Microplastic Concentrations in Orange City Wastewater

G. Raymon, G. Snyder, A. Van Tol, L. Craig, M. Kleinhesselink, L. Mulder, D. Strand, G. Fynaardt, K. Wojciechowski, and T. Tracy

Northwestern College, Department of Biology, Orange City, IA 51041

Abstract

Microplastics are increasingly polluting both terrestrial and aquatic ecosystems. Researchers have found that wastewater treatment plants are an entry point for microplastics into surface waters, and we wondered how effective our local wastewater treatment plant is in removing microplastics from wastewater, given that it was not engineered for the removal of microplastics. We sampled effluent water from the new wastewater treatment plant (WWTP) in Orange City, Iowa, to determine the amount of microplastics released from the plant into Orange City Slough. We found concentrations of 498 pieces of microplastic/cubic meter (0.498/L) in the effluent water, which is similar to published values for secondary wastewater treatment plants. Given that microplastics have been found in human blood and have been shown to cause various health effects in humans and other animals, we propose that WWTPs be engineered to prevent the release of microplastics into surface waters.

Introduction

For this study, we define microplastics as pieces of plastic less than 5 mm in size. Primary microplastics, such as glitter and microbeads from soaps and body washes, are manufactured at these sizes, while secondary microplastics fragment off larger plastic products, tires, paints, etc. (Figure 4) (Sun et al., 2019; Vethaak and Legler 2021).

Wastewater treatment plants (WWTPs) are designed for removing large debris/objects, pathogens, organic matter, and nutrients from wastewater but are ineffective at removing microplastics, and several studies have shown that microplastics are being released in treated wastewater discharged into surface streams, rivers, and lakes (Estahbanati and Fahrenfeld 2016). Sources of microplastics in wastewater include improper household disposal of plastic (e.g., via garbage disposal), plastics from fabrics (e.g., polyester fibers released during laundering), plastics from household products (e.g., microplastics from body wash), and the use of plastics in manufacturing (e.g., in wastewater from cleaning equipment). To determine to what extent our local community is contributing to the larger global issue of microplastic pollution in waterways and oceans, we sampled the effluent from Orange City's WWTP to look for microplastic contaminants.

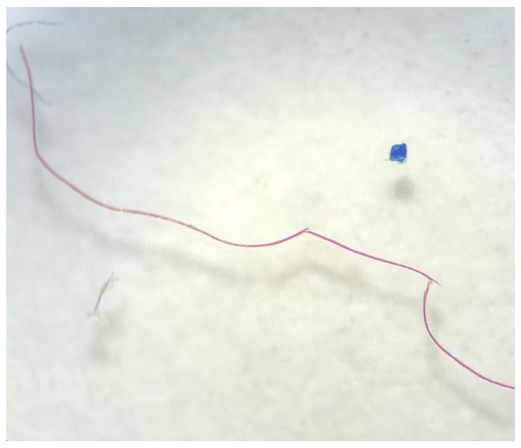

Figure 1. Examples of primary (bottom) and secondary microplastics (top).

Figure 2. The fall 2021 Ecology students touring Orange City's WWTP.

Materials and Methods

In October 2021, the Northwestern College Ecology students collected effluent water from the WWTP in Orange City, Iowa (Figure 2). We let effluent water flow through a 250-micron plankton net for two minutes. Using flow rate, net diameter, and depth of the effluent water, we determined that we filtered approximately 3.066 m3 (3066 L) of effluent water. We rinsed the contents of the net into an aqueous solution of 15% bleach. We then used Buchner funnels to filter the solution through twenty 3-inch diameter filters. We loosened microplastics and other debris from the filters by wetting the filters with 70% ethanol. Using dissecting microscopes, we counted the microplastics released from and embedded in each filter (Figures 3&4). We totaled the number of microplastics in our sample and calculated the approximate number of microplastics released by the Orange City WWTP daily and yearly, given the mean daily discharge of 650,000 gallons (appx. 2.5 million liters) of effluent into Orange City Slough.

