis also allowed the determination that many particles initially identified as microplastic were actually aluminum silicates. The aluminum silicate particles were determined to be coal ash and coal fly ash (Fig. 2) based upon a match between our SEM/EDS analysis and similar analyses performed by a commercial ash analysis firm (STS Analytical Testing Laboratory). Of our 21 samples, 8 were found to contain coal/fly ash, with an average contribution of 20% (within the 0.355–1 mm size classification). Our two samples with high particle counts, sample 20 & 21, contained 28% and 27% aluminum silicate, respectively, showing that visual observation alone is insufficient to separate microplastic from other debris.

Natural fibers, aluminum silicate particles and paint fragments were removed from all visually sorted samples. The adjusted microplastic abundance for all samples is given in Table 1. While the samples showed great spatial variability (Fig. 1), with particle counts ranging from ~450 up to over 450,000 per square kilometer, the samples from Lake Erie were consistently the most concentrated as compared to the other two Great Lakes sampled. In fact, Lake Erie samples account for ~90% of all the pelagic plastic debris, with samples 20 and 21 alone containing 85% of all microplastic particles collected in all samples combined. Lake Superior

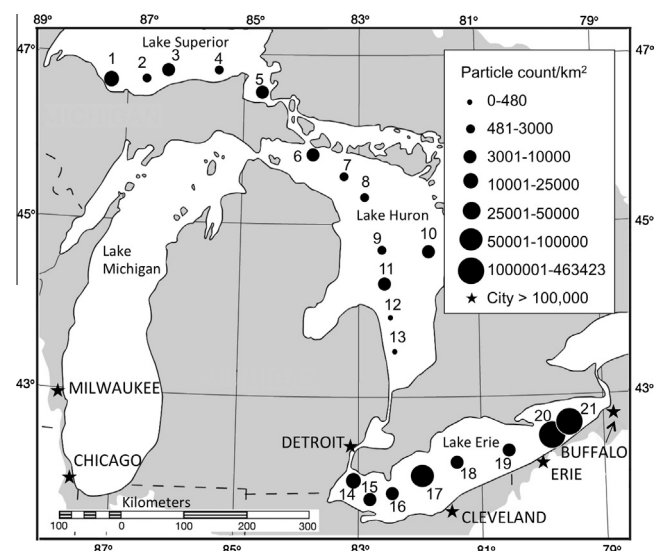


Fig. 1. Distribution of plastic particles by count for 21 samples collected in three of the Laurentian Great Lakes.

⁶ <http://www.5gyres.org>.

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