



## Hidden plastics of Lake Ontario, Canada and their potential preservation in the sediment record



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### ABSTRACT

Microplastics are a source of environmental pollution resulting from degradation of plastic products and spillage of resin pellets. We report the amounts of microplastics from various sites of Lake Ontario and evaluate their potential for preservation in the sediment record. A total of 4635 pellets were sampled from the Humber Bay shoreline on three sampling dates. Pellet colours were similar to those from the Humber River bank, suggesting that the river is a pathway for plastics transport into Lake Ontario. Once in the lake, high density microplastics, including mineral-polyethylene and mineral-polypropylene mixtures, sink to the bottom. The minerals may be fillers that were combined with plastics during production, or may have adsorbed to the surfaces of the polymers in the water column or on the lake bottom. Based on sediment depths and accumulation rates, microplastics have accumulated in the offshore region for less than 38 years. Their burial increases the chance of microplastics preservation. Shoreline pellets may not be preserved because they are mingled with organic debris that is reworked during storm events.

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## 1. Introduction

Plastic debris pollution remains a significant environmental issue because of its persistence on a global scale. Although the sources of plastic items are anthropogenic and thus originate on land, the extent of plastics pollution only became apparent once plastic debris reached Earth's oceans and became more visible in surface waters and along shorelines (e.g. Carpenter and Smith, 1972; Colton et al., 1974; Gregory, 1977; Morris, 1980; Dixon and Dixon, 1983; Ryan and Moloney, 1993; Moore et al., 2001). The dangers of plastic debris in marine environments have been well-documented. Recent examples demonstrating the effects of plastic on marine organisms point to ingestion (e.g. Denuncio et al., 2011; Possatto et al., 2011; Bond et al., 2014; Bravo Rebolledo et al., 2013; Van Cauwenberghe and Janssen, 2014) and entanglement (e.g. Laist, 1997; Sazima et al., 2002; Votier et al., 2011; Yorio et al., 2014) as the major threats. Plastics also assist in the transfer of

persistent organic pollutants (POPs) that may travel up the food chain (Endo et al., 2005; Rios et al., 2007; Colabuono et al., 2010; Rochman et al., 2013; Koelmans et al., 2014). In addition, floating plastic debris acts as transport media for encrusting organisms that may become invasive species (e.g. Winston, 1982; Barnes, 2002; Gregory, 2009). In contrast, relatively little is known about plastics pollution in fresh- or mixed-water settings. Characterization and quantification of plastic debris items in rivers (Lechner et al., 2014; Morritt et al., 2014; Rech et al., 2014; Sanchez et al., 2014; Castañeda et al., 2014) and estuaries (Browne et al., 2010; Lima et al., 2014; Yonkos et al., 2014) indicate that these are significant pathways for polymers travelling to larger bodies of water. Plastics accumulation in lakes remains poorly understood because only a minor amount of investigations have been conducted (Zbyszewski and Corcoran, 2011; Faure et al., 2012; Imhof et al., 2013; Zbyszewski et al., 2014; Free et al., 2014; Dreidger et al., 2015; Hoellein et al., 2015), and factors such as seasonal changes in surface water currents, locations of urban centres, and river and wastewater input are amplified by the relatively small size of a lake compared with an ocean.

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The types and distribution of plastics in open water and shoreline regions of the Great Lakes system of North America are relatively unknown. Available results show that polyethylene (PE) and polypropylene (PP) are the most common polymer types (Zbyszewski and Corcoran, 2011; Zbyszewski et al., 2014), the majority of the plastic items are <5 mm in size (Zbyszewski and Corcoran, 2011; Eriksen et al., 2013), and POPs were found sorbed to the surfaces of plastics (International Pellet Watch, 2005–2013; L. Rios, unpublished data). This information was provided through surveys of Lakes Superior, Huron, Erie and St. Clair. However, until 2014, the only available data concerning plastics pollution of Lake Ontario was provided through the Great Canadian Shoreline Cleanup and the Alliance for the Great Lakes Adopt-a-Beach Program. The latter indicates that from September, 2012 to August, 2014, 46% of visible debris items collected from shorelines was composed of plastic (Alliance for the Great Lakes, 2012–2014). Dreidger et al. (2015) combined the Adopt-a-Beach and Great Canadian Shoreline Cleanup data and found that 77–90% of all shoreline debris collected in 2012 was composed of plastic items.

To date, Castañeda et al. (2014) in their investigation of the St. Lawrence River, Canada, are the only researchers who have described microplastics in bottom sediments of a non-oceanic body of water. The primary objective of this paper is to provide quantitative and compositional results of microplastic (<5 mm) debris items sampled from shoreline and lake-bottom sediments of Lake Ontario, Canada (Fig. 1), and to assess their potential for preservation in the current sediment and future rock record.

