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Microplastics in municipal water: analysing variations in contamination in a Lowveld city, South Africa

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Abstract
There are some concerns regarding the presence of microplastics in drinking water, and thus, the potential effects of this on human health. This study assessed water quality and the occurrence and distribution of microplastics in municipal drinking water across different locations within Nelspruit, South Africa. Furthermore, variations in microplastic types and plastic polymers were analysed, along with household tap aerator cleaning frequency and water consumption patterns. Microplastics were classified by colour and type, and their polymer composition was verified using a Fourier Transform Infrared Spectrometer (FTIR). Study findings showed no significant association between water quality and aerator maintenance and water quality and municipal water consumption patterns amongst locations. However, a weak negative correlation was observed between fibre microplastics and household faucet aerator cleaning frequency, suggesting that less frequent cleaning may contribute to higher microplastic fibre accumulation in municipal treated water. Diversity indices revealed low variability in microplastic distribution, indicating relatively uniform contamination levels across the study area. Fragments and/or fibres were the most dominant microplastics identified among the different localities. Low–density polyethylene (LDPE), high–density polyethylene (HDPE), and ethylene propylene diene terpolymer (EPDM), were the most commonly detected polymers and were evenly distributed. The occurrence of microplastics in drinking water could, in part, be attributed to the poor water treatment methods, employed by the contracted water services provider, in capturing and removing microscopic particles. Additionally, less frequent aerator cleaning may also contribute towards increased microplastic accumulation in municipal treated water, subsequently exacerbating microplastic contamination in drinking water systems. These findings indicate the need for further evaluation of the water treatment processes and the importance of routine faucet aerator maintenance to minimise household microplastic exposure. In addition, the findings provide an important baseline information on microplastic presence in drinking water of African systems.

Keywords Faucet aerator, Fourier–transform infrared spectrometer, Microplastics, Drinking water treatment plants, Nelspruit, Faucet aerators

1 Introduction

There has been widespread attention regarding microplastics, and their potential effects on the environment and human health [1, 2]. Specifically, Oladoja and Unuabonah (2021) have highlighted the potential effects of microplastic pollution in freshwater systems and the consequent health–related implications for aquatic biota and humans. Microplastics can be ingested by humans through contaminated food and water, with drinking water being a major route of exposure. Studies (e.g., [3, 4]) estimate that individuals in the Global South consume approximately 4.26 microplastic particles per litre of drinking water, equating to over 3000 particles annually. Microplastics are defined as plastic particles smaller than 5 mm, and are categorised as either primary microplastics, which are manufactured as small particles, or secondary microplastics, which result from the breakdown of large sized plastic debris [5–7]. Recently, studies have detected microplastics in both marine [8–10] and freshwater [5, 11–13] environments. They enter aquatic systems through various pathways, including wastewater treatment plants (WWTP), urban stormwater/runoff, agricultural runoff, landfill leachate, and atmospheric deposition [5, 14]. Because of their low density and hydrophobic nature, they are highly mobile and are able to spread widely through water currents, thus, causing widespread water contamination [15, 16].

Contaminated water sources, such as rivers and reservoirs, contribute significantly to microplastic pollution in drinking water [17, 18]. Conventional drinking water treatment plants (DWTP) are not designed to remove microplastics effectively, and various studies (e.g., [13, 19–21]) have detected microplastics in treated water distribution networks. While a number of microplastics could be attributed to limitations of DWTP in capturing and removing them [21–24], aging infrastructure can also account for the presence of microplastics in some instances [25]. The wear and tear of plastic pipes within the distribution systems could lead to drinking water contamination with microplastics [25, 26]. Thus, it is important to assess the fate of microplastic post DWTPs, and specifically, at the consumption interface, which includes both physical interfaces (e.g., household fixtures, industrial and agricultural systems, public access points) and digital and smart interfaces (e.g., smart water meters, IoT-based water management systems).

The human health risks associated with microplastic ingestion are significant as these particles can accumulate in the gastrointestinal tract, causing inflammation, metabolic disruptions, and potential carcinogenic effects [26, 27]. Small microplastics (<150 µm) can penetrate cells and tissues, leading to chronic inflammation, hormonal disruptions, and even infertility [28, 29]. Furthermore, microplastics can act as carriers of toxic metals, microbes and pesticides which can cause various health complications in humans [30].

While both the Global North and South are affected by microplastic contamination in drinking water, the extent and nature of exposure can vary significantly. The Global North benefits from more advanced treatment facilities and regulatory measures yet may still contend with undetected finer particles. While there has been extensive research on the presence of microplastics in water systems, health and food items (e.g., [17, 31, 32]), studies that examine microplastics in drinking water are particularly limited within the Global South [26]. Even fewer studies (e.g., [28, 33, 34]) have investigated plastic contamination in the Global South drinking water systems and its potential health implications. The Global South, facing infrastructural and resource constraints, may experience higher contamination levels, though comprehensive data is lacking. Addressing this issue globally necessitates collaborative efforts to enhance water treatment technologies, establish standardized monitoring protocols, and implement effective waste management practices to mitigate microplastic pollution [35]. Hence, there is a need to better understand the occurrence, distribution and the potential human health implications of microplastics in drinking water.

The Crocodile River in the Mpumalanga province of South Africa acts as a reliable source of drinking water for the residents of City of Nelspruit (Mbombela), the capital of Mpumalanga Province, and is one of the rivers impacted by wastewater discharge and non–point sources of contamination [11, 12, 36–38]. The river is heavily affected by plastic pollution, and thus, has significant levels of macro– and microplastics loads that continuously contaminate drinking water sources [39, 40]. Microplastics enter the Crocodile River through urban runoff, industrial discharge, and improper waste disposal [11],Tatenda Dalu, *personal observation*). Despite the documented plastic pollution in the Crocodile River [39], no study has at present assessed the occurrence and distribution of microplastics post–water treatment for Nelspruit's drinking water.

The city's water is treated and distributed after undergoing various water treatment methods including coagulation, sedimentation, filtration, and disinfection (https://www.silulumanzi.com/water–processes). While these are common and standard water treat ment methods, their efficacy in capturing and removing microscopic particles, including microplastics, remain uncertain. Therefore, this study aimed to assess the distribution and presence of microplastics at the water consumption interface (i.e., municipal treated water) across the Nelspruit region and the surrounding areas, in order to better understand microplastic abundances and distribution with potential implications for human health. To achieve this, the study analysed the water consumption patterns of residents in the Nelspruit area and assessed the occurrence and distribution of microplastics in municipal treated water at household level among different localities within the City of Nelspruit and surrounding region. We hypothesised that microplastics will be present in high concentrations among household municipal treated water in various Nelspruit localities, with microplastic abundances influenced by the frequency of cleaning the faucet aerators. Findings from this study have the potential to contribute towards developing risk assessments and mitigation strategies for microplastic contamination and would help in protecting public health.

2 Materials and methods

2.1 Ethical consideration

Ethics approval was granted by the School of Biology and Environmental Sciences Research Ethics Committee of the University of Mpumalanga, ethics number: UMP/Xozumti220697809/BIO/BScHons/2024/1. An informed consent form was issued to all respondents before the commencement of the sampling process, with all respondents signing the consent form agreeing to carrying out of study and further having their drinking tap water faucet aerator assessed for microplastics. The consent form explained the research purpose and highlighted the significance of the respondents' participation in achieving the aims of the study. The respondents were allowed to withdraw at any point during the questionnaire interview, and their anonymity and confidentiality was ensured for those who proceeded with the study.

2.2 Study area

Nelspruit is the capital city of Mpumalanga province, South Africa. It is located within the lowveld region, in the northeastern part of the country. Nelspruit is 680 m above sea level, and forms part of the Mbombela Local Municipality [41]. The city covers an area of 72.63 km^2, with an estimated population of 58,672 people in 2011 to an estimated 159,549 people in 2024 (https://www.statssa.gov.za/?page_id=4286&id=11726). The City of Nelspruit is highly reliant upon water abstracted from the Crocodile River for domestic and industrial purposes [11]. Many of these households receive treated drinking water daily from local municipality. Nelspruit has a tropical savannah climate with warm, subtropical temperatures and high summer rainfall, and its temperatures during summer range between 16 °C and 27 °C, to 10 °C and 26 °C during the winter. The study area receives a mean annual rainfall of 667 mm per year, with generally wet summer, with mean rainfall of 400 mm [39]. Nelspruit is delineated into various zones of different socio–economic statuses and functions. It consists of low–income areas that include Nelsville, KaMagugu and Mataffin, middle–income such as West Acres, and wealthier neighbourhoods such as Sonheuwel and Steiltes [42].

Water samples were collected from a total of 97 households from the City of Nelspruit and the surrounding areas. All these households receive municipal drinking water and were categorised/delineated into one of the 8 localities: local university ($n = 60$), Nelsville ($n = 8$), KaMagugu ($n = 8$), Sonheuwel ($n = 4$), Stonehenge ($n = 3$), Steiltes ($n = 3$), West Acres ($n = 5$), and the areas surrounding Nelspruit that also receive water from the same service provider were categorised as "outside Nelspruit" ($n = 6$). Surveys were conducted between June and August 2024, when there was little to no rainfall.

2.3 Social component

A total of 97 questionnaires were administered to homeowners/caretakers, with the questionnaire consisting of open–ended and close–ended questions. The questionnaire had seven questions and required the general area in which the residence was located, the cleaning frequency of the faucet aerator in their municipal treated water tap, the number of years they had been residing in their home, a rating of the drinking water quality from their tap based on Lickert scale of 1 (very poor) to 5 (excellent), the number of residents living in the household and if they municipal treated water, and experienced water issues and other observations regarding their municipal treated water. The cleaning frequency of faucet aerators in Nelspruit households was categorised based on residents' cleaning habits: those who never clean their aerators, those who clean them rarely (i.e., when broken), and those who can clean them regularly (i.e. annually, in two–month intervals, quarterly, bi–weekly, three times in a year, monthly, and in two–day intervals).

2.4 Household water tap faucet aerators sampling

Household water tap faucet aerators' samples were obtained, through a systematic random sampling method, from 97 households in Nelspruit (i.e., KaMagugu, Nelsville, Sonheuwel, Steiltes, Stonehenge, local university, West Acres) and outside Nelspruit group. The systematic random sampling approach employed ensured that residents with different socioeconomic backgrounds were represented. This is particularly important since different households would have different strategies regarding the cleaning and replacing the household water tap faucet aerators, most related/influenced by affordability.

The faucet aerator component traps smallest particles transported from the water treatment plant or storage tanks through the treated water distribution network (Upgraded [43]). For faucet aerator removal instructions and sample collection, see Text S1. After the removal, the faucet aerators were rinsed using water from the household tap into a sterile 60 mL polypropylene container to collect the residue present on the aerator. Collected samples were temporarily stored in labelled individual Ziplock bags before being transported to the University of Mpumalanga's Aquatic Systems Research Laboratory for further analysis.

