Investigating the spatial and temporal patterns of microplastics in the Fraser River and Burrard Inlet (British Columbia, Canada)

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Abstract

In the absence of long-term monitoring, microplastics have become the forefront of concern regarding the health and well-being of major marine ecosystems. Despite their persistence and potential impacts, few investigations exist on the spatial and temporal variability of microplastics in aquatic environments, including highly dynamic riverine systems and shallow-sided marine fjords, such as those in British Columbia (BC). To address these concerns, we targeted sampling at multiple depths in the Fraser River and Burrard Inlet, two receiving water bodies in BC with a variety of microplastic sources. We built a multichannel sampling apparatus and utilized McLane large-volume pumps to investigate the vertical distribution of microplastics (≥50 µm) in the Fraser River and Burrard Inlet. A novel extraction method was developed to advance the ability to quantify microplastics from such organic-rich and brackish environmental matrices. We found that microplastic (MP) concentrations were significantly higher in Burrard Inlet (64.5 ± 27.7 particles · m^{-3}) than in the Fraser River (22.8 ± 19.7 particles · m^{-3}) (p-value < 0.05). Significant differences (p < 0.05) were revealed across depths in Burrard Inlet (0.5, 30, and 60 m), with the mid-depth layer (30 m) showing the highest concentration (68.6 ± 42.0 particles · m^{-3}) and greatest variability over the sampling period (CV = 0.613). No seasonal trends were found. FTIR analyses revealed that microplastics (MPs) ≥50 µm were dominant in both regions, with PET and PE being the most common polymers at the surface, while POM and PP were more prevalent at depth in Burrard Inlet and the Fraser River, respectively. This monthly, multi-depth, one-year time series will help broaden our understanding of the sources, dispersion, and distribution of microplastics in BC.

Introduction

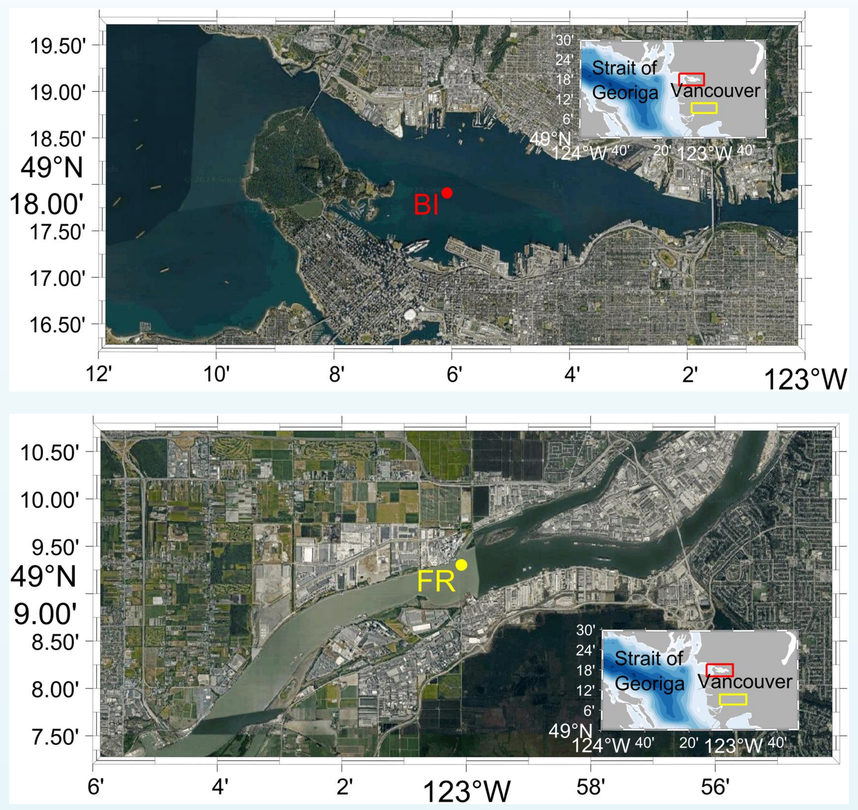

Figure 1. Microplastic sampling sites within the Greater Vancouver Region of British Columbia. The top map indicates Burrard Inlet (BI), and the bottom map the Fraser River (FR).

Microplastics (MPs; <5 mm) enter the ocean through various pathways: river runoff, wastewater treatment plant (WWTP) effluent, combined sewer overflows (CSOs), and atmospheric deposition. MP accumulation is influenced by distribution pathways, waste management practices, and local population size. Limited studies have conducted long-term water column sampling to investigate spatial variations and seasonal trends in fjord-like and riverine environments. Monthly sample collections (between Jan 2024 to Dec 2024) of MPs throughout the water column of Burrard Inlet and the Fraser River will enable us to compare values between sites and investigate dominant size classes, morphologies, and polymer types of anthropogenic MPs.