## 2. Materials and methods

### 2.1. Study areas

Lake Ontario is the smallest of the Laurentian Great Lakes with an average depth of 86 m, and a land drainage area of 64,030 km<sup>2</sup> (U.S. Environmental Protection Agency, 2012). The summer (May–October) surface water circulation pattern is mainly cyclonic, whereas during the winter months (November–April), the lake exhibits a two-gyre circulation pattern with cyclonic flow in the south and east, and anti-cyclonic flow in the northwest (Beletsky et al., 1999).

The Humber Bay region, located along the northwest shoreline of Lake Ontario (Fig. 1B), was selected for investigation for three reasons: 1) Humber Bay is proximal to the Greater Toronto area, and previous research has shown that a greater abundance of plastic debris accumulates near industrial centers (Gregory, 1977; Zbyszewski et al., 2014), 2) four tributaries drain into Lake Ontario within 12 km of Humber Bay; rivers and creeks are considered important pathways for the transport of plastic debris into larger bodies of water, and c) the Humber wastewater treatment plant drains into Humber Bay, and recent research suggests that microplastics in wastewater may not be completely removed during the treatment process (Fendall and Sewell, 2009; Eriksen et al., 2013). Two specific sampling sites were selected, which include a beach along the southern end of Humber Bay Park West peninsula (N43°36'49"/W79°23'46") and a swath along the eastern bank of the Humber River (N43°38'13"/W79°28'36") (Fig. 1C). In addition to land-based samples, two lake-bottom sediment core samples collected in October, 2013 were provided by Environment Canada. Sample 208 was collected from the Niagara Bar (N43°20'14"/W79°02'10") and sample 403 was collected from the deeper, north-central part of Lake Ontario (N43°35'12"/W78°14'10") (Fig. 1B).

### 2.2. Humber Bay field and laboratory methods

A quadrat measuring 25 m × 4 m on the Humber Bay Park West beach was surveyed for visible plastic debris (Fig. 1D). Sampling of the same beach quadrat was conducted on October 7, October 28 and November 18, 2013, in order to determine tri-weekly accumulation rates. In addition, a 10 m × 2.5 m swath along the bank of the Humber River was surveyed for industrial pellets on October 28 and November 18 (Fig. 1E). At the beach location, all visible debris at the surface and to a depth of 5 cm was collected. Once in the laboratory, the beach samples were sorted into four categories: 1) industrial pellets (microplastics), 2) plastic fragments, 3) intact or near-intact debris, and 4) expanded polystyrene (Fig. 2; Table 1). Fragments were further categorized into sizes of >5 cm, 1–5 cm and <1 cm, and the total number and mass of each type of debris was quantified (Table 1). In addition, industrial pellets were subdivided by colour in order to compare the relative proportions of each colour from the Humber Bay beach and Humber River sites.

Thirty pellets from the Humber Bay and Humber River sites from each sampling date were randomly selected using a sample splitter, then cleaned in distilled water in an ultrasonic bath for 5 min to remove surface soil residue. The pellets were air-dried for 24 h and their compositions were analysed using a DeltaNu Rock-Hound spectrophotometer. The Raman spectrum determined from each pellet was compared to a library containing spectra of known samples of low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polystyrene (PS) and polyethylene terephthalate (PETE).

### 2.3. Lake-bottom field and laboratory methods

Lake Ontario bottom sediment core samples were collected from aboard the CCGS *Limnos* using a mini box corer. Box cores were sub-sampled using polycarbonate tubes (7 cm diameter) and then extruded in 2 cm increments from 0 cm to refusal. Core increments were placed in Nalgene<sup>®</sup> high density polypropylene jars and frozen immediately for transport to the laboratory. Once in the laboratory, 15 sample increments from each core (depth of 30 cm) were thawed at room temperature, emptied onto aluminium pie plates and placed in a drying oven set to 70 °C for 8 h. The sample increments were sieved into grain size fractions of <0.5 mm, 0.5–0.71 mm, 0.71–0.85 mm, 0.85–1 mm, and >1 mm, in order that the sediment could be handled more easily during density separation. Each of the resultant 150 samples were weighed and then emptied into 250 ml of distilled water in a 700 ml beaker. The sediment was magnetically stirred for 1 min, and allowed to settle for approximately 5 min. Low density floating particles were removed from the water and the remainder of each sample was re-dried at 70 °C for 18 h. Once dried, the remaining samples were then emptied into a 250 ml sodium polytungstate solution with a specific gravity of 1.5 g/cm<sup>3</sup>. Following magnetic stirring for 1 min, the sediment was allowed to settle for approximately 10 min. All floating particles were removed from solution and washed using distilled water.

Once dried, floating particles from both separation procedures (densities <1.5) were microscopically analysed. Those particles resembling plastics were removed and placed into vials for analysis by Fourier transform infrared spectroscopy (FTIR) at Surface Science Western, University of Western Ontario. The samples were analysed using the micro attenuated total reflection objective (ATR) on the microscope attachment. The ATR objective has a germanium crystal which limits the analysis to an area approximately 80–100 microns in diameter and to a depth on the order of 1–2 microns.

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