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Microplastics in the sediments of a UK urban lake☆

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ABSTRACT

While studies on microplastics in the marine environment show their wide-distribution, persistence and contamination of biota, the freshwater environment remains comparatively neglected. Where studies on freshwaters have been undertaken these have been on riverine systems or very large lakes. We present data on the distribution of microplastic particles in the sediments of Edgbaston Pool, a shallow eutrophic lake in central Birmingham, UK. These data provide, to our knowledge, the first assessment of microplastic concentrations in the sediments of either a small or an urban lake and the first for any lake in the UK. Maximum concentrations reached 25–30 particles per 100 g dried sediment (equivalent to low hundreds kg^{-1}) and hence are comparable with reported river sediment studies. Fibres and films were the most common types of microplastic observed. Spatial distributions appear to be due to similar factors to other lake studies (i.e. location of inflow; prevailing wind directions; propensity for biofouling; distribution of macroplastic debris) and add to the growing burden of evidence for microplastic ubiquity in all environments.

1. Introduction

In recent years there has been increasing concern over the scale and impacts of plastic debris in the world's oceans. Since the 1950s an estimated 1 billion tonnes of plastic have been discarded and of the 280 million tonnes of plastics now produced annually (Rochman and Browne, 2013), more than 10% ends up in the marine environment (Cole et al., 2011), either by being intentionally or unintentionally discarded or being wind-blown from terrestrial sources. Such debris can cause entanglement in a number of species from cetaceans to crustaceans as well as suffocation and problems via ingestion (blockage of digestive tracts; internal wounding; satiation) in many aquatic fauna (Codina-García et al., 2013; Derraik, 2002; Gregory, 2009), transport of species via colonization (Zettler et al., 2013) and pollutant transfer (Teuten et al., 2007). Plastic debris is likely to persist for hundreds of years (Bergmann and Klages, 2012; O'Brine and Thompson, 2010) and even longer in polar or deep-sea environments (Woodall et al., 2014). With predicted estimates of an additional 33 billion tonnes of plastic production by 2050 (Rochman and Browne, 2013) and 99% of all seabird species to have ingested plastic by the same date (Wilcox et al., 2015), environmental impacts are likely to continue for many decades.

Much of the attention on large plastic debris in the marine environment has focussed on their concentration in oceanic gyres (Moore et al., 2001) but recently, it has been suggested that observed levels of plastics in marine ecosystems are not able to account for expected inputs, i.e. that some plastic has been 'lost'. This may be explained by photo-, physical or biological degradation into smaller secondary plastic particles, or 'microplastics' which pass through the nets used for sampling larger plastic debris (Cózar et al., 2014; Thompson et al., 2004). While definitions for microplastics vary they are typically considered to be less than 5 mm in one dimension (Eerkes-Medrano et al., 2015; Horton et al., 2017a,b). Primary microplastics (i.e. those generated to be this size) include plastic resin pellets, the raw material used for manufacturing, unintentionally released during manufacturing and transport and carried by surface run-off and rivers to the ocean, or to the ocean directly (Holmes et al., 2011; Mato et al., 2001). However, primary microplastics are also used as abrasives in personal care products (Gregory, 1996) or from shedding during the laundry of synthetic textiles (Napper and Thompson, 2016) and may pass unchanged through standard waste water treatment facilities (Engler, 2012).

Environmental impacts of microplastics, again principally observed in marine studies, include direct and indirect ingestion (filter feeders and feeders of organic particles in mud are especially at risk) (Teuten et al., 2009); transfer of pollutants through food

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chains (including plastic additives as well as contaminants adsorbed onto surfaces such as trace metals (Holmes et al., 2011)), PAHs, PCBs, organochlorine pesticides (Mato et al., 2001; Cole et al., 2011) and brominated flame retardants (Engler, 2012; Zarfl and Matthies, 2010); and species transfer via colonization of plastics as a novel habitat (Zettler et al., 2013).

However, while a considerable amount of recent work is now available for microplastics in the marine environment, there have been relatively few studies on freshwaters although early indications are that their presence is likely to be as equally pervasive (Eerkes-Medrano et al., 2015). All lake studies have so far focused on very large waterbodies, with a number of studies focused on the Laurentian Great Lakes where the locations of urban and industrial centres have accounted for microplastic distributions in shoreline sediments (Corcoran et al., 2015; Driedger et al., 2015; Faure et al., 2015; Zbyszewski and Corcoran, 2011) and in surface waters (Eriksen et al., 2013). Similar distributions have also been observed in surface waters of other large lakes, which are more removed from urban settings, such as Lake Hovsgol, Mongolia (Free et al., 2014) and Lake Garda, Italy where microplastic distributions in shore-line sediments were related to wind-induced surface circulation patterns and fishing activities (Imhof et al., 2013). In rivers, microplastics in sediments from the Rhine-Main system in Germany (Klein et al., 2015) and the St Lawrence River in Canada (Castañeda et al., 2014) were also related to urban locations. Lechner et al. (2014) demonstrated the scale of contamination in major rivers by estimating that more than 1500 tonnes of microplastics enter the Black Sea each year via the River Danube alone. Sanchez et al. (2014) reported the presence of microplastics in the digestive tracts of the gudgeon (*Gobio gobio*), a sedentary cyprinid, in a number of French rivers. In the United Kingdom, studies on plastics in freshwaters have, to date, been only restricted to rivers. Morritt et al. (2014) compared the scale of submerged versus floating macroplastic debris in the River Thames showing sewage treatment works to be major sources while Horton et al. (2017a) indicated sewage as well as road and land run-off as sources of microplastics in River Thames sediments.