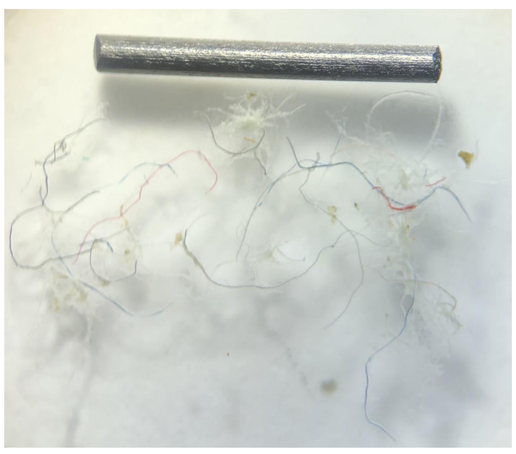

Figure 3. Size comparison of sampled microplastics with a 6 mm x 0.7 mm piece of pencil lead.

Figure 4. Method for counting microplastics.

Sample	Pieces of microplastic per liter
Orange City WWTP water-Secondary treatment	0.498
WWTP-Primary treatment only (Ziajahromi 2018)	1.5
WWTP-With secondary treatment (Ziajahromi 2018)	0.5
WWTP-With tertiary treatment (Ziajahromi 2018)	0.4
Tap water (Cox et al. 2019)	4.23
Bottled water (Cox et al. 2019)	94
Air (Cox et al. 2019)	9.8

Table I. Comparison of our findings to environmental microplastic concentrations reported in recent publications.

Results

Across the 20 filters, we found a total of 1526 pieces of microplastics, which translates to 498 pieces of microplastic per cubic meter (0.498/L) of effluent water. The Orange City WWTP discharges an average of 2460 m3 (2,460,000 L) daily. Based on our results, we determined that over 1.2 million pieces of microplastic are released daily in Orange City (~447 million yearly). For comparison, Ziajahromi (2018) found that WWTPs with only primary treatment release effluent that with average microplastic concentrations of 1.5/L, while WWTPs with secondary or tertiary treatments have average microplastic concentrations of 0.5/L and 0.4/L, respectively. Cox et al. (2019) found that tap water consists of 4.23 microplastics/L, air has 9.8 microplastics/L, and bottled water has 94 microplastics/L (Table I).

Figure 5. Orange City's new WWTP, constructed in 2019.

Discussion

In this study, we filtered effluent from Orange City's WWTP to determine the extent to which our local community is contributing to the growing problem of microplastics in aquatic environments (Figure 5). We found a considerable amount of microplastics in the effluent, with estimated concentrations similar to those reported in similar studies elsewhere.

Ziajahromi (2018) sampled microplastic levels in a river into which effluent water was being discharged. Samples upstream of the WWTP had 19 times less microplastics compared to samples from downstream of the plant, supporting that WWTPs do not remove microplastics (Estahbanati and Fahrenfeld 2016; Ziajahromi 2018). Estahbanati and Fahrenfeld (2016) identify WWTPs as a primary source of microplastic pollution, and improvements in WWTPs may reduce microplastic concentrations in effluent water.

Sun et al. (2019) point out that there are no criteria for microplastics research, which leads to varied or inaccurate results. Via FT-IR analysis, Ziajahromi (2018) determined that 22-90% of potential microplastics in their samples were not actually plastic. Microplastics adsorb to various surfaces, making proper sampling difficult (Duis and Coors, 2016). Conversely, Löder and Gerdts (2015) claim that microplastics on clothing or sampling equipment can artificially raise estimates. We likely failed to catch microplastics smaller than our 250-micron net, potentially lowering our estimates. Furthermore, we did not use grids on the filters to count microplastics, as were utilized by Sun et al. (2019).

Humans are constantly inhaling and consuming microplastics unknowingly. (Vethaak and Legler 2021) Microplastics have been found in human blood (Leslie et al. 2022) and have been shown to be cytotoxic to human cells, cause oxidative stress, and interfere with hormone receptors (Zimmermann et al. 2019). Due to the diverse characteristics of different kinds of plastics, the full effects of microplastics on human health are unknown (Zimmermann et al. 2019). Given the known harmful effects of microplastics and the likelihood of many harmful effects that are yet unknown, we propose that WWTPs be engineered to remove microplastics from their effluent before discharging the effluent into surface waterways.

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