Sample Collection

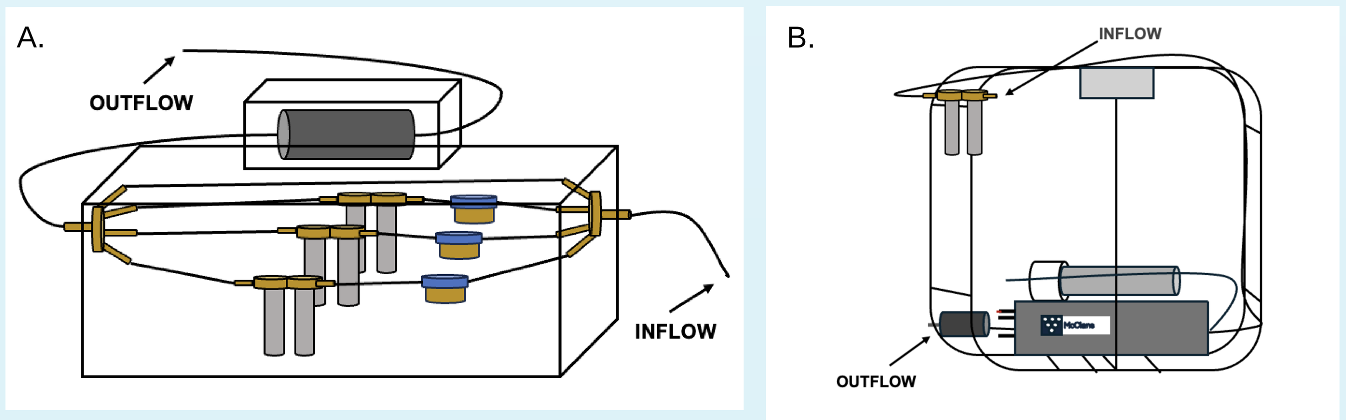

Figure 2. An engineered multi-channel, sequential filtration (500 and 50 µm pore size) system is designed to sample at all depths (0.5 m and 6 m) in the Fraser River and near-surface waters (0.5 m) in Burrard Inlet (A). Adapted McLane LVPs with sequential candlestick filters are utilized to filter at depths (30 m and 60 m) in Burrard Inlet (B).

Methodology

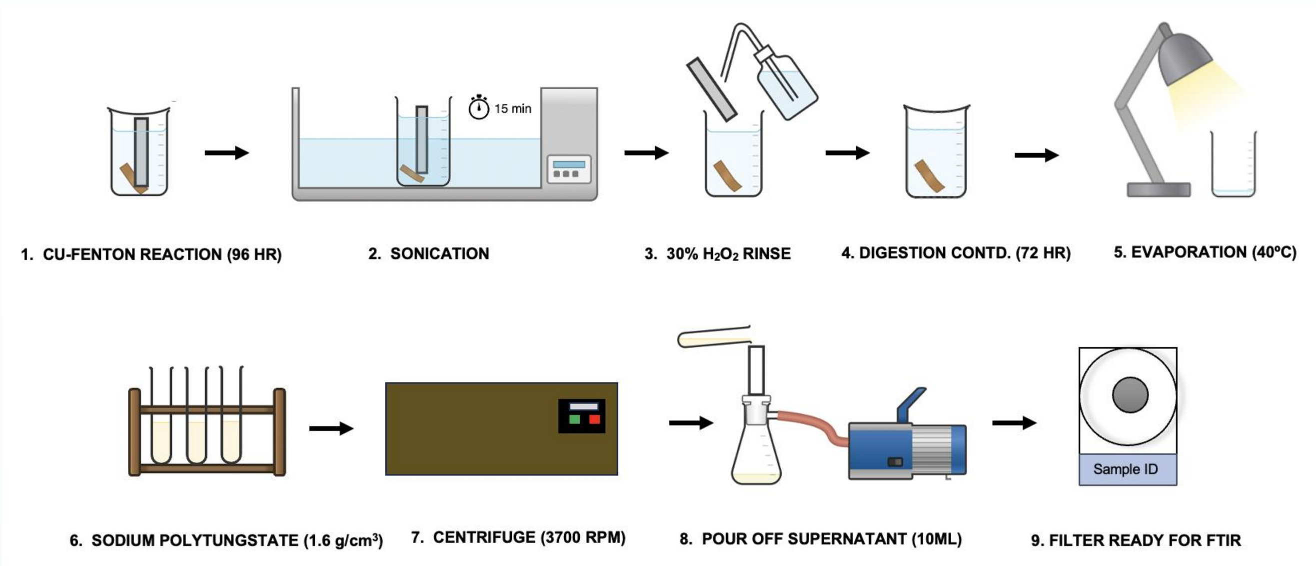

Figure 3. General stepwise method for processing seawater and freshwater samples for microplastics. Size fractions (500 and 50 µm pore size) were combined for each sample during processing and filtered onto 25 µm silicon filters for FTIR analysis.

