MICROPLASTICS IN WASTEWATER IN NEW ZEALAND: CURRENT DATA AND KNOWLEDGE GAPS

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ABSTRACT (500 WORDS MAXIMUM)

Microplastics, plastic particles <5 mm in diameter, are emerging contaminants of increasing concern. Microplastics have been detected in a range of remote locations, and are being shown to be ingested by a growing list of aquatic and terrestrial organisms. International literature has shown wastewater treatment plants (WWTPs) to be a major source of microplastics to the environment. Microplastics present in industrial and residential wastewater, particularly microfibres from the washing of textiles, are diverted to WWTPs which are not designed to remove microplastics during treatment. Microplastics from WWTPs are retained in the sewage sludge or are released directly to the environment through the discharge of effluent. There is currently a lack of data available on the concentration and types of microplastics entering and exiting WWTPs in New Zealand. This study is the first to have characterised microplastics in wastewater influent and effluent of four different WWTPs in New Zealand. Findings from this investigation will be presented along with a discussion of the wider impacts of microplastics exiting WWTPs.

Little is known worldwide about the fate, behaviour and potential impacts of the microplastics that are discharged from WWTPs to the environment. Microplastics have been shown to adsorb heavy metals and hydrophobic organic contaminants, and also act as a substrate for diverse microbial communities. These factors have been documented in a range of aquatic and terrestrial environments. Microplastics therefore act as a vector for these adsorbed contaminants and microorganisms, which are often sheltered from degradation during WWTP processes, and are subsequently released into sensitive aquatic and terrestrial ecosystems with the discharge of treated effluent. To address the knowledge gaps a study as part of the Aotearoa Impacts and Mitigation of Microplastics (AIM^2) research programme is currently investigating the interactions of plastics, contaminants and microbes, and the associated risks to Aotearoa New Zealand's environments. This is being done by deploying five different plastic types of known composition (polymer + additives), and age in the oxidation pond of a WWTP. Preliminary results of this year-long experiment (ending in June 2021) will be presented.

KEYWORDS

MICROPLASTICS, WASTEWATER TREATMENT PLANTS, MICROBIAL BIOFILMS, EMERGING CONTAMINANTS

PRESENTER PROFILE

Helena Ruffell is a PhD student at the University of Canterbury, investigating whether microplastics affect productive soil systems. Sources of plastic to productive soils include domestic green waste and food waste compost, biowaste, and plastic products used to support crops in horticultural soils. This research follows on from her MSc which investigated if wastewater treatment plants are a significant source of microplastics to the environment in New Zealand.

INTRODUCTION

Plastic and microplastics

Mass production of plastic has significantly increased from 1.5 million tonnes in 1950 to over 335 million tonnes annually at present day (*Plastics—The Facts 2017, An Analysis of European Plastics Production, Demand and Waste Data*, 2017). Plastics have become a highly sought after and ideal product in a range of applications due to them being light weight, having low production cost, sterility, and versatility, allowing them to be moulded into a large variety of products (Brydson, 1999). This convenience has come at a cost to the environment, with the incidence of plastic pollution rising annually, with approximately 19 – 23 million metric tonnes of plastic released into the ocean each year (Borrelle et al., 2020). Plastics in the environment are subject to weathering by a number of physical, chemical, photochemical, and biological mechanisms, which fragment plastic into smaller pieces (Wu et al., 2017).

Microplastics are plastic particles smaller than 5 mm in their longest dimension (Arthur et al., 2009). Secondary microplastics arise from the fragmentation of larger plastic in the environment and include the shedding of plastic fibres from synthetic materials (Wu et al., 2017). Primary microplastics are purposefully produced to be small for use in a range of applications including cleaning, cosmetics (e.g. microbeads), and glitter (Fendall & Sewell, 2009).

Environmental harm

Previously regarded as environmentally inert, macro- and microplastics are an emerging contaminant of increasing concern to regulators worldwide. The fragmentation of plastics into microplastics and smaller nanoplastics (<1 μm) in the environment is a significant concern. These small particles are bioavailable to a larger range of organisms. Microplastics may be mistaken for prey and food by a range of aquatic and terrestrial organisms (Wright et al., 2013). Microplastic may also be passively taken up by filter-feeders, including whale, bivalves, and worms (Browne et al., 2008). Once ingested, microplastics may accumulate in the gut, where their presence may result in false satiation, causing the organism to starve (Wright et al., 2013; Zhang et al., 2019). Microplastics may also cause internal lesions to a range of organs, which may result in the promotion of uncontrolled cell growth and the formation of tumours (Wright et al., 2013). Microplastics have been shown to translocate from the gut to a number of different areas in biological systems, and also transfer from prey to predator (Browne et al., 2008; Farrell & Nelson, 2013; Nelms et al., 2018).

The production of plastic items often include a vast range of additives to improve the properties and appearance of the product, including plasticisers, antimicrobial compounds, UV filters, and colouring agents. These additives, in particular bisphenol-A, have raised concerns regarding their safety in a range of applications. With weathering and exposure to certain factors, including temperature, these additives may leach out from the plastic product into the environment (Lithner et al., 2012; Teuten et al., 2009). The hydrophobic nature of plastics and their varying surface charges may attract and adsorb a number of chemical contaminants and biological organisms and pathogens to attach to their surface. Microplastics act as a vector for the transport of these contaminants through the terrestrial and aquatic environment, where these contaminants may be shielded from environmental degradation, and are available for uptake into sensitive biological systems (Teuten et al., 2009). There, these contaminants are able to desorb from the microplastics and are able to be translocated throughout the biological system and may bioaccumulate (Lithner et al., 2012; Teuten et al., 2009). Microplastics have been shown to negatively affect on a range of aquatic and terrestrial plants. These impacts include inhibition of germination, and reduced growth and nutrient uptake (Guo et al., 2020).

The impact of microplastics on human health remains unclear. Studies have hypothesised that intake of microplastics into the human body may cause lesions, uncontrolled cell growth, and respiratory damage (Galloway, 2015).

Abundance and retention of microplastics in WWTPs

Sources of microplastics into the environment are vast and include direct littering and mis-managed waste, and the general wear and weathering of plastic products (Cole et al., 2011; Duis & Coors, 2016). Wastewater has been shown worldwide to contain microplastics and wastewater treatment plants are a source of microplastics to the environment. WWTPs are not designed to remove microplastics, and microplastics are able to bypass initial screens at WWTPs and be released into the environment with the final effluent (Duis & Coors, 2016).

Concentrations of microplastics in influent of overseas studies range from 1 – 7216 particles/L and generally decrease to the final effluent, detected in concentrations from 0.008 – 81 particles/L (Carr et al., 2016; Leslie et al., 2017; Magnusson & Norén, 2014; Simon et al., 2018). The retention of microplastics throughout the WWTP range from 72 – 99.9% from influent to effluent and can depend on the level of treatment the wastewater undergoes (Carr et al., 2016; Leslie et al., 2017; Magnusson & Norén, 2014). A study from Switzerland found a strong positive correlation between total suspended solids (TSS) and plastic concentration in sludge and effluent. The findings from that study suggest that additional steps included to reduce TSS in the WWTP process may effectively retain and remove microplastics from treated effluent (Frehland et al., 2020). An Australian study compared the effluents of three different WWTPs and found the abundance of microplastics in effluent to decrease from 1.54 to 0.48 and 0.28 particles/L in primary, secondary, and tertiary WWTPs, respectively (Ziajahromi et al., 2017). A Scottish study found microplastics to reduce on average by 6%, 68%, 92%, and 96% after pre-treatment, primary, secondary, and tertiary treatment stages, respectively (Blair et al., 2019).

Despite the relatively large decrease of microplastics from influent to effluent, the concentrations of microplastics present in effluent correspond to a daily discharge of between 36,000 – 65 million particles per day into the receiving environment from previous studies (Magnusson & Norén, 2014; Murphy et al., 2016). The microplastics removed from the final effluent throughout the WWTP process are retained in the sludge. A study from the United States of America estimated that approximately 930,000 particles are discharged daily to the environment with the treated effluent, and 1.09 billion particles are retained in the sludge (Carr et al., 2016). Concentrations of microplastics in sludge in previous studies range from 0.113 – 170,900 particles/kg (dry weight) (Lares et al., 2018; Magni et al., 2019). A previous study found sludge disposed of on land 5 years prior to contain microplastic fibres in concentrations from 580 – 1,210 particles/kg of soil (dry weight) (Zubris & Richards, 2005). The same study found microplastics to be intact at a field site which had ceased to receive effluent 15 years prior to sampling. It is estimated that approximately 127 – 864 tonnes of microplastic particles (per one million inhabitants) are deposited annually on European agricultural soils from sewage sludge or processed biosolid application (Nizzetto et al., 2016). Approximately 50% of biosolids in Europe are applied onto agricultural land (Kelessidis & Stasinakis, 2012).

The continual discharge of microplastics from WWTPs to the receiving environment are a concern. Microplastics in the aquatic environment may travel long distances downstream in rivers or in coastal waters, where they may be transported to other tributaries, lakes, estuaries, settle in benthic sediments, and wash up on coastlines (McCormick et al., 2016). Microplastics in soil may travel through to groundwater or aquatic environments through surface runoff (Leslie et al., 2017). Microplastics discharged from final effluent and sludge into the receiving environment are available to be ingested by a range of aquatic and terrestrial organisms (Wright et al., 2013).

Behaviour and retention of microplastics in WWTPs

Little is known about the behaviour of microplastics in WWTPs. It has been hypothesised that microplastics may settle out based on their specific density through various stages in the WWTP (Carr et al., 2016). High-density polymers (e.g. polyamide, polyvinyl chloride, polyethylene terephthalate) are predicted to sink and settle in sedimentation basins, compared to low-density polymers (e.g. polypropylene, polyethylene, polystyrene) which may float on the surface and be removed during surface skimming (Carr et al., 2016; Nizzetto et al., 2016). Polymers of a similar density to the wastewater may remain suspended in the water column and travel throughout the WWTP (Dris et al., 2015). The density of particles may be altered by the growth of biofilms on the surface of fragments, causing lower-density particles to sink (Van Cauwenberghe et al., 2015). The growth of biofilms may be dependent on the solids content of the wastewater and residence time through the WWTP (Carr et al., 2016).

Photo-oxidative degradation by ultra-violet (UV) radiation facilitates the fragmentation of common polymers in the environment, including polyethylene and polystyrene (Duis & Coors, 2016). Low oxygen levels, biofouling, high turbidity in the water column, and sediment all reduce exposure to UV radiation (Duis & Coors, 2016). Degradation by UV radiation is found to be effective on the surface of the water column and shorelines but is slower at greater depths in the water column, if microplastics are buried in sediment or soil, or obscured by poor clarity waters, such as those of WWTPs (Andrady, 2011; Hammer et al., 2012; Shah et al., 2008). Physical degradation of microplastics may be aided by wave action, water turbulences, and abrasion of particles travelling through the WWTP (Hammer et al., 2012; Shah et al., 2008).

A number of plastic-degrading organisms have been isolated from a range of environmental matrices, however little is known about them, particularly in WWTPs (Devi et al., 2019; Kyaw et al., 2012). These organisms are able to degrade plastics into smaller fragments, and some are able to mineralise microplastics into constituents including carbon dioxide, water, methane, and their monomers.

At present, little is known about microplastics in New Zealand. This study is the first of its kind to investigate the abundance, morphotype, and polymer type of microplastics in wastewater influent and effluent. The findings of this study will only be presented during the WaterNZ conference presentation by the speaker.

STUDY DESIGN

MICROPLASTICS IN INFLUENT AND EFFLUENT

Influent and effluent from four WWTPs in Canterbury (Christchurch, Kaiapoi, Lyttelton, Governors Bay) were sampled on a weekday and weekend to assess the variation of microplastics within a working week in the month of June 2018. A second study was undertaken to determine the temporal variation of microplastics in effluent only at three WWTPs (Christchurch, Kaiapoi and Lyttelton) in June, August, October, and December in 2018. A 24-hour composite sample of a total volume of 10 L was collected at each sampling event. The sample was processed in the laboratory by wet-sieving over a stack of sieves (1 mm and 300 μm), digestion by wet-peroxide oxidation to remove organic material, and vacuum filtration onto a glass fibre filter (GFC). The filtered sample was first visually inspected under stereomicroscope, and suspected microplastics were classified by morphotype, into either a fragment, fibre, film, or bead. All suspected microplastic particles were chemically identified to determine their polymer type by Fourier transform infra-red spectroscopy (FTIR).

PRELIMINARY RESULTS

Microplastics in influent and effluent

Microplastics were detected in wastewater influent and effluent at concentrations within the lower range of those detected overseas. The concentration of microplastics at each WWTP decreased from influent to effluent at Christchurch, Kaiapoi, and Lyttelton WWTPs. This trend was not observed at Governors Bay WWTP. The retention percentages of microplastics from influent to effluent in Christchurch, Kaiapoi, and Lyttelton WWTPs were lower than those observed in international studies. Few temporal trends were identified in terms of abundance, particle morphotype and polymer type, highlighting the complex nature of wastewater.

CONCLUSIONS AND RECOMMENDATIONS

Microplastics were detected in all influent and effluent samples at four WWTPs in Canterbury, concluding that WWTPs are a significant source of microplastics through the discharge of treated effluent to the Canterbury coastline. Further work is required to understand the environmental fate and impacts of discharged microplastics. More research into the removal of microplastics from sludge and effluent during the WWTP process is required, however employing greater levels of treatment and filtration at WWTPs are costly to implement and will not effectively remove microplastics from all mediums. Greater understanding of the relative contributions from both commercial and personal activities to influent microplastic load is needed in order to write more effective, targeted regulatory policy to mitigate sources of plastic waste to WWTPs, and the receiving environment.

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