2.5 Sample preparation (filtration) and microplastic extraction

Before laboratory analyses, the air–conditioning in the laboratory was switched off to prevent airborne microplastic contamination. Samples were filtered through a mixed cellulose membrane (MCE) filter (diameter 47 mm, mesh size 0.45 µm), with distilled water being used to rinse particles stuck on the containers and vacuum filtration unit. This was done to ensure that all possible microplastics were captured by the membrane filter. After filtration, the membrane filter was transferred to a labelled petri–dish, which was immediately closed to prevent airborne microplastic contamination and left to air dry for 72 h before identification and quantification of all microplastic present.

2.6 Quantification of plastic particles

After extraction, the samples were identified and quantified using an Olympus compound light microscope at × 200 magnification. Any potential microplastics were analysed and categorised according to their colour (i.e., black, blue, green, orange, pink/red, white, yellow, translucent/transparent, and other) and shape (i.e., beads, fibres, film, foam, fragments) following methods highlighted in Dalu et al. [12] and Nkosi et al. [39]. Particles were identified as microplastics if they displayed artificial colouration (i.e., bright or multi–coloured), and/or unnatural shapes (i.e., sharp edges or perfectly spherical shapes) [12]. A compact Fourier Transform Infrared Spectrometer (FTIR) ALPHA II (Bruker Nano GmbH, Berlin, Germany) was used for the polymer characterisation of potential microplastics identified under the microscope.

2.7 Data analyses

Microsoft Excel was used to capture the questionnaire survey and microplastic quantification data, which was analysed on the IBM SPSS Statistics version 25 software. Chi–square tests were used to determine differences in cleaning frequencies of the faucet aerator, rating of the drinking water quality, and water quality issues. A one–way ANOVA was performed to analyse microplastic types, colours, and diversity indices across different localities.

The study analysed microplastic particles in samples by calculating γ-diversity (total particle 'species' per sample) and α-diversity (particle 'species' per household water tap, representing within-habitat diversity; [44]). Whittaker β-diversity was used to measure particle 'species' turnover within locations, calculated as $\beta W = \gamma/\text{mean } \alpha$ (Koleff et al., 2003). The Shannon–Wiener diversity index and evenness were also computed for microplastics (see [45]). Additionally, a Pearson correlation analysis explored relationships between microplastic types, faucet aerator cleaning frequency, and home age.

3 Results

3.1 Water consumption patterns and household tap faucet cleaning frequency

There were variations in proportions of residents reliant on municipal water for each locality; the local university (86.7%), Steiltes (66.7%), outside Nelspruit (66.7%), West Acres (60.0%), Stonehenge (33.3%), and Sonheuwel (75.0%) (Fig. 1a). Residents of KaMagugu and Nelsville, sampled in the present study, were entirely reliant on municipal for drinking water. Using Chi–Square tests, we observed significant differences ($\chi^2 = 3.781$, df = 7, $p = 0.014$) in patterns in terms of water consumption for municipal and store–bought water, with more residents drinking municipal water. Outside Nelspruit (100%), Stonehenge (100%), local university (86.7%), Steiltes (66.7%), KaMagugu (62.5%) and Nelsville (62.5%) had a high proportion of residents who never cleaned faucet aerators, with West Acres (60%) having high cleaning frequencies of faucet aerators (Fig. 1b). We observed no significant differences ($\chi^2 = 11.947$, df = 7, $p = 0.102$) in proportion of residences that clean their household tap faucets among the different localities.

