A Historical Sediment Record of Microplastics in an Urban Lake, London, UK

Simon Turner*, Alice A. Horton‡ and Neil L. Rose* Contact: simon.turner@ucl.ac.uk

*Environmental Change Research Centre, Department of Geography, University College London, Gower Street, London, WC1E 6BT, UK
‡Centre for Ecology & Hydrology, Maclean Building, Benson Lane, Crowmarsh Gifford, Wallingford, Oxfordshire, OX10 8BB, UK

Background

Without historical, large-scale and long-term monitoring of plastic waste, lake sediments allow an assessment of the occurrence, usage patterns and changing types of plastics through time.

Especially valuable, with regard to contextualising current plastic waste in the environment, is the presence of well-refined, dateable sediments over the last c. 150 years that, compared to marine cores are more easily accessible and proximal to terrestrial sources of plastic contamination. Lakes represent catchment-scale sinks for microplastic debris compared with oceans which are subject to global-scale, long-range transport from multiple catchments.

Microplastics have been found incorporated into lake sediments with inputs linked to urbanization, industrial activities and wastewater influences, but high-resolution sediment evidence of the historical incorporation of microplastics in lake sediments, indeed in any dated aquatic sediment horizon, is surprisingly rare.

This research therefore provides a significant contribution to our knowledge of sources, transport pathways and fate of plastic debris in freshwaters. This and ongoing research provides evidence of the historical ubiquity of microplastics in global environments.

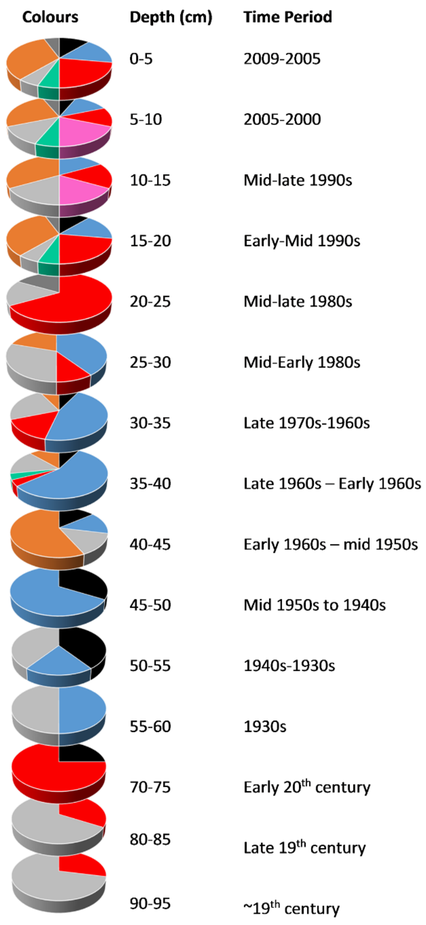
Site Description

Hampstead No.1 Pond is a small waterbody (1.5 ha, max 3m depth) in North London (Lat 51.5575°, Lon -0.1655°, 69m above sea level). The small catchment (0.7 km^2) consists of open parkland, woodland, and housing (late-19th century stock) with gardens. The pond is the lowest in a chain of three water bodies, separated by embankments and connected by drains and culverts. In the upper part of the catchment some sections of streams are open and in semi-natural woodland. The open parkland west of the pond has been historically used for seasonal fairs. (*Above* – view of site looking NE)

Objectives and Methods

The objective of this research is to assess the historical accumulation and identification/quantification of microplastic debris in lake sediments co-measured by radiometric dating (^{210}Pb, ^{137}Cs).
Known age lake sediment core samples were disaggregated with deionized water and washed through 1 mm and 500 µm stainless steel sieves. The >1 mm and 1mm - 500 µm retained fractions of each sample were collected for analysis. A sodium polytungstate (SPT) solution (2.1 g cm^{-3} density) was then used to isolate microplastics. Method blanks were incorporated within batches of lake sediment samples. Following microscopic identification and categorising a representative subsample of microplastics were analysed by Raman spectroscopy (HR800UV, Jobin Yvon Horiba, with an integrated Olympus BX21 microscope). Spectra were obtained using a near-infrared laser (785 nm) and analysed using the BioRad KnowItAll® Informatics System – Raman ID Expert (2015) software.

Results: Colour and Type



Colour variation and particle concentrations with depth indicates that an historical assessment of microplastic accumulation is feasible in dated benthic lake sediment cores. Sediments are dominated by fibres (40-100% of particles).
Blue fibres were the most abundant overall in the core (25% particles) followed by white (22%), red (17%), black (8%), pink/purple (3%) and green/turquoise (2%).
Left: Microplastic colour variability found in core depth/age slices. Colours of fibres as shown.
Right: Selection of fibres and particles found in core samples. Particles of polystyrene were identified, but for many fibres the man-made dye was identified rather than the polymer composition of the fibre.

