Sewage Derived Microplastic and Anthropogenic Fibre Retention by Integrated Constructed Wetlands

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Background

Emerging contaminants, including microplastics and anthropogenic fibres, can be discharged from wastewater treatment plants (WWTPs) and contaminate receiving water bodies (Woodward *et al.*, 2021; Clara *et al.*, 2010). **Integrated Constructed Wetlands** (ICWs) are potentially well suited to provide a **cost-effective** mitigation solution at small WWTPs where upgrading existing treatment is prohibitively expensive (Cooper *et al.*, 2020).

ICWs are supplied entirely from WWTP effluent and generally consist of a series of connected, surface flow ponds that are planted with a diverse array of native aquatic vegetation (Scholz *et al.*, 2007). They combine the objectives of **improving water quality** with that of integrating into the local landscape and enhancing its **biological value**.

This research assesses the extent to which an ICW, **Northrepps**, retains sewage derived microplastics, anthropogenic fibres, and plasticizers.

Northrepps ICW (Norfolk, England) consists of three shallow (~30 cm), unlined cells that are planted with 15,000 native aquatic plants including *Iris pseudacorus, Carex riparia, Sparganium erectum, Alisma plantago-aquatica, Mentha aquatica and Veronica beccabunga*.

The ICW was operational in October 2014, receiving WWTP effluent (**secondary treatment** with an aeration and final settlement tank) from **~800 people**.

Methods

	Sampling design	Sample collection	Organic matter removal	Density separation	Identification
Water samples	Monthly samples from the inlet and outlet (June 2022 to May 2023)	Large water samples filtered through 38 µm sieve	50 % (V/V) NaClO at 40 °C for 24 hours		40x light microscope Micro-ATR-FTIR validation: 369 fibres
Sediment samples	23 samples from Northrepps in December 2022	Agitating fine sediments into suspension and sieving turbid water samples (2mm – 38 µm)	50 % (V/V) NaClO at 40 °C for 24 hours **x2**	1.5 g cm^{-3} $ZnCl_2$	40x light microscope Micro-ATR-FTIR validation: 140 fragments

Results

- Fibres were found in all WWTP effluent samples, with a mean of **5.48 (SD = 9.70) fibres L^{-1}**, equating to a loading rate of **349,920 (±763,776) fibres day^{-1}** into the Northrepps ICW.
  - Of these fibres, 27.2 % were approximately >800 µm in length, 56 % were 800–250 µm, and 16.8 % were 38–250 µm.
- Fibres were detected in 30 % of the Northrepps ICW outlet water samples, with mean concentrations of 0.01 (SD = 0.02) fibres L^{-1}, equating to a **99.3 % removal**.
  - **No seasonal variation** in removal performance was found.

- In the first cell, average concentrations were 8152 (SD = 7022) anthropogenic fibres kg^{-1} and 1938 (SD = 991) suspected microplastic fragments kg^{-1} dry weight sediment. Concentrations in cells 2 and 3 were <LOD.
- Of the 369 **fibres** validated by micro-ATR-FTIR: **54.7 % are plastic** (dominated by polyester) and **35.5 % are cellulosic** (of which 10.7 % are artificially dyed).

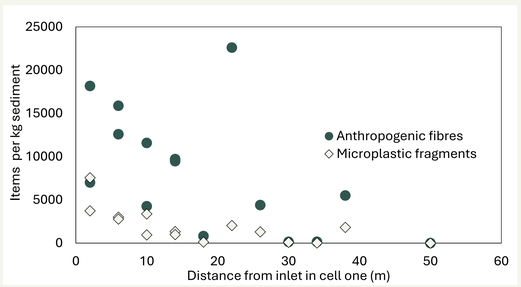


Figure 1 Both fibres and microplastic fragment concentrations declined with increasing distance from the inlet in the first cell at Northrepps ICW.

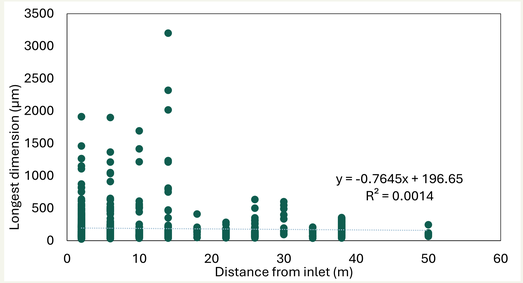


Figure 2 The size of both fibres and microplastic fragments did not change significantly with distance from the inlet.