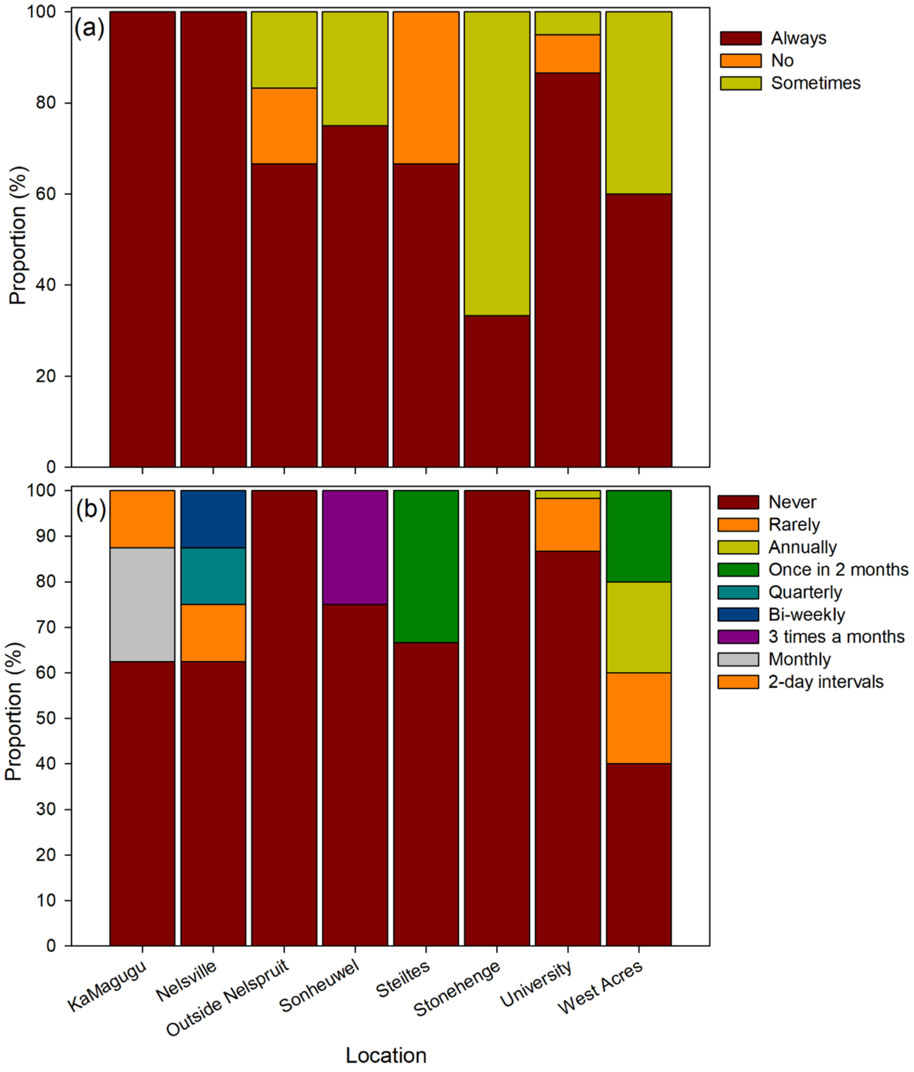

Fig. 1 The proportion of **a** residents reliant on municipal drinking water and **b** the cleaning frequency for faucet aerators in household taps among different localities in Nelspruit, South Africa

3.2 Water quality concerns

Numerous households reported concerns regarding drinking water quality in terms of unusual taste (range 0–66.7%) and discolouration (range 15–50%), with residences in Nelsville (50%), Sonheuwel (50%), Stonehenge (100%), local university (56.7%) and West Acres (60%) having high water quality problems related to either discolouration or unusual taste (Fig. 2). Based on Chi–squared analysis, water quality issues were significantly different among localities ($\chi^2 = 17.418$, df = 7, $p = 0.043$). A correlation analysis highlighted that water quality issues were not significantly ($r = 0.062$, $p = 0.274$) correlated with water consumption patterns.

3.3 Microplastics dynamics

The water samples collected from the study area consisted of beads, fibres, film, foam, fragments, and rubber of different colours in varying densities (Fig. 3). Fragments were most dominant in Nelsville (55.5 ± 53.7 particles L^{-1}), Stonehenge (95.3 ± 103.4 particles L^{-1}), and the local university (59.1 ± 72.7 particles L^{-1}), while fibres were dominant in KaMagugu (39.4 ± 30.5 particles L^{-1}), outside Nelspruit (22.3 ± 9.9 particles L^{-1}), Sonheuwel (61.5 ± 43.9 particles L^{-1}), Steiltes (39.0 ± 35.5 particles L^{-1}), and West Acres (23.0 ± 14.7 particles L^{-1}) (Fig. 3). The results of one–way ANOVA ($p > 0.05$) revealed no significant differences in in either beads, fibres, film, foam, fragments, and rubber across the study area (Table 1). The identified microplastic colours do not differ significantly across the localities, apart from yellow microplastics (F = 2.229, df = 7, $p = 0.039$) which were found to be significantly different had varying numbers across localities (Table 1).

The Shannon–Wiener (mean 2.01 ± 0.3) and γ–diversity (13.8 ± 4.3) indices were high in Sonheuwel, whereas Whittaker–β diversity (mean 2.64) and evenness (mean 0.39 ± 0.17) was low in Sonheuwel and Riverside, respectively (Fig. 4). There were no significant variations ($p > 0.05$) in γ–diversity, Shannon–Wiener, evenness and Whittaker–β diversity indices of microplastic types across localities (Table 1).

3.4 Plastic polymers

The Fourier Transform Infrared Spectroscope (FTIR) identified three plastic polymers: low–density polyethylene (LDPE), high–density polyethylene (HDPE) and ethylene

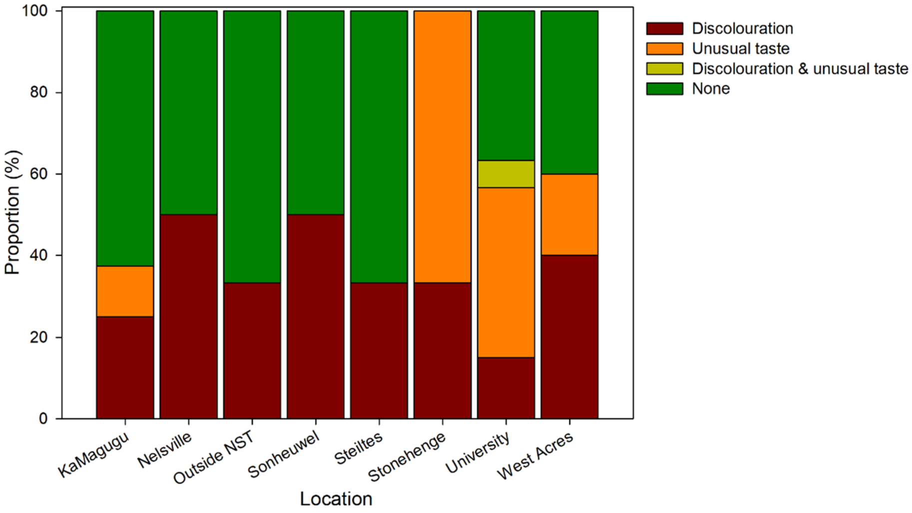

Fig. 2 Water quality issues reported by residents within different localities across Nelspruit, South Africa