These studies indicate the importance of urban centres as sources of both macro- and microplastic contamination to freshwaters, a situation which is only likely to be exacerbated as urban areas and populations continue to expand over coming decades. Therefore, it may be expected that urban lakes would receive higher levels of microplastics from both inflowing streams draining residential, commercial and industrial areas, as well as via degradation of wind-blown macroplastic debris and possibly atmospheric deposition (Dris et al., 2016). However, no published data exist for microplastics in urban lakes. Here, we present data demonstrating the abundance and distribution of both macroplastic debris and microplastics in the surface sediments of an urban lake in central Birmingham, UK. To our knowledge this is the first microplastic study for a UK lake and, more broadly, the first such study for either a small or an urban lake.

2. Methods

2.1. Sample site

Edgbaston Pool (52.4552°N; 01.9212° W) is located 3 km from the centre of Birmingham. It is 127 m above sea level, has a surface area of 7.2 ha and a maximum depth of 2.5 m found towards the southern end near the dam wall (Fig. 1a). The lake was formed by the damming of Chad Brook, a small stream which enters from the north. This provided power for water mills, forming an Upper (the current pool) and a Lower Edgbaston Pool which is now infilled and overgrown. The mill is known to have existed by 1557 when it was used as a fulling mill. In the 17th century the mill was being used for blade-making which continued to the mid-19th century when it became used for gold and silver rolling (Turner et al., 2013). From 1875 the mill was no longer used and the pool is shown as a 'fish pond' on early-20th century maps. While once surrounded by industry, the lake is now bordered by the Winterborne Botanic Gardens to the west and Edgbaston Golf Course to the east. The lake and surrounding area was given SSSI (site of special scientific interest) status in 1986 for the diverse woodland and wetland habitats around its margins. The main outflow is in the south-east corner of the lake. An additional outflow exists in the south-west corner but usually remains dry. The catchment area is shown in Supplementary Information (Fig. S1).

2.2. Sampling methods

A sediment sampling transect was established at four locations around the perimeter of Edgbaston Pool. Transects were perpendicular to the shoreline and established by fixing a rope on land close to the water edge and attaching this to a buoyed anchor line off-shore. Given the shallow shelving nature of the lake bathymetry (Fig. 1), samples were taken at each 0.5 m depth to 1.5 m (labelled A-D; e.g. T1A, T1B etc.). At the northern end of the lake the shallow water depths precluded establishing a transect with any significant depth difference within 50 m of the lake shore (Fig. 1), so Transect 3 was treated as a surface sample only (T3A). However, because of the shallow nature of this part of the lake, extra surface sediment samples were taken to provide greater spatial coverage. In addition to these transects 11 surface sediment samples were collected at approximately 150 m intervals around the lake perimeter except for the northern end where samples were more closely located. Surface sediment samples were taken as close as possible to the shore where clear sediment accumulation was visible.

At each sampling point, a sediment sample was collected from the boat using an HTH gravity corer (Renberg and Hansson, 2008) fitted with a sample tube with an internal diameter of 7.8 cm. The top 10 cm of each core was collected from each location. Radiometric chronologies for recent sediment cores from Edgbaston Pool indicate sediment accumulations of between 0.8 and 1.6 cm yr^{-1} (Turner et al., 2013; Yang et al., 2016) such that each surface sample approximately represented the most recent 10 years of accumulation. Also, at each sampling location, a visual assessment of macroplastic debris on the lake bottom was undertaken using a bathyscope from the boat. Finally, all litter was collected from 5 m either side of the start of each transect in order to determine the proportion that plastic contributes to overall debris in each location. These items were stored separately.

2.3. Microplastic extraction from lake sediments

There is no established standard method for the extraction of microplastics from either marine or freshwater sediments (Horton et al., 2017b) although in recent reviews of marine studies (Hidalgo-Ruz et al., 2012; van Cauwenberghe et al., 2015) consensus seems to be moving towards a combination of size- and density separation. Sieving may result in size distribution artefacts, especially with such different particle morphologies as fibres and fragments, but given the nature of the collected sedimentary material it was important to remove as much larger material as possible. 100 g of each sediment sample was sieved, first through a 1 mm and then a 500 μm sieve. There is no universal size-classification of microplastics but these ranges have been used regularly in previous studies (e.g. Hidalgo-Ruz et al., 2012; van Cauwenberghe et al., 2015). Each sieve's contents were washed several times with water to ensure no smaller particles remained. All material passing