Microplastic Concentrations

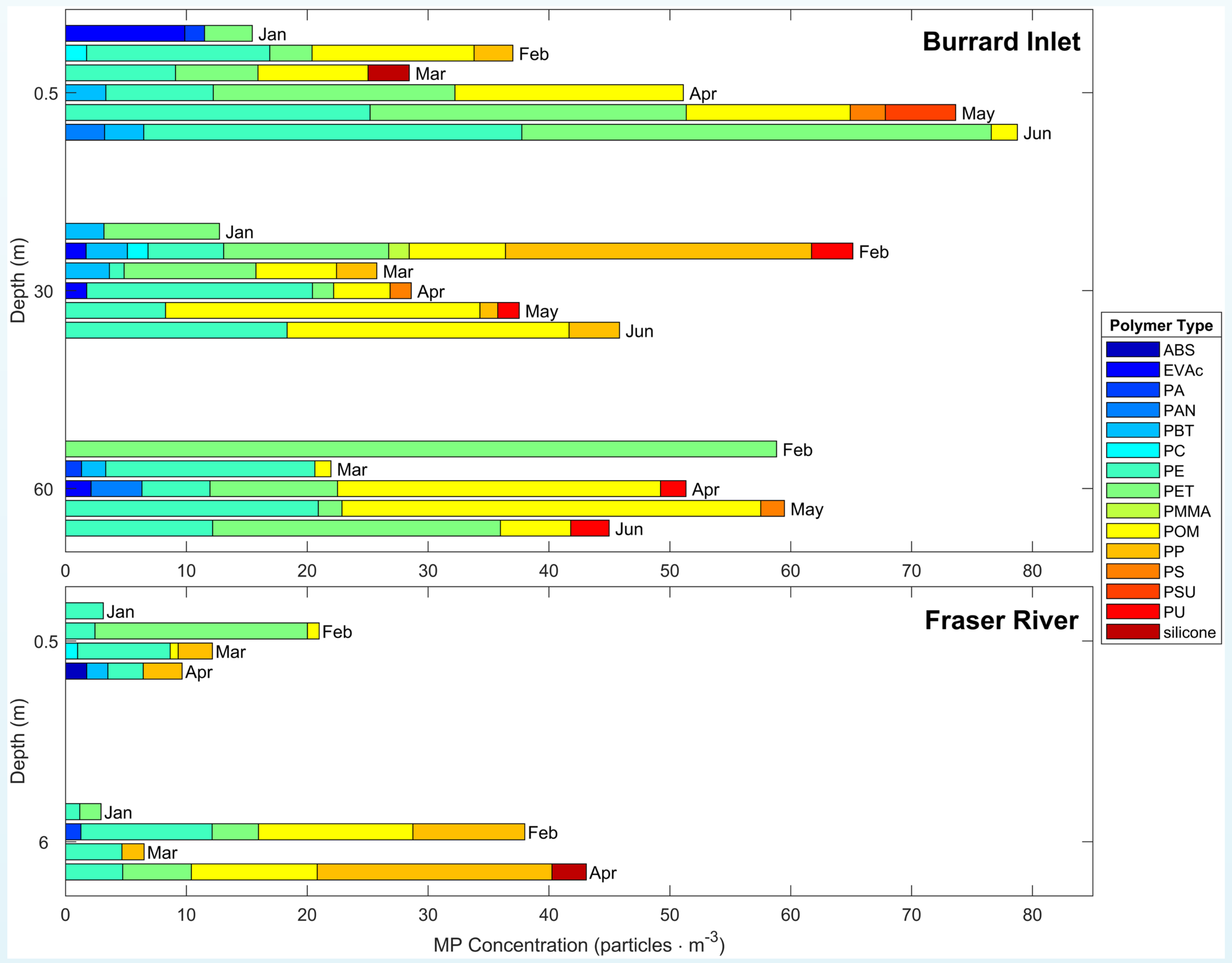

Figure 4. Vertical gradient of MP concentrations ≥50 µm in Burrard Inlet (at depths 0.5m, 30m, and 60m) and the Fraser River (at depths 0.5m and 6m). Abbreviated month samples are located at the end of each bar. The polymer composition is represented within the total concentration.