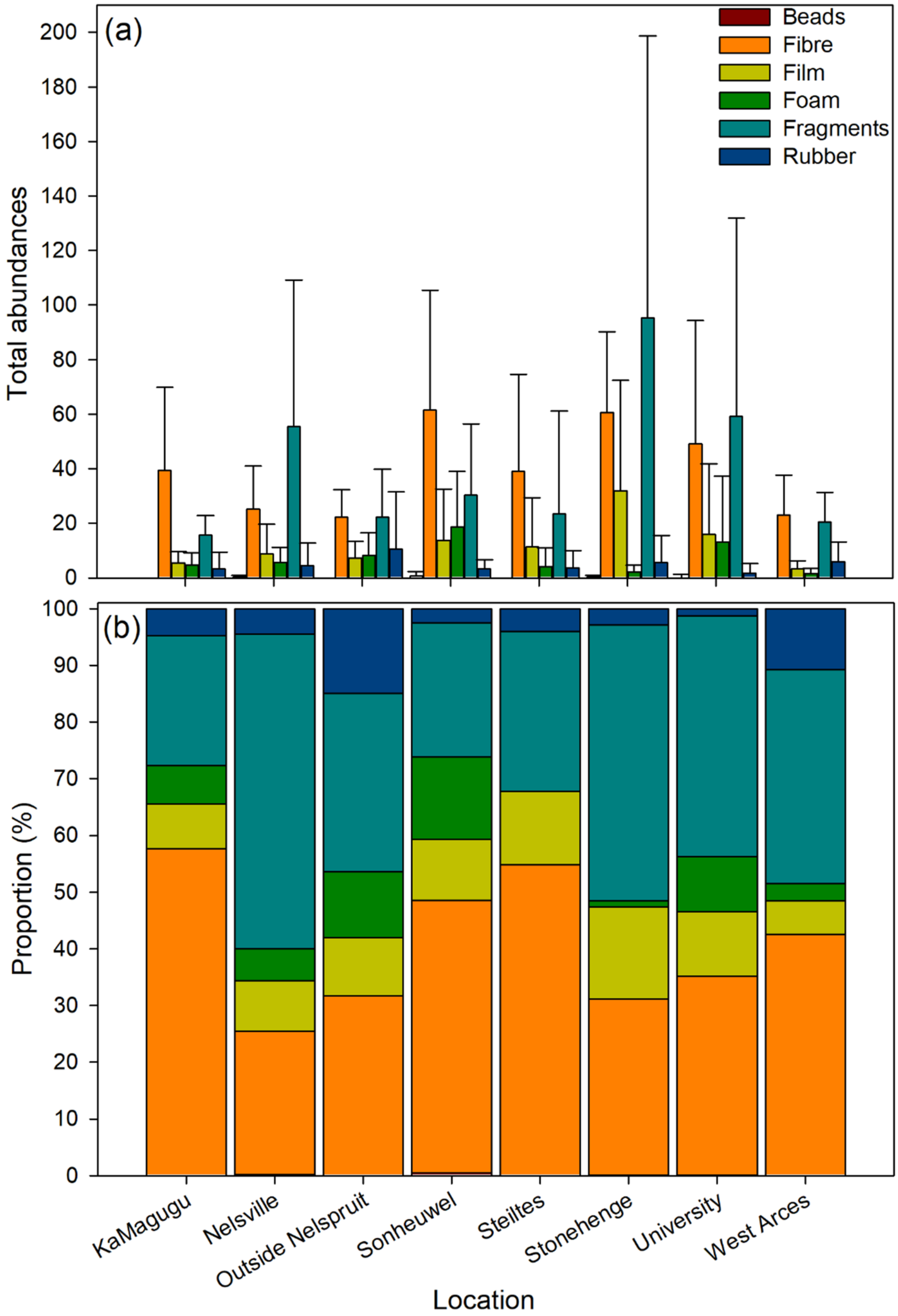

Fig. 3 Mean **a** total abundances (particles per faucet) and **b** proportion of microplastics recorded within the Nelspruit and the surrounding areas

propylene diene terpolymer (EPDM) including red petroleum wax (RP wax) and vaseline (Fig. 5). Low–density polyethylene (LDPE), HDPE and EPDM were most common in West Arces, Nelsville and KaMagugu, respectively (Fig. 5). No significant differences were observed for LDPE (F = 0.641, df = 7, p = 0.720), HDPE (F = 0.641, df = 7, p = 0.720), and EDPM (F = 0.880, df = 7, p = 0.526) across the study sites. The RP wax was found at all sites, with vaseline being found in Nelsville, Steiltes and West Acres, and furthermore traces of sulphur compounds were found in all the localities.

Table 1 One–way ANOVA results for microplastic type, colour and diversity across Nelspruit, South Africa

Variable	df	F	*P*
Types			
Beads	7	0.439	0.875
Fibre	7	1.064	0.394
Film	7	0.792	0.596
Foam	7	0.690	0.680
Fragment	7	1.184	0.320
Rubber	7	1.544	0.163
Colours			
Black	7	1.157	0.336
Blue	7	0.212	0.982
Green	7	0.631	0.729
Orange	7	0.510	0.825
Pink/red	7	0.515	0.821
White	7	0.277	0.961
Yellow	7	**2.229**	**0.039**
Colourless	7	1.367	0.229
Diversity indices			
Richness	7	0.230	0.924
Dominance	7	0.161	0.959
Shannon–Wiener	7	0.087	0.988
Evenness	7	1.580	0.548
Whittaker–β	7	0.396	0.844

Values in bold indicate significance at $p < 0.05$

3.5 Relationship between social components and microplastic abundances

Most correlations were weak, indicating minimal to no significant association with either cleaning frequency or age of home (Table 2). The only significant and negative relationship was observed between fibres and cleaning frequency ($r = -0.22$, $p = 0.034$). There were no significant correlations observed for other microplastic types with cleaning frequency and age of home (Table 1).

