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The Occurrence and Risk Assessment of Microplastics: different treatment technologies for wastewater treatment plants in Oman

Yavari Z[1], Al-Amri A[2], Nikoo M[3].

[1] Assistant professor, Department of Civil and Architectural, College of Engineering. Sultan Qaboos University, Muscat, Sultanate of Oman. Z.yavari@squ.edu.om

[2]Ms. C student, Department of Civil and Architectural, College of Engineering. Sultan Qaboos University, Muscat, Sultanate of Oman. s132299@student.squ.edu.om

Associate professor, Department of Civil and Architectural, College of Engineering. Sultan Qaboos University, Muscat, Sultanate of Oman. m.reza@squ.edu.om

*corresponding author:
e-mail: Z.yavari@squ.edu.om

Abstract: Microplastics (MPs) are considered an emerging pollutants and one of the greatest challenges for the environmental and Sewage treatment plants (STPs) are suspected of being major contributors to environmental MPs. The purpose of this study is to quantify and characterize MPs at different treatment technologies in major STPs in Oman. The Sampling points were Primary, tertiary effluent, and sludge. The samples were sieved in stainless sieves with a different mesh size and undergo wet peroxidation (WPO) to remove the organic matter. Suspected MPs were counted under a light microscope and morphologically characterized into fibers, fragments, foams, spheres, and others. Fiber MPs were dominant in all effluent types, followed by a considerable amount of fragments. Almost all shapes colors and several sizes of MPs were detected in the sludge sample which is considered the sink of MPs. Nonetheless, diverse treatment stages are capable of removing a significant proportion of MPs, However fiber MPs can effectively survive in advanced treatment using ultrafiltration. The outcomes of this study showed that a considerable number of MPs are discharged into the environment through treated effluent and sludge. The application of on-site management advanced practices for MPs remediation such as nanotechnology shall be recommended to the wastewater management authority in Oman.

Keywords: Sewage, Priority Pollutant, Microplastic, Detection

1. Introduction

The widespread occurrence of Microplastics (MPs) in the environment increases many concerns regarding their potential hazards, to human health and aquatic life. Microplastics are known as small plastic particles that are less than 5 mm in size (Ivleva, et al., 2017). MPs consider an emerging pollutant that can get into the food chain and migrate up the tropical food chain and end up in the human body (Athey et al., 2020). Wastewater treatment plants are recognized to be a major source of microplastic in freshwater via treated effluent and sludge products (Ziajahromi et al., 2017). Several studies demonstrated that wastewater treatment plants are effective in the removal of microplastic (Murphy et al., 2016; Carr et al., 2016). However, the few percentages of MPs that passed daily will contribute in huge quantity in terms of total annual load. The reported concentration of MPs in raw wastewater was measured in previous studies and reported as 1- 10044 particle/L (Sun et al., 2019). According to research that done by Sun et al., they reported during pre-treatment and primary treatment 35-59% and 50-98% of microplastics could be eliminated, respectively (Sun et al., 2019). During the biological treatment process, the sludge flocs in the aeration tank will trap the plastic particles which will settle later in the secondary clarifier. So the performance of this stage for removal of MPs was 0.2-14%. (Sun et al., 2019). Moreover, the flocculating agents added in the secondary treatment can effectively remove microplastics by aggregating the suspended matter forming flocs (Murphy et al., 2016).

The abundance of microplastics along the Sultanate of Oman Coastline has been reported by some researchers. (Aliabad et al., 2019; Hosseini et al., 2020). This study is the first study that aims to quantify and characterize MPs in three wastewater treatment plants in Oman utilizing different treatment techniques. In addition, Oman has located in an arid region with a scarcity of freshwater resources, as a result, treated wastewater can be a valuable source that can be used for different purposes including planting and domestic use. However, such emergent pollutants can potentially affect treated water quality which limits its uses. Moreover, the current study estimated the concentration of MPs trapped in sewage sludge that is released into the terrestrial environment in Oman due to their potential impact on the environment. Furthermore, there is a necessity for risk assessment of MPs on human and ecology. To the best of our knowledge, this is the first time that we performed the risk assessment of MP in WWTPs in Oman based on experimental parameters.

