Advanced International Journal for Research (AIJFR)
E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Abundance and Distribution of Microplastics as Emerging Contaminants in Public Water Supply Dams of Jos-Bukuru Metropolis, Plateau State

Buba M. Wufem[1], Nangbes J. Gungsat[2], Dapam L. Isaac[3], Shakede O. Iramofo[4]

[1,2,3,4]Department of Chemistry, Plateau State University Bokkos, PMB 2012 Jos, Plateau State Nigeria

Abstract

The distribution of microplastic across water treatment infrastructure in Jos and its environs was determined using oil extraction methods. Raw water from the water storage facilities was analysed for microplastics and physico-chemical properties. The physico-chemical properties of the water showed pH range of 7.16 - 7.44, electrical conductivity of 15.67 - 73.2 µS/cm, Total Dissolved Solids 34.3 - 95 mg/L and Total Suspended particles ranging between 33.3 - 48.9 mg/L. The results indicated the presence of microplastics in all the storage facilities ranging from 3,368 to 4,353 particles/L, and the mean levels of 4,353 particles/L, 4,230 particles/L, 3,746 particles/L and 3,368 particles/L, for Lamingo Dam, Liberty Dam, Yakubu Gowon Dam and Yelwa Pond respectively. The distribution of microplastic particles in Lamingo Dam showed a higher variability suggesting the influence of point-source pollution or localized anthropogenic activity. Liberty Dam in contrast, showed relatively uniform distribution pointing to more homogeneous contamination inputs. The microplastic abundance levels across the studied water facilities were relatively high with tyre debris being dominant. This suggests the particles to be of vehicular origin due to tyre wear. The presence of microplastics in the municipal water sources may pose health threat to the municipality and aquatic lives.

Keywords: Microplastics, emerging contaminants, raw water, storage reservoirs, Tyre-wear.

1. Introduction

Microplastics in water bodies have become a growing concern in water quality due to their persistence and potential health implications in water resources. Microplastics are consistently detected in raw waters entering drinking-water treatment plants (DWTPs) via water run-off. Reported levels of microplasticsfrom literature range from ~1,473 – 3,605 particles/L in raw influent to 338 – 628 particles/L in treated water, with particles < 10 µm dominating counts (Pivokonský et. Al., 2018). In reservoirs such as China's Luhun Reservoir, MPs are typically much lower (1.6 – 13.3 items/L), reflecting different minimum particle sizes. African studies have also shown MPs in boreholes (0 – 11 items/L), with FTIR confirmation of polymer types (Li *et al.*, 2024. Globally, road runoff and tyre-wear are major contributors to MP loads in urban reservoirs, highlighting traffic intensity as a critical source. In the city of Jos and its environs, Dams serve as reservoirs for pipe borne water supply operated by the Jos Water Service Corporation in Plateau State, Nigeria apart from agricultural uses. The proliferation of microplastics (MPs) in aquatic environments has emerged as a pressing environmental and public health concern, with increasing evidence of their presence even in raw water sources destined for municipal treatment (Eerkes-Medrano *et al*., 2015). Urban water treatment plants, especially those serving densely populated areas, are increasingly reporting the presence of microplastics in raw water storage facilities, where untreated surface or groundwater is temporarily held before processing (Pivokonsky *et al*., 2018). These facilities, once considered safe intermediaries in the water supply chain, are now being recognized as critical points of contamination. Microplastics can originate from urban runoff, industrial discharge, and atmospheric deposition, entering storage systems and potentially affecting the efficiency of water treatment processes (Li *et al*., 2021). Understanding the abundance and characteristics of microplastics at this early stage of the treatment process is vital for designing effective mitigation strategies and ensuring safe potable water supply to urban populations.

2. Methods

2.1 Study Area and water sampling

Raw water samples were collected from storage water facilities Dams under the management of Plateau State Water Board. These facilities include Lamingo Dam, Liberty Dam, Yelwa Treatment Pond, and Yakubu Gowon Dam. Raw Water was collected by grab Sampling into 2–3 times rinsed 250 cm^3 capacity plastic sampling container at 30 cm depth with mouth facing upstream according to APHA, AWWA, & WEF (2017) Standard Methods. This procedure was carried out until a volume of 4 L of surface water was collected at every sample collection point. Samples were brought to the Laboratory for immediate physicochemical analysis.

2.2 Physicochemical Analysis

The physicochemical properties of pH, Electrical conductivity, and Total dissolved solids were measured using an electrometric method according to standard methods (APHA (2017). Total suspended solids were determined by Pycnometer method according to Method 2710 H, of APHA, AWWA, & WEF (2017). Density was similarly measured according to ASTM D5907-18 *(*ASTM International, (2018).

2.3 Microplastic Analysis

Samples were subjected to wet hydrogen peroxide (H_2O_2) oxidation using a 30% H_2O_2 solution heated to 80 °C for 7 h to remove organic material from the sample before the analysis. Following the wet oxidation, the resulting sample were subjected to density separation using olive oil. The oil extraction method for the isolation and recovery of microplastic debris from the water samples was carried out as described by Scopetani *et al*., (2020) using Olive oil with a density of 912 kgm^{-3} with modification to the procedure where necessary. This was done by transferring 50 cm^3 of the water samples into a 100 cm^3 separation glass flask, to which 10 cm^3 of olive oil was added, and vigorously shaken for 5 minutes, after which the mixture was let to settle for 15 – 30 min. The lower layer was released from the funnel into another 100 cm^3 separation flask, to which another 10 cm^3 of oil was added again, to repeat the extraction process. The oil layer was filtered through a pre-weighed Whatman filter paper. The filter paper was rinsed with 100 cm^3 Chloroform/Ethanol mixture (1:1) to remove oil layer from microplastic particles. After this, the filter papers were carefully transferred to Petri dishes, left to dry at 37 °C in a hot air oven. After Drying, the weight of the filter paper was taken

2.3 Data Analysis

The number of microplastic is expressed as a function of density by dividing the total number of particles found in the volume of water analyzed from each station and sampling event (particles/L). The physicochemical variables of the water were analyzed using descriptive statistics using SPSS version 25.