Results

- MP concentrations were averaged across depths and months to reflect seasonal and spatial variability. The total average concentration of Burrard Inlet (64.5 ± 27.7 particles · m^{-3}) was significantly higher than in the Fraser River (22.8 ± 19.7 particles · m^{-3}) (t-test, p-value: < 0.05).
- There is a statistically significant difference among depths (0.5, 30, and 60 m) in Burrard Inlet (surface: 67.2 ± 11.7 particles · m^{-3}; mid-depth: 68.6 ± 42.0 particles · m^{-3}; deep: 56.3 ± 18.9 particles · m^{-3}) (ANOVA, p-value: < 0.05).
- The mid-depth layer (30 m) in Burrard Inlet exhibited the greatest variability in microplastic concentrations (68.6 ± 42.0 particles · m^{-3}) based on the coefficient of variation (CV = 0.613).
- MP concentrations were not significantly different among depths in the Fraser River (surface: 14.9 ± 8.8 particles · m^{-3}; mid-depth: 30.7 ± 25.8 particles · m^{-3}) (t-test, p-value: > 0.05).
- The average MP concentrations for Winter, Spring, and Summer were not significantly different in Burrard (ANOVA, p-value: > 0.05) nor the Fraser River (p-value: > 0.05).
- FTIR analyses established that MPs ≥50 µm in diameter represented the vast majority of microplastics in Burrard (65.2%) and the Frazer River (73.87%).
- In the surface waters of the Fraser River, the dominant polymers are PET (38.26%), PE (35.18%), and PP (13.17%). With increasing depth PP (33.70%), POM (25.61%), and PE (23.68%) become dominant.
- In the surface waters of Burrard Inlet, the dominant polymers are PET (34.90%), PE (31.51%), and POM (20.08%). With increasing depth POM (31.84%) becomes more abundant.

Conclusions

Few studies have focused on vertical profiles of suspended microplastics in riverine and fjord-like environments, or long-term sampling to investigate seasonal trends and spatial variations. Many are limited to surface waters and floating plastic debris[1]. MP abundance in the Fraser River (22.8 ± 19.7 particles · m^{-3}) is within the error of a previous study in this river conducted in 2021 by Parizi[2] (13.6 ± 5.8 particles · m^{-3}) and is comparable to other regions, such as the Putney and Greenwich Rivers[3] (28.9 - 44.5 particles · m^{-3}) and the Chicago River[4] (1.9 - 18 particles · m^{-3}).

However, we found significant differences among depths in Burrard Inlet (surface: 67.2 ± 11.7 particles · m^{-3}; mid-depth: 68.6 ± 42.0 particles · m^{-3}; deep: 56.3 ± 18.9 particles · m^{-3}) (ANOVA, p-value < 0.05), more specifically between mid and deep depths (Tukey HSD, p = 0.03). In the North Sea Strait, no significant difference in MP concentrations among depths was found (surface: 18-87 particles · m^{-3}; mid-depth: 16-157 particles · m^{-3}; deep: 13-95 particles · m^{-3}) (Kruskal-Wallis Test, p > 0.5)[5]. In contrast, in the semi-enclosed bays and coastal zones of South Korea, MP concentrations were reported highest at the surface (1736 particles · m^{-3}) relative to deeper depths (mid-depth: 423 particles · m^{-3}; deep: 394 particles · m^{-3})[6]. This suggests the vertical distribution of microplastics in such dynamic fjord-like environments is highly complex and variable.

The greatest variability and abundance of MP was found at 30m in Burrard Inlet (68.6 ± 42.0 particles · m^{-3}). Similarly, in the Netravathi-Gurupura estuary of Southwest India, MP abundance increased with depth and was highest at mid-depth (8,620 ± 363 particles · m^{-3}; vs. deep depth: 939 ± 402 particles · m^{-3})[7]. Vertical variations of MP in the subsurface of Burrard Inlet may be due to physical factors such as tidal mixing, wind, wind-driven currents, geostrophic circulation, and changes to flow velocity[5]. Additionally, this may be due to changes in biological activity such as the spring phytoplankton bloom which can increase the export of plastics to the deep through increased biofilm growth and the release of fecal pellets[6,8].

There is a difference in low-density and high-density polymers throughout the water column at both stations. Polyoxymethylene (POM) (ρ = 1.39-1.42 g/cm³), denser than seawater—and widely used in automotive and mechanical industries, electronics, consumer goods, and home appliances[9]—is abundant with increasing depth of Burrard, as may be expected[11]. Interestingly, polyethylene terephthalate (PET) in Burrard Inlet and polypropylene (PP) in the Fraser River do not follow the expected density gradient. The PET (ρ = 1.38-1.39 g/cm) found at the surface of Burrard may indicate source contributions of urban dust from Vancouver, changes in biological activity such as the removal of biofilms by the active foraging activity of marine organisms, or turbulent hydrodynamic conditions all of which can result in the reappearance of microplastics on the water surface[10]. The PP (ρ = 0.85-0.92 g/cm³) at depth in the Fraser River could suggest particle aggregation or a deeper source such as the nearby plume from the Annacis wastewater treatment plant.

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