2. Title

2.1. Sampling

Three wastewater treatment plants with different treatment technologies were studied. The plants were Conventional Activated Sludge (CAS) WWTP A, Sequencing Batch Reactor (SBR) WWTP B, and Membrane Bioreactor (MBR) WWTP C, located in the Sultanate of Oman. The sampling time were in the July, Augustus, and September 2022. The Sampling points were Primary, tertiary effluent, and sludge. Wastewater samples were grabbed from each sampling point via stainless-steel containers and stored in 2.5 L glass bottles to avoid background contamination. The bottles were immediately transported to the Environmental Engineering Laboratory at Sultan Qaboos University, Muscat. The bottles were kept at the lab temperature to proceed with the analysis.

2.2 Extraction of MPs from wastewater samples

The samples were sieved through 1mm, 425 um, and 45 um stainless metal sieves. The remained particles in each sieve were rinsed with deionized water in 500 ml beakers. The transferred particles from the sieving stage were subjected to wet peroxidation (WPO) utilizing 30% H_2O_2 in the presence of Fe (II) as a catalyst (Fenton's reagent). WPO was performed in a hot plate at 70 °C and stirred using a magnetic stir bar at 300 rpm. Raw wastewater samples (RW) were treated with 340 ml of Fenton's reagent, while treated effluent (TE) samples required 60 ml of the digestive agent.

2.3 MPs characterization

Filter papers were observed under a dissection light microscope (Olympus SZ-PT) with 6x magnification. The suspected particles were categorized and counted based on size (1mm, 425 µm, 45 µm), color (blue, white, black, pink, purple, green, other), and morphology (fiber, fragment, foam, sphere, other). MP images were taken by compound light microscope (Olympus BX51) under 4x and 10x magnification coupled with a digital camera. The chemical characterization of MPs was conducted using Agilent Cary 610/620 FTIR Microscope. The spectra were obtained in transmission mode between 500 to 4000 cm^{-1} wavenumbers at 4 cm^{-1} resolution and 32 scans. Moreover, OMNIC spectroscopy software was used to analyze the spectral data and identify the polymer type.

3. Results

3.1. Abundance and removal of microplastics in WWTPs

10% of MP particles from each sampling point of all examined WWTPs were taken for chemical characterization using FTIR. The most abundant type was low-density polyethylene (LDPE), followed by polypropylene (PP), polyethylene terephthalate (PET), polyurethane (PUR), and polyvinyl chloride (PVC). The chemical characterization of each sampling point allows the understanding of the hazards of each sampling site as well as the types of polymers entering and leaving each WWTPs. The type of polymers and percentage at each sampling point of three WWTPs are shown in Figure 1. The percentage distribution of MPs particles in all collected wastewater samples are shown in Figure 2.

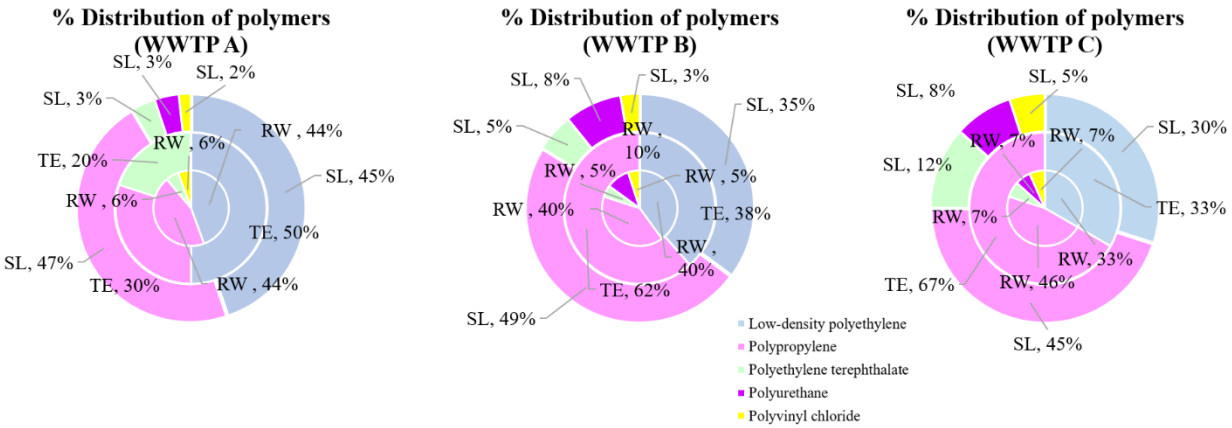

Figure 1. Distribution of polymer types across each collected sample of the three WWTPs