4 Discussion

There were no clear differences in terms of drinking water consumption patterns across localities. Microplastics were detected in all localities, with either fragment or fibre particles dominating. Thus, the findings of the study confirmed the presence of microplastic in treated municipal drinking water across various households in Nelspruit. No clear site differences were observed in terms of microplastic abundances, types and colours. These findings highlight the potential eco–toxicological effects of household drinking water on residents of Nelspruit region.

4.1 Water consumption patterns of Nelspruit residents

Households in the study area receive their drinking water from the local municipality and it is, therefore, not surprising that many of these households reported similar water quality issues such as unusual taste and discoloration. Furthermore, differences in municipal or bottled drinking water consumption and treatment patterns between urban low– and high–density areas are driven by infrastructure quality, income levels, and accessibility. For example, residents of KaMagugu (medium density area) and Nelsville (low density area) were entirely reliant on municipal for drinking water, being

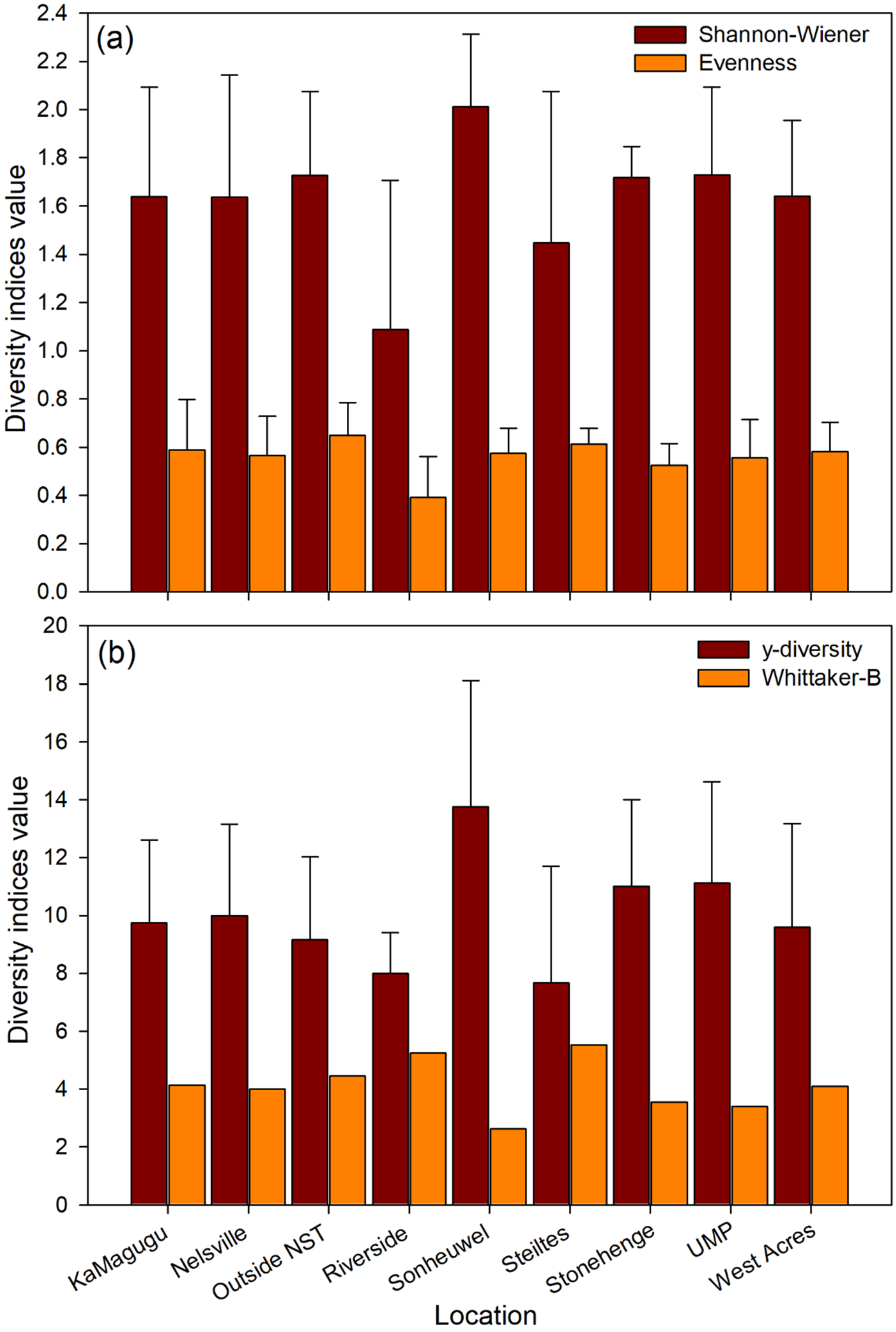

Fig. 4 Microplastic diversity indices for microplastics found in the municipal treated water around City of Nelspruit: **a** Shannon–Wiener and Evenness indices, and **b** γ–diversity and Whittaker–β diversity indices

unable to opt for alternative water sources such as purchasing of bottled water. Thus, residents of these areas are potentially susceptible to microplastics ecotoxicological effects. In contrast, more affluent low–density areas such as Steiltes have residents invested in additional filtration systems and they regularly purchase drinking water. Socio–economic factors, such as income levels and education, also influence water consumption habits and preferences [46]. These findings are similar to Sobsey et al. [47] who highlighted that the social–cultural drivers influence household water treatment choices