0-5 cm (2009-2005) Polystyrene
0-5 cm (2009-2005) Starch polymer
5-10 cm (2005-2000) Polystyrene
15-20 cm (mid-late 1990s) Red fibre
25-30 cm (Mid-Early 1980s) Indigo pigment polymer
35-40 cm (Late-Early 1960s) Indigo (twisted polymer)
50-55 cm (1930s-1940s) Indigo polymer
70-75 cm (Early 20th C.) Knotted polymer
90-95 cm (~19th C) Red fibre

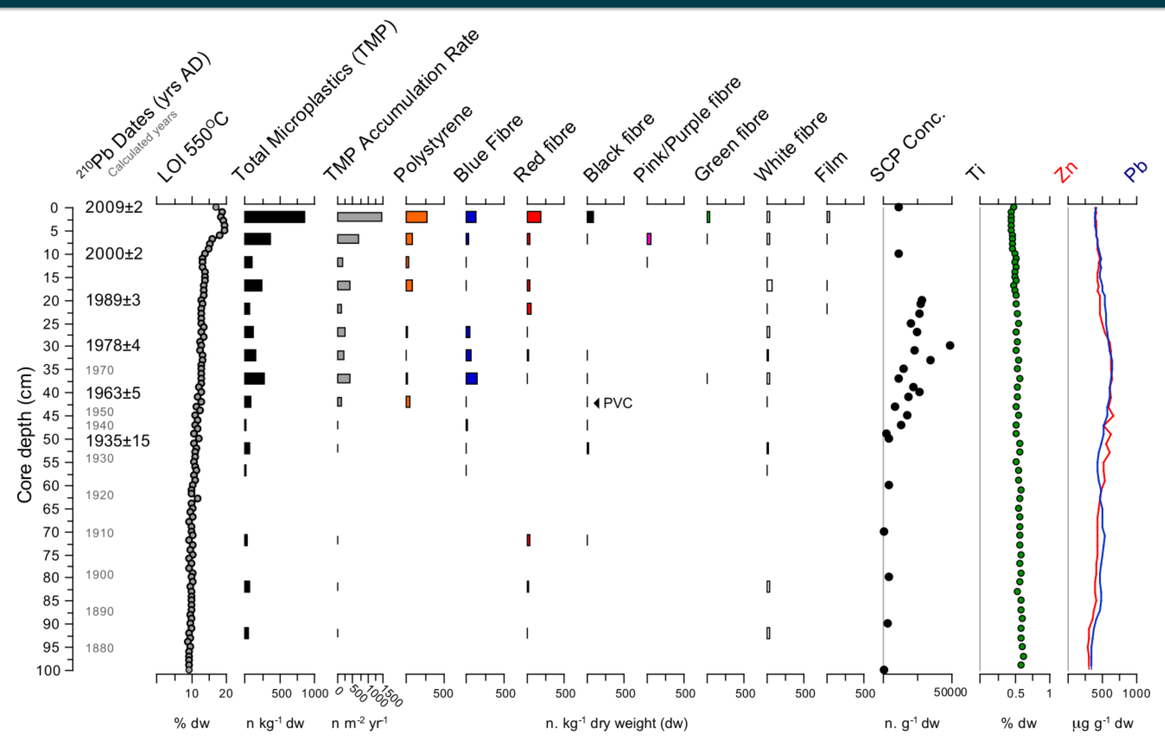
Results: Microplastic stratigraphy

Unsupported ^{210}Pb and ^{137}Cs activities provide a robust sediment chronology from c.1935 (50 cm depth) to 2009.

Microplastics and coloured fibres increase in abundance in sediments post 1940-1950. This correlates with the increase in power station fossil fuel emissions (Spheroidal Carbonaceous particles, SCPs, *right*) and trace metals.

Polystyrene particles occur first in sediments aged 1963±5 that corresponds timewise with its history of usage/mass production.

Low concentrations of fibres in older (pre-1930s) sediments are equivalent to numbers in laboratory blanks.



Above: Stratigraphic diagram of sediment core. Core depth (cm) is shown with measured and calculated dated intervals (grey). LOI 550 °C is a measure of sediment organic matter, TMP is a total of all fibres and microplastics. Accumulation rate is calculated concentration x sediment accumulation rate. Ti (Titanium), Zn (Zinc) and Pb (Lead) are element abundances in sediment samples measured by XRF (x-ray fluorescence).

Discussion

- Benthic sediment microplastic concentrations (33-882 kg^{-1}) in the core are broadly comparable to the number of particles reported in surface sediments of other lakes worldwide.
- Wastewater and sewage inputs of microplastic fibres into Hampstead Pond No.1 are likely to have been low due to its small, parkland catchment.
- Microplastics in the lake sediment are proposed to derive principally from atmospheric deposition – onto the lake surface and indirectly via soil transport. Other likely sources are litter (polystyrene), clothing (swimming ponds upstream) and abraded fishing line.
- Assessing the abundance and first appearance of man-made fibres is limited by the presence of equivalent numbers and forms found in sample blanks and logistical effort of determining polymer composition.

Conclusions

- This ^{210}Pb dated sediment core assessment indicates that microplastic abundance, type and colour changes may reflect changes in microplastic production and usage over time . A recent increase in microplastic concentration and accumulation rate is evident in post-millennium sediments.
- A conservative estimate is of hundreds of millions of microplastic particles have been incorporated and remain in the benthic sediment of the lake.
- This study shows that the routine extraction of microplastics from radionuclide dated lake sediment cores is feasible and can be measured alongside other contaminant and environmental proxies.
- With improved contaminant detection and proportion of microplastic polymers identified, future paleolimnological work will undoubtedly assist in quantifying the historical flux of microplastic waste, from freshwater to marine environments.

Further Reading
Horton, A. A.,Dixon, S. J. (2018). Microplastics: An introduction to environmental transport processes. Wiley Interdisciplinary Reviews: Water, e1268-n/a, doi:10.1002/wat2.1268.
Vaughan, R., Turner, S. D.,Rose, N. L. (2017). Microplastics in the sediments of a UK urban lake. Environmental Pollution, 229, 10-18.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL