ScienceDirect

Science of The Total Environment
Volume 884, 1 August 2023, 163866

Review

Abundance and characteristics of microplastics in drinking water treatment plants, distribution systems, water from refill kiosks, tap waters and bottled waters

Seren Acarer

Show more

Share Cite

https://doi.org/10.1016/j.scitotenv.2023.163866
Get rights and content

Highlights

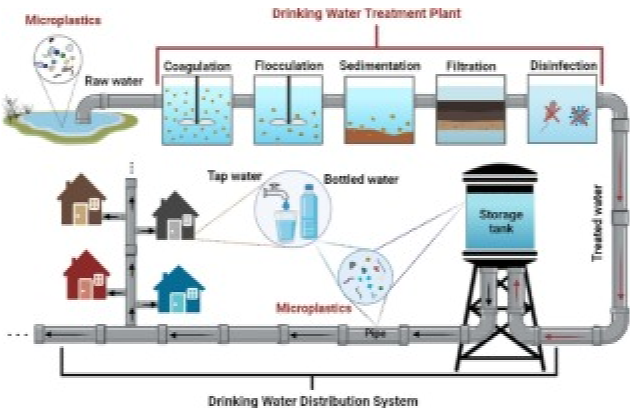
- Studies on the abundance and characteristics (polymer type, size, shape) of microplastics in drinking water are reviewed.
- Influent and effluent of DWTPs, tap water, bottled water and water from refill kiosks are included in this review.
- More research is needed to address microplastic release from drinking water distribution systems to treated water.

- Particularly small size (<10 μm), fiber and fragment shaped MPs dominate in DWTPs, tap water, and bottled water.

Abstract

Limited research studies have revealed the presence of microplastics (MPs) of different polymer types, shapes, and sizes in drinking water sources, influents of drinking water treatment plants (DWTPs), effluents of DWTPs, tap water, and bottled water. Reviewing the available information on MP pollution in waters, which is becoming more worrying in correlation with the increasing plastic production in the world every year, is noteworthy for understanding the current situation, identifying the deficiencies in the studies, and taking the necessary measures for public health as soon as possible. Therefore, this paper, in which the abundance, characteristics, and removal efficiencies of MPs in the processes from raw water to tap water and/or bottled water are reviewed is a guide for dealing with MP pollution in drinking water. In this paper, firstly, the sources of MPs in raw waters are briefly reviewed. In addition, the abundance, and characteristics (polymer type, shape, and size) of MPs in influents and effluents of DWTPs in different countries are reviewed and the effects of treatment stages (coagulation, flocculation, sedimentation, sand filtration, disinfection, and membrane filtration) of DWTPs on MP removal efficiency and the factors that are effective in removal are discussed. Moreover, studies on the factors affecting MP release from drinking water distribution systems (DWDSs) to treated water and the abundance and characteristics of MPs in tap water, bottled water and water from refill kiosks are reviewed. Finally, the deficiencies in the studies dealing with MPs in drinking water are identified and recommendations for future studies are presented.

Graphical abstract



Download: Download high-res image (137KB)

Download: Download full-size image

Introduction

Plastics are widely used today due to their low cost, lightness, easy processing, durability, and flexibility (Kundu et al., 2021). Global plastic production is 390.7 million tons in 2021, of which 90.2% is fossil-based plastics, 8.3% is post-consumer recycled plastics and 1.5% is bio-based/bio-attributed plastics (Plastics Europe, 2022). In addition to the increasing production/consumption of plastic, the weak management of plastic waste in particular causes plastic pollution in the environment, and as a result, concerns about the impact of plastic pollution on the health of humans and other living organisms are growing (Acarer, 2023).