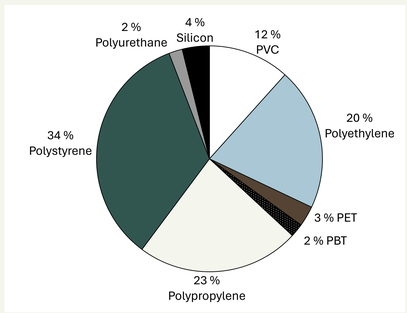


Figure 3 The material composition of the 111 confirmed microplastic fragment analysed by micro-ATR-FTIR (with HQS>0.7).

Discussion

Dense vegetation in ICWs acts as an efficient barrier to anthropogenic fibre and microplastic fragment transport.

Microplastics and fibres may also aggregate with **flocculent suspended particulate matter**, thus increasing the relative size of the particle and the likelihood of entrapment (Leiser *et al.*, 2021). The nutrient rich WWTP effluent that supplies ICWs promotes the formation of flocculent material, particularly nearest the inlet.

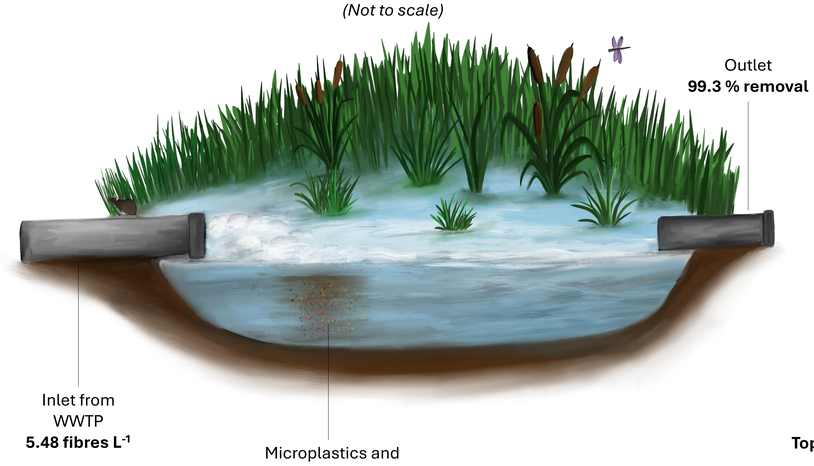
Dredging of sediment is a long-term management practice in CWs. However, the high concentrations of plastics (micro and macro) and anthropogenic fibres accumulated in this sediment may **complicate disposal** options.

Endocrine disrupting plasticizers, such as phthalates, leach slowly from microplastics (Henkel *et al.*, 2022). Phthalates, including **DEHP** and **DBP**, generally have high octanol-water partition coefficients, meaning they will readily adsorb to organic material, suspended solids and sediment (Staples *et al.*, 1997). Biodegradation rates of phthalates are higher in eutrophic waters and in the presence of acclimated microbial communities, thus **degradation is expected in ICWs**.

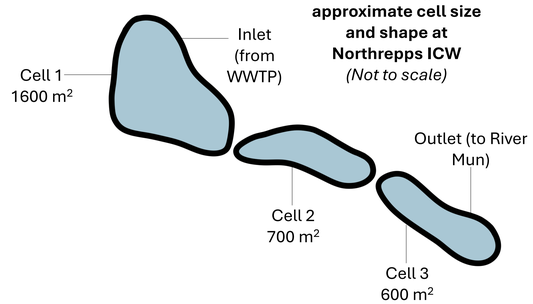
Because most microplastics are retained within the first cell and close to the inlet, future ICWs could be designed with a **smaller first cell**, simplifying disposal of accumulated material. Chemical leachates from plastics may also be degraded as they travel through the proceeding cells, reducing contamination in receiving waterbodies.

A 2900 m^2 **constructed wetland** retains up to **276 million** sewage derived anthropogenic **fibres** per year.
Simple design and maintenance considerations may address the long-term problem of **plasticizer** leaching.

Cross section view of 1st ICW cell
(Not to scale)



Top-down view outlining approximate cell size and shape at Northrepps ICW
(Not to scale)



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