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Review

Insights into Anthropogenic Micro- and Nanoplastics Accumulation in Drinking Water Sources and Their Potential Effects on Human Health

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Abstract:

Currently, anthropogenic microplastics (MPs) and nanoplastics (NPs) are ubiquitous pollutants found in aquatic, food, soil and air environments. Recently, drinking water for human consumption has been considered a significant pathway for ingestion of such plastic pollutants. Most of the analytical methods developed for detection and identification of MPs have been established for particles with sizes > 10 μm, but new analytical approaches are required to identify NPs below 1 μm. This review aims to evaluate the latest information on the exposure to MPs and NPs through daily human consumption of water, particularly drinking tap water and commercial bottled water, and their potential dermal, inhalation and ingestion effects on human health. Emerging technologies used to remove MPs and/or NPs from drinking water sources and their advantages and limitations were also assessed. The main findings showed that the MPs with sizes > 10 μm were completely removed from drinking water treatment plants (DWTPs); the smallest NP identified by using pyrolysis gas chromatography mass spectrometry (Pyr-GC/MS) has a diameter of 58 nm; contamination with MPs/NPs can occur along the distribution network to tap water consumers, when opening and closing the screw cap or using recycled plastic or glass bottles. To conclude, this comprehensive study highlights the importance of a unified approach to detect MPs and NPs in drinking water, as well as raising the awareness of regulators, policy makers and the public about the impact of these pollutants, which pose a human health risk.

Keywords: drinking water treatment plant; microplastics; nanoplastics; tap water; bottled water; quantification; toxicological effect

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Table S1. Physico-chemical methods used to remove MPs/NPs from drinking water.

Sample	MPs/NPs Characteristics	Method Used	Efficiency of MPs/NPs Removal	Ref.
Water spiked with fluorescent plastic PE and PS (beads)	PE: 10–20 μm, 45–53 μm, and 106–125 μm; PS: 180 nm and 1.2 μm	CFS and filtration Alum ($Al_2(SO_4)_3$; PolyDADMAC	CFS: the removal rate increased in the case of polyDADMAC; Filtration: 86.9% ± 4.9% and 99.9% ± 0.1% removal for particles sizes up to 106 μm and in the range of 106–125 μm, respectively	[1]
Water spiked with PS NPs	Molecular weight (MW) of 8 × 10^5 Da Concentration of 2.5 μg/L Initial pH of 6.43 ± 0.03	Ozonation and chlorination (sodium hypochlorite, 12.5% Cl_2 by weight)	Achievements after 240 min reaction: 99.9% MW degradation and 42.7% mineralization by ozonation, 7.1% MW degradation and 4.3% mineralization in the case of chlorination	[2]
NPs (17 mg/L) containing a PAN core labeled with palladium (Pd) and a PS shell in drinking water	Hydrodynamic diameter (Z-average) of 214.7 nm ± 1.4 nm (polydispersity index: 0.07) and zeta (ζ-potential) of − 41.1 mV ± 0.3 mV (from first synthesis batch)	Ozonation (1.15 mM), sand and activated carbon (AC) filtration	Application of ozonation treatments at concentrations of 0.5, 1 and 5 mg/L, respectively, for 45 min had a minor impact on NPs removal; NPs retention increased with filter length; a sand filter length of 0.1 m and 0.9 m led to NPs removal of 70% and 99.5%, respectively; NPs retention was slow (10%) in the case an AC filter with an initial filter length of 0.9 m	[3]
Positively charged PS NPs hydrazine (PS NPs (PS-NH-NH_2^+) in water	Concentration of 4.6 g/L, mean diameter of 124 ± 38 nm (measured by NTA) and 110 ± 25 nm (estimated by SEM)	Filtration Coagulation	GAG filtration: 73.9% ± 2.3% removal efficiency Sand filtration: 54.3% ± 3.1% removal efficiency Overall filtration: 88.1% ± 2.1% removal efficiency The use of PACl resulted in the increase in the removal of NPs to 99.4% ± 1.1%	[4]
DWTP from Catalonia, Spain	Outlet, concentration of 0.06 ± 0.04 MPs/L; Inlet, concentration of 0.96 ± 0.46 MPs/L; Particle size of MPs between 20 μm–5000 μm, PS and PES are the main polymers types detected by μ-FTIR	Coagulation and sand filtration	93% ± 5% overall removal efficiency	[5]

DWTP, India	MPs were reduced from 17.86 ± 2.66 items/L in the case of raw water to 2.75 ± 0.92 items/ L for treated water (evidenced by ATR FT-IR); Fibers and films/fragments were predominant	Pre-disinfection, coagulation-flocculation, pulse clarification, sand filtration and post-disinfection	85% removal efficiency	[6]
DWTP, Geneva, Switzerland	MPs sizes: 63 to 1 000 μm; 0 and 4 MPs/m^3 and 0 to 3 synthetic fibers/m^3 were found in water; PA, PE, PES, PMMA, PP, PS, PVA and PEVA were the identified MPs	Pre-treatment, sand filtration, activated carbon filtration and pH correction; PACl with a concentration of 0.36 mg Al^{3+}/L was used as coagulant	Coagulant presence led to a higher efficiency of 97% ± 3% and 96% for MPs and synthetic fibers removal, respectively, compared to sand filtration	[7]
Advanced DWTP located in Yangtze River Delta, China	MPs >10 um were removed in coagulation/sedimentation PET, PE, PP, PAM, PS, PVC were the identified MPs	Coagulation/flocculation, sedimentation, sand filtration and ozonation integrated with GAC filtration	Overall eficiency of 82.1–88.6% Fibers (51.6–78.9%) and fragments (14.4–38.3%) were the predominant shapes of MPs	[8]

Polyethylene (PE), diallyldimethylammonium chloride (PolyDADMAC), poly(acrylonitrile) (PAN), palladium (Pd), nanoparticles tracking analysis (NTA), scanning electron microscopy (SEM), polyaluminum chloride (PACl), polyester (PES), poly(methyl methacrylate) (PMMA), polypropylene (PP), poly(vinyl alcohol) (PVA), ethylene (vinyl acetate) copolymer (PEVA), polyacrylamide (PAM).

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