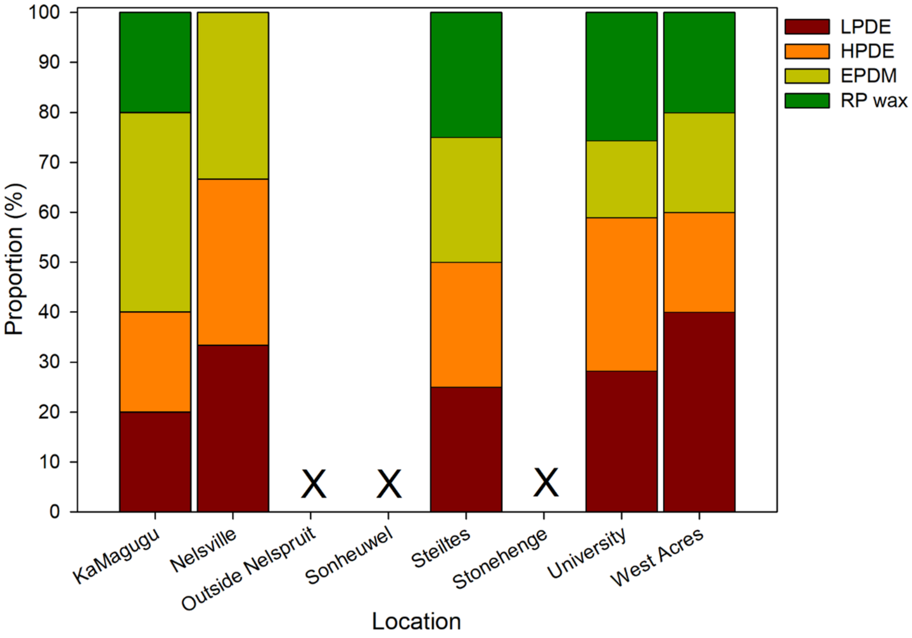

Fig. 5 Distribution of plastic polymers across various localities in the study area. Symbol "X" indicates no polymers were tested for the specific location, LPDE—low density polyethylene, EPDM—ethylene propylene diene terpolymer, HPDE—high density polyethylene, RP wax—red petroleum wax

Table 2 Correlation between microplastic types and household factors (aerator cleaning frequency and age of home) across sampled Nelspruit households, South Africa

Microplastic type	Cleaning frequency		Age of home	
	r	*p*	*r*	*P*
Beads	− 0.01	0.895	0.01	0.926
Fibres	**− 0.22**	**0.034**	− 0.15	0.142
Film	− 0.06	0.532	0.05	0.607
Foam	− 0.12	0.248	− 0.06	0.565
Fragment	− 0.12	0.225	− 0.01	0.899
Rubber	− 0.08	0.447	− 0.01	0.948

Bold values indicate significant differences at $p < 0.05$

and practices of individuals, households, and communities. The above highlighted trends contrast drinking water dynamics in high–density areas who fall within the lower economic brackets such as the local university, to which its residents are highly dependent on municipal drinking water and had also high numbers of reported water quality concerns. It is important to note that, residents in high–density areas may have greater access to municipal water services, while those in low–density regions might rely more on bottled water, especially if municipal infrastructure is lacking or water quality is perceived as inferior [48]. High–density areas often rely on centralised municipal systems due to economies of scale, while low–density areas may depend on bottled water due to inadequate infrastructure or contamination risks [49]. Income disparities influence affordability of bottled water or advanced household treatment systems [48]. Perceived water quality and trust in municipal systems also play a role, with low–density areas often sceptical of safety [50]. Urban planning and resource allocation further exacerbate these disparities [51].

The significant variation in faucet aerator cleaning frequency across localities supports the study by Shakya et al. [52] which highlights the potential gap in public awareness on the importance of regular tap maintenance in ensuring good water quality. The significant negative correlation between aerator cleaning frequency and fibres suggests that households with infrequent aerator cleaning practices may have high microplastics abundances, which could potentially lead to microplastic accumulation overtime on the faucet aerator [53]. Thus, this highlights the role of maintenance in mitigating microplastic pollution, a growing environmental and health concern [54]. Effective cleaning practices can improve water quality and reduce human exposure to microplastics.

4.2 Occurrence and distribution of microplastics in municipal water

The study highlighted no clear variation in microplastic abundances and types among localities, owing to one water source supplier. Once contaminants, such as microplastics, enter a distribution network, all connected users are potentially similarly affected [55]. Microplastics detected after DWTP treatment indicate inefficiencies in their removal. Conventional methods such as coagulation, sedimentation, and filtration are not fully effective at removing smaller microplastics [54]. Additionally, microplastics can enter distribution systems through aging pipelines, atmospheric deposition, and/or secondary contamination from urban runoff [56]. Thus, advanced treatments such as membrane filtration are needed to address this emerging contaminant.