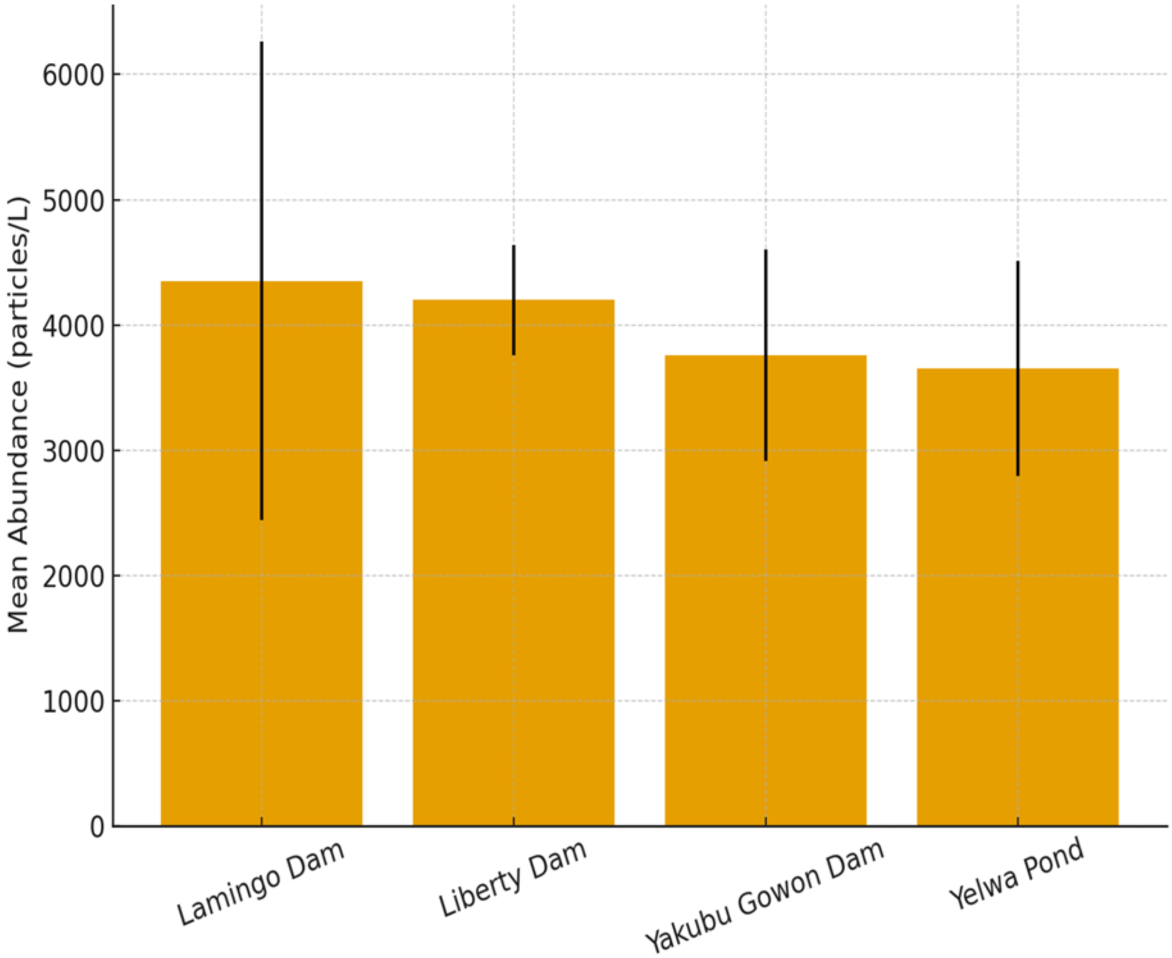
3. Results

3.1 Physicochemical Characterization

The physico-chemical properties of the water showed pH values that were slightly alkaline, with the average for each location being 7.43, 7.22, 7.35 and 6.78 for Lamingo Dam, Liberty Dam, Yakubu Gowon Dand and Yelwa Pond. Changes in pH was found to alter the surface charge of microplastics and the surrounding ions, which affects MP aggregation and distribution. Higher pH increases negative ion concentrations, influencing MP behaviour in water (Amir *et al*., 2024). In another finding in the Karnaphuli River estuary, MP abundance was **negatively correlated with pH** during the wet season (r = –0.74) where lower pH coincided with higher MP levels (Refat, *et al*., 2023). The Mean electrical conductivity were 29.4 µS/cm, 37.4 µS/cm, 15.6 µS/cm and 24.2 µS/cm for Lamingo Dam, Liberty Dam, Yakubu Gowon Dam and Yelwa Pond respectively. Elevated ionic strength and conductivity can enhance aggregation of MPs with natural matter, which may potentially aid their removal from surface waters. The Average Total Dissolved Solids contents was 50.0 mg/L for Lamingo Dam, 51.4 mg/L for Liberty Dam, while 95.0 mg/L and 50.0 mg/L, are for Yakubu Gowon Dam and Yelwa Pond. The mean Suspended Solid particles were 33.3 mg/L, 34.3 mg/L, 48.9 mg/L and 42.8 mg/L for Lamingo Dam, Liberty Dam, Yakubu Gowon Dam and Yelwa Pond respectively.

3.2 Microplastic Abundance

All waters samples collected from the water reservoirs of the Plateau Water Management Board, Jos were found to contain microplastics in different numbers. The abundance of microplastic particles in Lamingo Dam ranges from 1,640 - 7,120 particles/L, with an average abundance of 4,353 particles/L. This value is higher than the average abundance of microplastics in Liberty Dam, 4,200 particles/L, which ranged from 3,480 - 4,880 particles/L for all the samples collected at this location. This was not much different from the abundance of microplastics in Yelwa Pond, whose abundance ranges from 2,140 - 5,200 particles/L, with an average abundance of 3,654 particles/L. For Yakubu Gowon Dam, the abundance of microplastic particles ranges from 2,300 - 4,880 particles/L, with an average abundance of 3.760 particles/L. Collaborating these research finding, a study by Oni *et al*. (2020) found the level of microplastic in Ox-Bow Lake, Nigeria to be 1,604 - 8.329 items/m^3 while a microplastics abundance of 4147 items/m^3 (Zhao *et al*., 2014), have been reported for the Yangtze River Estuary, China, 100.6 fibre /m^3 in Marne River, Paris, France (Dris *et al*., 2017).



.

Figure 1. Abundance of Microplastics in water storage facilities of Jos Water Service Corporation.

The highest abundance of microplastics among the source points of these water reservoirs are 7,120 particles/L at Lamingo Dam, 5,200 at Yelwa Pond and 4,880 at Yakubu Gowon Dam and Liberty Dam, respectively, and the lowest in with the lowest for any source point being 1,640 particles/L. The fluctuations in the abundance of microplastics at different source point within and among these different water reservoirs is indicative of the heterogeneous and varied concentration of their distribution. Figure 1 underscores that Lamingo Dam exhibits the highest mean microplastic abundance and variability, suggesting strong localized anthropogenic influences such as road runoff and nearby settlements. Liberty Dam, by contrast, shows more uniform values, indicating more consistent contamination sources. Figure 2 illustrates these trends in temporal-spatial variability, where the wide error margins at Lamingo and Yelwa reflect heterogeneous deposition patterns, consistent with studies of estuarine and reservoir systems elsewhere. These rresults (3.37 – 4.35 × 10^3 particles/L, with peaks up to 7,120 particles/L) align more closely with DWTP influent studies that include sub-10 µm particles, rather than reservoir studies with larger detection thresholds. This indicates that methodological choices may have been responsible (size cut-off, extraction) for the strongly influence abundance estimates. The high heterogeneity observed at Lamingo Dam mirrors global findings where local runoff and shoreline activities drive variability. Fragments dominated particle types, consistent with global raw water studies, but attributing them solely to tyre debris requires spectroscopic or chemical confirmation. Physicochemical parameters did not explain variability, supporting the interpretation that source proximity and hydrodynamics dominate. Compared with Nigerian borehole studies (0 – 11 items/L), your surface water counts are much higher, emphasizing the importance of including small size fractions in monitoring programs.

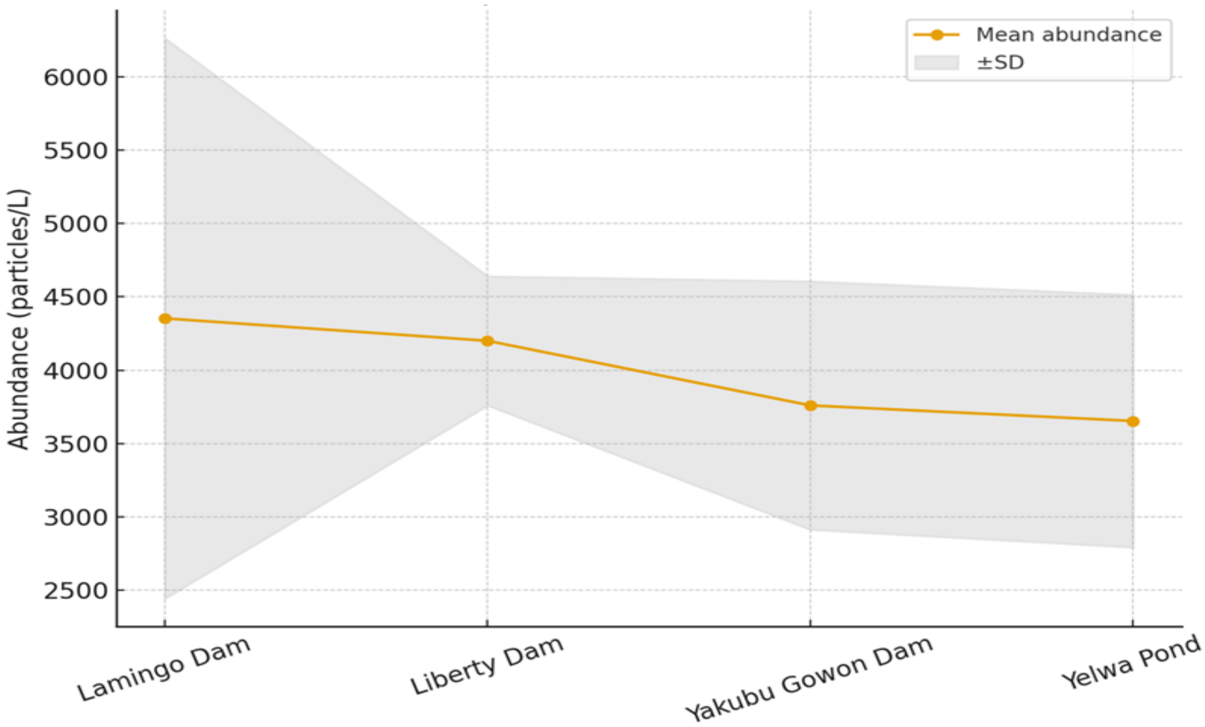


Figure 2. Variation in microplastic abundance across reservoirs with shading highlighting heterogeneity in Dams

Going by the suggestion of Medrano *et al*., (2015), this observed difference in the abundance of microplastics, could have been influenced by the characteristic intensity of the ongoing activities around the locations from where the samples were collected, being that whatever is been done there, accounts for the physical forces in the degradation and dispersion of microplastics within the water bodies. While, the concentration of microplastics in these water reservoirs appears to be higher, Cable *et al*., (2017) have pointed out that it is a common observation, with water bodies that lie around densely populated areas and this somewhat disproportionately higher concentrations of microplastics is indicative of the plastic waste that are introduced as a result of the activities of the inland community. This is more so, when it is considered that microplastics pollution has significantly been attributed to, the proximity of water bodies to highly populated urban areas, industrial hubs and other anthropogenic activities such as tourism, fishing, and agriculture (Saad *et al*. 2022). Plastics occur in the environment due to many anthropogenic activities, which increases with increasing population and usage (García Rellan *et al*., 2023). Studies have shown that the major forms of microplastics in the environments are mainly synthetic textiles, bottles and packaging materials (Tian *et al*., 2022). Also, microplastics from tyres and bitumen have been reported by Osterlund et. al., 2023. The major contributors to the release of microplastics into the air are synthetic fibres from materials like clothing, rubber from tyre wear etc (Amato-Lourenço *et al*., 2020).

Plastics are durable and often break down into smaller-size. When plastics degrade to particles of ≤ 5 mm in size, they are termed microplastics (An *et al.,* 2022) and when they are degraded to between the range of <5mm to 100 nm or less, they are termed nanoplastics. Microplastics smaller than 10 µm can cross cell membranes as to enter the body systems. The efficiency of the movement of the particles through the body increases with decreasing microplastic size (Zhu *et al*., 2023). It's been found that the accumulation of microplastic particles of polyethylene origin may cause oxidative stress responses, hemocytic encapsulation, increased mucous secretion, disrupted microbiota balance and declination of phenoloxidase activity (Zhang *et al*., 2022). Various authors have reported the effects of the accumulation of microplastics in mammals (Liu *et al*., 2022; Wei *et al*., 2022; Wang *et al*., 2022b; Sun *et al*., 2021; Wang *et al*., 2022a). MPs (<10 µm) can cross biological barriers once taken in and may cause inflammation, oxidative stress, and cytotoxicity in cells (Prüst *et al*., 2020). However, when inhaled or ingested it can accumulate in lung tissue or enter the bloodstream, potentially affecting cardiovascular health (Leslie *et al*., 2022). The presence of MP in the gut can alter gut microbial composition, reducing beneficial bacteria and promoting dysbiosis linked to metabolic and immune dysfunction (Jin *et al*., 2019). Studies have reported 10^2–10^3 microplastic particles/L in bottled water (Mason *et al*., 2018), with smaller particles (<10 µm) dominating counts (Schymanski *et al*., 2018). It was detected in human placenta, feces, lungs, blood, and breast milk (Leslie *et al*., 2022; Ragusa *et al*., 2021), confirming systemic exposure.

3.3 Particles type

Morphological characteristics (shape, color, and size) of microplatic particles were analysed. Microscope images of the most frequently detected shapes are shown in Fig. 2. The are usually four major types of microplastics particle types which are namely sheet, film, fiber, and fragment. Notably, fibers and fragments are frequently reported as the most abundant types of microplastics particles in several freshwater bodies, examples include the Karnafully River in Bangladesh, the Chengdu River in China, and several freshwater lakes and Rivers in Russia (Chen *et al*. 2022; Frank *et al*. 2022; Hossain *et al*. 2022). According to Wu *et al*., (2017), the grouping of microplastic particles based on shape or type is indicative of the origin of those particles. Whiles, fiber-type microplastics usually have their origin from textiles and fishing equipment, fragments come from the degradation and fragmentation of other plastics.

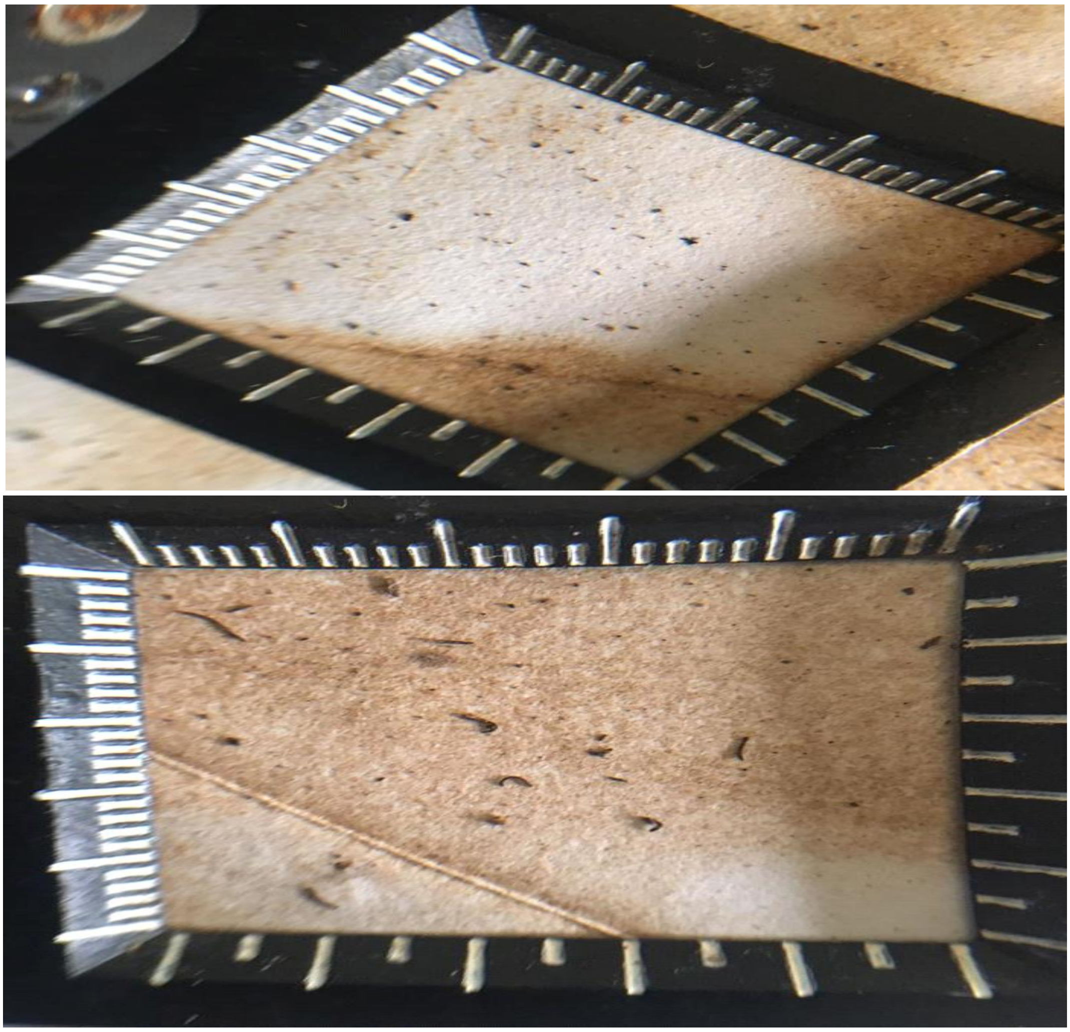


Figure 3. Microscopic Images of Microplastics

Microplastic fibres were not found in water samples of any of the reservoirs, this is because there is no fishing activity going on in these water bodies. Also, there is hardly any evidence that domestic laundry services were done along their waterfront. The major microplastic types that were found in the collected water samples were majorly fragments. A possible contributory source of this high level of fragment type of microplastic particles is probably from the wear and degradation of vehicular tyre, probably plumbing and artisanal vulcanizing services since all the water sources are corridored by busy motor ways and such anthropogenic activities.

4. Conclusion

This study provides the first evidence of significant MP contamination in Jos–Bukuru reservoirs, with levels among the highest reported in municipal raw waters. Findings highlight the urgent need for routine MP monitoring in Nigeria's water sector, methodological harmonization (size-binning, spectroscopic confirmation, QA/QC), and integration of MPs into existing water quality frameworks. Future work should address seasonal dynamics, polymer-specific risks, other emerging contaminants such as detergents, herbicides and insecticides as well as treatment plant removal efficiencies using membrane filtration techniques.

Reference

1. Amato-Lourenço, L. F., Carvalho-Oliveira, R., Júnior, G. R., Dos Santos Galvão, L., Ando, R. A., & Mauad, T. (2020). Tyre wear particles: An emerging contaminant of the atmosphere. Atmospheric Environment, 223, 117252.
2. Amir Muhammad Noh, Amin Abdul Rahman, Arjulizan Rusli, Muhammad Khalil Abdullah, Raa Khimi Shuib, Zuratul Ain Abdul Hamid, Ku Marsilla Ku Ishak, Muaz Mohd Zaini Makhtar, Mariatti Jaafar, Mohamad Danial Shafiq (2024) A review of microplastic surface interactions in water and potential capturing methods. Water Science and Engineering Volume 17, Issue 4, Pages 361-370
3. An, L., Cui, T., Zhang, Y., Liu, H., (2022). A case study on small-size microplastics in water and snails in an Urban River. Sci. Total Environ. 847, 157461.
4. APHA (2017), Standard Methods for the Examination of Water and Wastewater, Method 4500-H^+B; Method 2510 B; Method 2540 C
5. APHA, AWWA, & WEF (2017), Standard Methods for the Examination of Water and Wastewater, Method 1060 B.
6. APHA, AWWA, & WEF (2017). Standard Methods for the Examination of Water and Wastewater (23rd ed.), Method 2710 H
7. ASTM International. (2012). ASTM D1293-12: Standard Test Methods for pH of Water. ASTM International.
8. ASTM International. (2018). ASTM D5907-18: Standard Test Methods for Filterable Matter and Nonfilterable Matter in Water. ASTM International.
9. Cable R N, Beletsky D, Beletsky R, Wigginton K, Locke B W, Duhaime M B (2017) Distribution and modeled transport of plastic pollution in the Great Lakes, the world's largest freshwater resource Frontiers in Environmental Science (5): 1–18
10. Chen J, Rao C, Yuan R *et al* (2022) Long-term exposure to polyethylene microplastics and glyphosate interferes with the behavior, intestinal microbial homeostasis, and metabolites of the common carp (Cyprinus carpio L.). Sci Total Environ 814:152681.
11. Dris, R., Gasperi, J., & Tassin, B. (2017). Sources and fate of microplastics in urban areas: A focus on Paris megacity. In The Handbook of Environmental Chemistry (Vol. 58, pp. 69–84). Springer.
12. Eerkes-Medrano, D., Thompson, R. C., & Aldridge, D. C. (2015). Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Research, 75, 63–82.
13. Frank Y, Ershova A, Batasheva S *et al* (2022) Microplastics in freshwater: a focus on the Russian Inland waters. Water 14:3909
14. García Rell´ an, A., V´ azquez Ares, D., V´ azquez Brea, C., Francisco Lopez, ´ A., Bello Bugallo, P.M., (2023). Sources, sinks and transformations of plastics in our oceans: review, management strategies and modelling. Sci. Total Environ. 854, 158745.
15. Hossain MJ, AftabUddin S, Akhter F *et al* (2022) Surface water, sediment, and biota: the first multi-compartment analysis of microplastics in the Karnafully river, Bangladesh. Mar Pollut Bull 180:113820.
16. Leslie, H. A., *et al*. (2022). Discovery and quantification of plastic particle pollution in human blood. Environment International, 163, 107199.

17. Li, Y., Lu, L., Zheng, X., Zhang, Y., & Gong, J. (2021). Microplastics in surface water and sediments of urban lakes in China: Distribution and ecological risks. Environmental Pollution, 269, 116174.
18. Li, Y., Qin, L., Dou, Y., Shen, M., Chen, X., Liang, X., Ao, T., Jin, K., & Duan, X. (2024). Occurrence and Risk Assessment of Microplastics in a Source Water Reservoir in Middle Reaches of Yellow River. Water, 16(17), 2478. https://doi.org/10.3390/w16172478
19. Liu, K., Wang, X., Fang, T., Xu, P., Zhu, L., & Li, D. (2019). Source and potential risk assessment of microplastics in water and sediment from urban rivers in Wuhan, Central ChLiu, K., Wang, X., Fang, T., Xu, P., Zhu, L., & Li, D. (2019). Source and potential risk assessment of microplastics in water and sediment from urban rivers in Wuhan, Central China. Science of The Total Environment, 659, 94–102.
20. Mason, S. A., *et al*. (2018). Synthetic polymer contamination in bottled water. Frontiers in Chemistry, 6, 407.
21. Medrano D E, Thompson R C, Aldridge D C (2015). Microplastics in freshwater system: A review of the emerging treats, identification of knowledge gaps and prioritisation of research needs Water Research 75: 63–82
22. Oni, B. A., Ayeni, A. O., Agboola, O., Oguntade, T., & Obanla, O. (2020). Comparing microplastics contaminants in (dry and raining) seasons for Ox-Bow Lake in Yenagoa, Nigeria. Ecotoxicology and Environmental Safety, 198, 110656.
23. Osterlund, ¨ H., Blecken, G., Lange, K., Marsalek, J., Gopinath, K., Viklander, M., (2023). Microplastics in urban catchments: review of sources, pathways, and entry into stormwater. Sci. Total Environ. 858, 159781.
24. Pivokonský, M., Čermáková, L., Novotná, K., Peer, P., Cajthaml, T., & Janda, V. (2018). Occurrence of microplastics in raw and treated drinking water. Science of the Total Environment, 643, 1644–1651. https://doi.org/10.1016/j.scitotenv.2018.08.102
25. Prüst, M., *et al*. (2020). Health effects of micro- and nanoplastics: a critical review. Environmental Science & Technology, 54(19), 11467–11479.
26. Ragusa, A., *et al*. (2021). Plasticenta: First evidence of microplastics in human placenta. Environment International, 146, 106274.
27. Refat Jahan Rakib, *a Sultan Al Nahian,b Reyhane Madadi,c Sayeed Mahmood Belal Haider,b Gabriel Enrique De-la-Torre,d Tony R. Walker,e M. P. Jonathan,f Win Cowger, gh Mayeen Uddin Khandakerij and Abubakr M. Idris kl (2023) Spatiotemporal trends and characteristics of microplastic contamination in a large river dominated estuary† Md. Environmental Science Processes & Impacts , Royal Society of Chemistry: DOI: 10.1039/d3em00014a
28. Saad D, Alamin H (2024) The first evidence of microplastic presence in the River Nile in Khartoum, Sudan: using Nile Tilapia fish as a bio-indicator. Heliyon 10:e 23393.
29. Schymanski, D., *et al*. (2018). Analysis of microplastics in water by micro-Raman spectroscopy: Release of plastic particles from beverage bottles. Water Research, 129, 154–162.
30. Scopetani, C., Chelazzi, D., Mikola, J., Leiniö, V., Heikkinen, R., Cincinelli, A., & Pellinen, J. (2020). Olive oil-based method for the extraction, quantification and identification of microplastics in soil and compost samples. Science of The Total Environment, 733, 139338.

31. Sun, R., Xu, K., Yu, L., Pu, Y., Xiong, F., He, Y., Huang, Q., Tang, M., Chen, M., Yin, L., Zhang, J., Pu, Y., (2021). Preliminary study on impacts of polystyrene microplastics on the hematological system and gene expression in bone marrow cells of mice. Ecotoxicol. Environ. Saf. 218, 112296.
32. Tian, Z., Zhao, H., Peter, K. T., Gonzalez, M., Wetzel, J., Wu, C., Hu, X., Prat, J., Mudrock, E., Hettinger, R., & Kolodziej, E. P. (2021). A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon. Science, 371(6525), 185–189.
33. Wang, Q., Wu, Y., Zhang, W., Shen, T., Li, H., Wu, J., Zhang, L., Qin, L., Chen, R., Gu, W., Sun, Q., Liu, C., Li, R., (2022a). Lipidomics and transcriptomics insight into impacts of microplastics exposure on hepatic lipid metabolism in mice. Chemosphere 308, 136591.
34. Wang, S., Han, Q., Wei, Z., Wang, Y., Xie, J., Chen, M., (2022b). Polystyrene microplastics affect learning and memory in mice by inducing oxidative stress and decreasing the level of acetylcholine. Food Chem. Toxicol. 162, 112904
35. Wei, Z., Wang, Y., Wang, S., Xie, J., Han, Q., Chen, M., (2022). Comparing the effects of polystyrene microplastics exposure on reproduction and fertility in male and female mice. Toxicology 465, 153059.
36. Wu C, Zhang K, Xiong X (2017) Microplastic pollution in inland waters focusing on Asia the Handbook of Environmental Chemistry (58) 85–99
37. Zhang, X., Jin, Z., Shen, M., Chang, Z., Yu, G., Wang, L., Xia, X., (2022). Accumulation of polyethylene microplastics induces oxidative stress, microbiome dysbiosis and immunoregulation in crayfish. Fish Shellfish Immunol. 125, 276–284.
38. Zhao, S., Zhu, L., Wang, T., & Li, D. (2014). Suspended microplastic in the surface water of the Yangtze estuary system, China: First observation on occurrence and distribution. Marine Pollution Bulletin, 86(1–2), 562–568.
39. Zhu, J., Zhang, Q., Li, Y., Tan, S., Kang, Z., Yu, X., & Wang, J. (2020). Microplastic pollution in the Maowei Sea, a typical mariculture bay of China. Science of The Total Environment, 707, 135601.
40. Zhu, L., Zhu, J., Zuo, R., Xu, Q., Qian, Y., An, L., (2023). Identification of microplastics in human placenta using laser direct infrared spectroscopy. Sci. Total Environ. 856, 159060