Plastics between 5 mm and 1 μm in size are called microplastics (MPs) (Koelmans et al., 2022) and are divided into two classes according to their source, primary and secondary. Primary MPs are microspheres consciously produced for use in personal care and cosmetics and are mostly made of polyethylene (PE), polypropylene (PP), and polystyrene (PS) (Ju et al., 2021) or raw plastic pellets used for the manufacture of plastic products (Praveena Mangala et al., 2018). Secondary MPs are more irregularly shaped MPs that result from the breakdown of large plastics (such as plastic bags, bottles, packages, ropes, nets, automobile tires, and, synthetic clothes) (Egessa et al., 2020). Primary and secondary MPs in different polymer types (such as PE, PP, PS, PET (polyethylene terephthalate), PVC (polyvinyl chloride)) in different shapes (such as fiber, fragment, film, bead, foam), different colors (transparent or colored), and different sizes (1 μm-5 mm) exist in the waters (Adib et al., 2021; Mukotaka et al., 2021; Sun et al., 2021a; Tong et al., 2020). MPs in drinking water sources adsorb heavy metals (Ta and Babel, 2020), antibiotics (Guo and Wang, 2019), pesticides (Mo et al., 2021), polyaromatic hydrocarbons (PAHs) (Tan et al., 2019), polychlorinated biphenyls (PCBs) (Llorca et al., 2020), bisphenol A (BPA) and its analogues (i.e. bisphenol AF (BPAF), bisphenol B (BPB), bisphenol F (BPF), bisphenol S (BPS)) (Wu et al., 2019) in water through their small size, large surface area and hydrophobic properties (Han et al., 2021) and MPs coexist with the pollutants they adsorb and also affect the distribution of these pollutants in water. Moreover, MPs ingested by living organisms in the aquatic environment accumulate in their bodies and are then transferred to other living organisms through the food chain (Ma and You, 2021), causing toxic effects on organisms with their polymeric structures, adsorbed pollutants, and additives they contain (Li et al., 2021).

In drinking water treatment plants (DWTPs), the main purpose is to make freshwater drinkable in terms of color, odor, and taste, as well as to remove pathogenic microorganisms and harmful substances from the water. MPs in drinking water sources are removed with different efficiency in different treatment units where coagulation, flocculation, sedimentation, sand filtration, disinfection and advanced treatment processes are applied in DWTPs, and therefore DWTPs prevent direct access to consumers of MPs in concentrations as high as raw water contains (Dronjak et al., 2022; Sarkar et al., 2021). However, even though the water passes through different treatment units in DWTPs, DWTPs cannot remove MP with full efficiency (100%) and MPs with different characteristics in the effluents of DWTPs reach consumers through tap water. Depending on the ambient conditions, MPs are released into the water from the pipes, which is one of the components of the Drinking Water Distribution System (DWDS), or the MPs in the water are adsorbed on the pipes (Chu et al., 2022). Bottled waters contain MP due to the packaging (plastic bottle and cap) as well as the preparation process (Weisser et al., 2021). In addition, the type and mechanical strength of the plastic packaging and plastic packaging deformation as a result of mechanical effects during transport, use, and capping may result in the release of more MPs into bottled water (Oßmann et al., 2018; Schymanski et al., 2018).

Compared to the number of studies addressing the abundance, characterization, and removal efficiency of MPs in WWTPs, the number of studies addressing these issues in DWTPs is relatively limited. Since MPs in drinking water pose a potential risk to human health, evaluation of MP abundance, characteristics (polymer type, size, shape), and removal by drinking water treatment processes in influents and effluents of DWTPs allows: (I) to determine the current status/deficiencies of MPs in DWTPs, (II) to develop new treatment strategies for removal and (III) to take necessary measures. For this reason, in this study, firstly, the sources of MPs in surface and ground waters were mentioned, and then the abundance, properties and removal activities of MPs in DWTPs located in different parts of the world were reviewed. MP removal by coagulation-flocculation-sedimentation (CFS), sand filtration, disinfection, and membrane filtration treatment stages in DWTPs are discussed separately. In the next section, an overview of the impact of DWDSs on MP release into water is given. Subsequently, studies examining the abundance and characteristics of MPs in tap water and bottled water are reviewed. Finally, deficiencies in the studies on MPs in drinking water are presented and recommendations for future studies are presented.

Section snippets

Sources of microplastics in the influents of DWTPs

The presence of MPs in drinking water sources (surface waters and groundwater) has been proven in some studies (Ferraz et al., 2020; Negrete Velasco et al., 2022). Surface water sources contain MP from the breakdown of plastic waste, discharge of domestic/industrial wastewater treated in WWTPs and untreated domestic/industrial wastewater into receiving environments (Franco et al., 2021), atmospheric deposition (Dris et al., 2015), and surface runoff (He et al., 2022). Especially in WWTPs where…

Coagulation/flocculation/sedimentation

In the coagulation/flocculation process, by adding chemicals to the water, the non-settled colloids and suspended solids in the water are brought together and converted into flocs (Katrivesis et al., 2019). The flocs obtained by coagulation/flocculation are settled and separated from the water. Aluminum and iron salts are commonly used coagulants in DWTPs (Poleneni et al., 2019). It has been reported that aluminum (Al) salts perform better than iron (Fe) salts in removing PE and PS MPs from…