Microplastics did not differ according to colour across the study area, with only yellow microplastics being significantly different. This is attributed to the overexposure of ultra–violet radiation on plastic infrastructure such as water distribution system pipes, causing them to become brittle and yellow due to chemical reactions in the material [57]. Furthermore, yellow pigments are commonly used in industrial and consumer plastics, making them more prevalent in urban environments [58]. Inadequate removal by conventional drinking water treatment processes allows these coloured particles to persist in treated water, highlighting the need for advanced filtration methods to address microplastic contamination.

Overall, there was no significant variation in microplastic types, therefore microplastic abundances and diversity was consistent across the localities, with fragments and fibres being the two dominant types. This is a similar pattern observed in drinking water across the world (see [20, 24]). One of the most consumed microplastic particle type by humans are fibres, followed by fragments [59], and these have been reported as emerging microplastic contaminants in drinking water [56]. Moreover, the high prevalence of fibres and fragments in drinking water is attributed to the fragmentation of macroplastics in raw water, which then bypass conventional drinking water treatment processes [60]. The widespread presence of these microplastics across different localities in the present study highlights the pervasive nature of plastic pollution, even in treated municipal water [60].

The LDPE and HDPE plastic polymers are among the most used in everyday products [61]. Moreover, EPDM is a non–biodegradable polymetric material that is non–reusable and often discarded after a single use [62]. It is often used as hose pipes and seals [63]. The overall concentration of EPDM rubber varied across Nelspruit from that of LDPE and HDPE in the identified localities. The EPDM rubber was prevalent in the local university and is often used in industrial applications and/or household plumbing (i.e., faucet washer) [63] and indicates the potential contamination from rubber in the drinking water. High–density polyethylene is the material commonly used for making pipes and other materials in DWTP purification and supply chain systems [56] and potentially suggests that the source of contamination may be related to infrastructure degradation. In contrast, areas such as KaMagugu and Nelsville showed low levels of these polymers, possibly due to differences in filtration systems and age of household areas.

The presence of microplastics in drinking water is a cause for concern for the residents of Nelspruit. The health implications of ingesting microplastics over a long period include inflammation in body tissues, oxidative stress, and potential cellular damage due to the immune response of trying to break down the foreign particles existing as localised particle toxins [26, 29]. Thus, effective water treatment methods designed to effectively capture and remove microparticles (including microplastics) are urgently required. There are various microplastic removal techniques that can be adopted by DWTPs to effectively remove microplastics from raw water. A study by Sarkar et al. [64] highlighted that the pulse clarification stage in DWTPs results in significant microplastic removal and the process involves the creation of a sludge jacket through a vacuum column which effectively filters out flocculated particles, including microplastics. Additionally, Wang et al. [65] suggests that while coagulation and sedimentation processes effectively remove microplastics, particularly fibres, their efficiency can be enhanced when coupled with granular activated carbon (GAC) filtration. This approach is further supported by Tang and Hadibarata [66], who advocates for the combination of ultrafiltration with GAC or sedimentation/flocculation in conventional DWTP due to its improved ability to remove microplastics from drinking water despite some limitations. To address microplastic contamination in municipal water, policymakers should enforce stricter wastewater treatment regulations, invest in advanced filtration technologies, and promote public awareness campaigns to reduce plastic use. Local governments must monitor contamination hotspots, collaborate with researchers for data-driven solutions, and integrate microplastic management into existing water quality frameworks, ensuring sustainable water safety.

5 Conclusion

The present study provides evidence of microplastic presence in Nelspruit drinking water and these findings suggest that microplastics are widespread across the studied regions. The findings also highlight the limited capabilities of current treatment methods in effectively capturing and removing microplastics in drinking water. Residents of Nelspruit region that are highly/totally reliant on municipality as the sole supplier of drinking water, such as those from low–income households, are particularly at a high risk of microplastic exposure. More advanced methods, such as advanced microplastic removal techniques (e.g., ultrafiltration), and regular pipe maintenance, could significantly reduce the presence of microplastics in municipal drinking water. The implementation of such multifaceted approaches can ensure the long–term preservation of the health and well–being of Nelspruit's residents.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1007/s43621-025-01690-z.

Supplementary Material 1.

Author contributions

TD: conceptualization, methodology, investigation, supervision, visualisation, data analysis, funding, writing—reviewing and editing; AX: methodology, investigation, visualisation, data analysis, writing—reviewing and editing; MTBD: conceptualization, methodology, investigation, supervision, visualisation, data analysis, funding, writing—reviewing and editing; LFM: methodology, visualisation, writing—reviewing and editing; SMN: methodology, investigation, writing—reviewing and editing; STT: methodology, investigation, writing—reviewing and editing; RM: methodology, investigation, writing—reviewing and editing; PM: methodology, visualisation, writing—reviewing and editing.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

The study has been ethical approved by University of Mpumalanga School Research Ethics Committee: UMP/Xozumti220697809/BIO/BScHons/2024/1, and permission to conduct the study was granted by the Mpumalanga Tourism and Parks Agency: MPB5859. An informed consent form was issued to all respondents before the commencement of the sampling process, with all respondents signing the consent form agreeing to carrying out of study and further having their drinking tap water faucet aerator assessed for microplastics. All methods were carried out in accordance with relevant guidelines and regulations. All authors agreed to the participation in this manuscript. An informed consent form was issued to all respondents before the commencement of the sampling process, with all respondents signing the consent form agreeing to carrying out of study and further having their drinking tap water faucet aerator assessed for microplastics.

Consent for publication

All authors agreed to the publication of this manuscript.

Competing interests

The authors declare no competing interests.

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