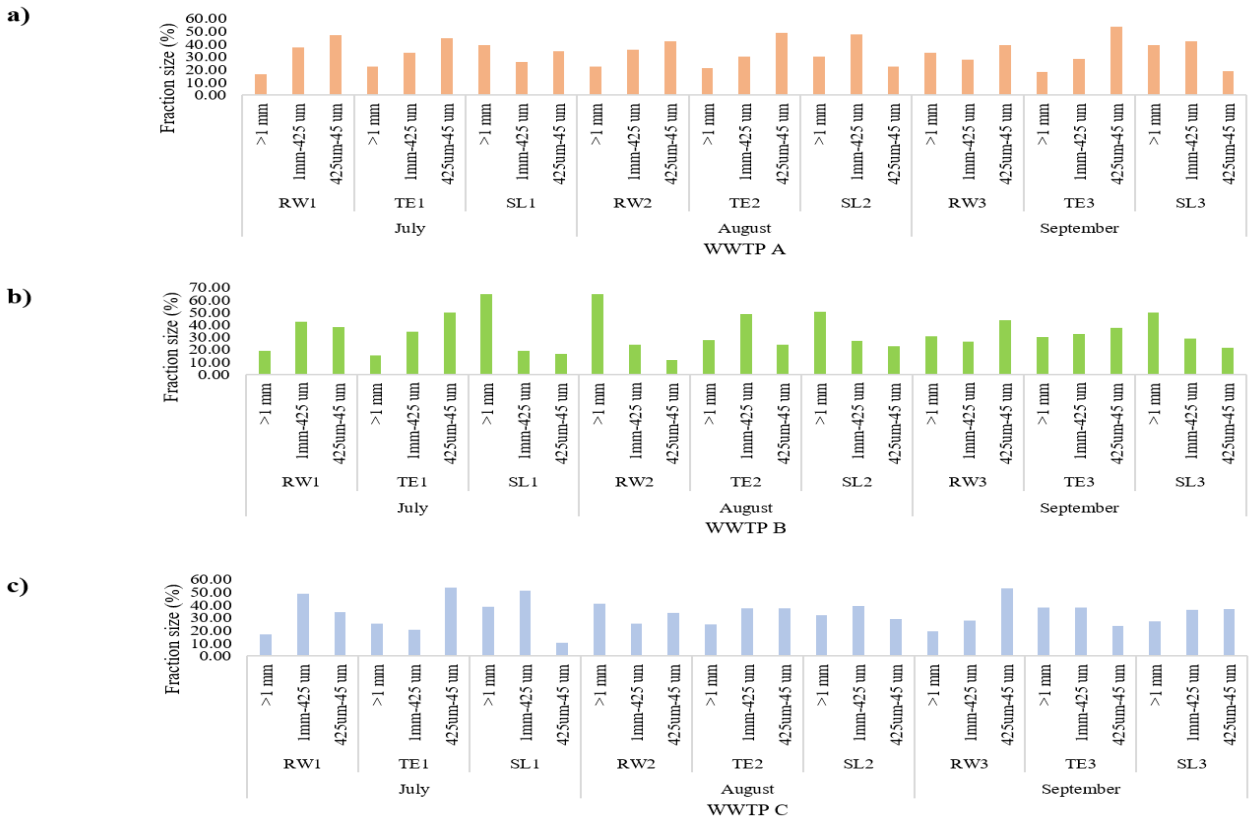

Figure 2. Percentage distribution of the different size groups of microplastics in three wastewater plant

5. Conclusion

In this study, the microplastic characteristics of raw wastewater, waste-activated sludge, and treated effluent from three wastewater treatment plants of different treatment processes located in the Sultanate of Oman were compared. The overall efficiency was 82.5%, 77.4%, and 79.2% for WWTP A, WWTP B, and WWTP C, respectively, which may be associated with the sources of wastewater as well as the treatment technology used in each WWTP. The most abundant shape was fiber which is mainly released from garments and is considered to have high toxicity to human and marine ecosystems. Hazardous polymers such as polyvinyl chloride and polyurethane were also discovered in the sludge samples. This study illustrates that a considerable percentage of microplastics were removed by different treatment technologies. Nevertheless, the few percentages of microplastics that passed daily will contribute in huge quantities in terms of total annual load. The number of microplastics released from the wastewater treatment plants in Oman points to the urgent implementation of advanced techniques to enhance the removal of microplastics from the final treated effluent. Furthermore, management and technological approaches are required for sludge treatment to minimize microplastic contamination in soil.

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