Microplastics in drinking water distribution systems

DWDSs connect DWTPs to consumer taps and consist of pipes, storage tanks, pumps, and valves (National Research Council, 2006). Steel, cast iron, and plastic (PVC and high-density polyethylene (HDPE)) pipes are generally used in DWDSs (Hajibabaei et al., 2018; Mintenig et al., 2019). Gomiero et al. (2021) found the abundance of MPs$\geq 1\,\mu m$ in raw water, outflow of the water treatment plant, pressurization station, and hydrant to be 93.2, 9.7, 12.8, and $6.1\,\mu g/m^3$, respectively. In the study of …

Microplastics in tap water

Since the MPs in the water cannot be completely removed during the treatment of fresh waters containing MP with DWTPs, the drinking waters obtained from these waters contain MP. In addition, as mentioned in Section 4, MP may be released from DWDS to the water depending on the structure of the materials used in DWDS and/or environmental conditions during the process until the water treated in DWTP reaches the tap via DWDS.

Humans are exposed to MPs through ingestion, inhalation, and dermal…

Limitations and recommendations for future research

Since the methods, devices, and detection limits of the devices used in studies reporting MP abundance in raw water (influent of DWTPs), treatment stages, and effluent of DWTPs, tap water, and bottled water are quite different from each other, the results of the studies cannot be directly compared with each other. For instance, different stains such as Nile Red and Rose Bengal are used for the microscopic detection of MPs (Abdulmalik Ali, 2019; Kosuth et al., 2018). Staining of MPs takes less…

Conclusion

MPs of different polymer types, sizes, and shapes, which are present in raw water from drinking water, as a result of the effect of different sources, reach the influent of DWTPs. Conventional DWTPs cannot completely remove MPs from treated water, as DWTPs are not designed solely and specifically consider the removal of MPs. The literature analysis showed that MPs in fiber form, smaller than 10μm in size and polymer types PE, PP, PET, PS, PVC, and PA predominate in influents and effluents of…

CRediT authorship contribution statement

Seren Acarer: Conceptualization, Investigation, Writing - Original Draft, Writing- Review & Editing and Visualization. Seren Acarer contributed 100% to this manuscript.…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

Recommended articles

References (104)

D. Castagnetti *et al.*

Effect of chlorinated water on the oxidative resistance and the mechanical strength of polyethylene pipes

Polym. Test. (2011)

X. Chu *et al.*

Occurrence and distribution of microplastics in water supply systems : in water and pipe scales

Sci. Total Environ. (2022)

K. Conley *et al.*

Wastewater treatment plants as a source of microplastics to an urban estuary : removal efficiencies and loading per capita over one year

Water Res. X (2019)

R. Dris *et al.*

Synthetic fibers in atmospheric fallout : a source of microplastics in the environment ?

Mar. Pollut. Bull. (2016)

L. Dronjak *et al.*

Screening of microplastics in water and sludge lines of a drinking water treatment plant in CataloniaSpain

Water Research (2022)

A.A. Franco *et al.*

Microplastic pollution in wastewater treatment plants in the city of Cádiz : abundance, removal ef fi ciency and presence in receiving water body

Sci. Total Environ. (2021)

X. Gan *et al.*

Impacts on characteristics and effluent safety of PVDF ultrafiltration membranes aged by different chemical cleaning types

J. Membr. Sci. (2021)

A. Gomiero *et al.*

Application of GCMS-pyrolysis to estimate the levels of microplastics in a drinking water supply system

J. Hazard. Mater. (2021)

X. Guo *et al.*

Sorption of antibiotics onto aged microplastics in freshwater and seawater

Mar. Pollut. Bull. (2019)

M. Hajibabaei *et al.*

Life cycle assessment of pipes and piping process in drinking water distribution networks to reduce environmental impact

Sustain. Cities Soc. (2018)

View more references

Cited by (32)

The impact of microplastics on the efficacy of urban wastewater treatment processes

2024, Journal of Environmental Chemical Engineering

Show abstract

First occurrence and risk assessment of microplastics in enteral nutrition formulas

2024, Food and Chemical Toxicology

Show abstract

Microplastics in landfill leachate: Sources, abundance, characteristics, remediation approaches and future perspective

2024, Desalination and Water Treatment

Show abstract

A review on cigarette butts: Environmental abundance, characterization, and toxic pollutants released into water from cigarette butts

2024, Science of the Total Environment

Show abstract

A systematic review of microplastics emissions in kitchens: Understanding the links with diseases in daily life

2024, Environment International

Show abstract

Biotechnological advancements in microplastics degradation in drinking water: Current insights and Future perspectives

2024, Case Studies in Chemical and Environmental Engineering

Show abstract

View all citing articles on Scopus ↗

View full text