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Potential of Heavy Metals and Microplastics Contamination in River Mpanga, Fort Portal, Kabarole District, Uganda

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ABSTRACT

Anthropogenic environmental pollution is a major development challenge in Ugandan rivers and lakes, the key drivers being industrialization, agriculture, and urbanization. The aim of the study was to assess the potential of heavy metal and microplastic contamination in River Mpanga, Fort Portal, Uganda. Triplicate water and sediment samples were collected from three sampling sites, preserved, and analyzed at the Chemistry Department, Makerere University for heavy metals, while microplastics analysis was conducted at NaFIRRI, Jinja. Sediment heavy metal contamination was assessed from the geoaccumulation index, while microplastic characterization and quantification were determined from stereomicroscopy and morphological features. Arsenic was the most prevalent metal with a mean concentration of 13.2 ppm thus higher than permissible maximum limits of WHO. The mean concentrations (ppm) of copper, lead, and cadmium were 0.01, 0.01, and 0.001 respectively, and below the permissible maximum. Sediment samples revealed very strong arsenic contamination, strong contamination for copper, moderate to strong contamination for lead, and a potential lack of contamination for cadmium. The higher concentrations of the heavy metals in the sediments compared to water could be attributed to bioaccumulation, as evidenced by the high geoaccumulation values. Microplastics occurred throughout the river and included fragments, filaments, film, pellets, form, and fibers. The presence of heavy metals and microplastics was attributed to anthropogenic activities within the river vicinity, which discharged heavy metal-laden waste into River Mpanga. High arsenic concentrations and sediment accumulation of contaminants pose serious potential public health threats to the local communities.

INTRODUCTION

Environmental pollution is a major development challenge in Uganda. The recent advances in economic growth, industrialization, farming, and urbanization have been key drivers of water, air, and land pollution (Pierre & Karani 2016). In Uganda, the rate of urbanization has been reported at 4.5% per annum (Yusuf et al. 2019). The majority of the urban areas in Uganda are slums, characterized by unplanned urban centers and urban settlements. These have limited access to clean water, sanitation infrastructure, and facilities for waste disposal (Jonas & Kirungyi 2020). They tend to generate a lot of waste, exerting pressure on the already inadequate municipal and local authority waste management schemes (Aryampa et al. 2019).

Sustainable municipal solid waste (MSW) management is a major concern for all African cities (Aryampa et al. 2019). Poor disposal of solid waste and wastewater exposes underground and surface water systems to physical, biological, and chemical contamination (Vasanthi et al. 2008). Industrial and urban wastes resulting from anthropogenic activities are usually discharged into aquatic ecosystems, leading to heavy metal, microbial, and plastic contamination (Bentum et al. 2011).

The Mpanga Catchment

In Uganda, lakes and rivers are the main sources of water for domestic and commercial purposes. The Mpanga catchment in Western Uganda covers an area of 4,700 km² (Businge et al. 2021). Mpanga River begins in the foothills of the Rwenzori Mountains in Kabarole District. It starts as a small river but increases in size as a diverse range of streams and rivers join it. The river flows through forested, highly populated, and cultivated areas in the districts of Kabarole, Kyenjojo, and Kamwenge before discharging its water into Lake George (Businge et al. 2021, Onyutha et al. 2021).

River Mpanga catchment has four major sub-catchments, including Upper Mpanga, Middle Mpanga, Lower Mpanga, and Rushango, with drainage areas equal to 384, 1174, 477, and 3170 km^2, respectively (Onyutha et al. 2021). It is the main source of water in several urban areas in the western part of Uganda including Fort Portal, Kamwenge, and Ibanda.

Despite its economic importance, recent reports indicate deterioration in the water quality of River Mpanga, posing contamination risks not only to communities that depend on its waters but also to its flora, fauna, and the water quality of Lake George. For example, Businge et al. (2021) reported fecal coliform contamination in the river. Coliform contamination also indicates the presence of other microbial contaminants, including *Salmonella*, rotaviruses, hepatitis E virus, and *E. coli* (Korajkic et al. 2018). Besides microbial contamination, other potential forms of water pollution accruing from anthropogenic sources include heavy metal and microplastic contamination (Baguma et al. 2022, Basooma et al. 2021).

Effect of Heavy Metal Contamination

Heavy metals are chemical elements with high molecular weights and a specific gravity at least five times greater than that of water and are toxic at concentrations that exceed their threshold values. Heavy metals are used in domestic, industrial, agricultural, medical, and technological applications, which have led to their uncontrollable distribution in the environment. Their physicochemical nature makes them persistent, toxic, and bio-accumulative. Owing to their high degree of toxicity, As, Cd, Cr, Pb, and Hg are listed as priority heavy metals that are of public health significance (Singh et al. 2022). Humans get exposed to heavy metals through three main pathways, namely, ingestion, inhalation, and skin absorption (Kumar et al. 2020).

Heavy metals react with biological systems by losing one or more electrons and forming cations that can ably bind with the nucleophilic sites of the vital macromolecules. Their toxicity is caused by the disruption of cellular activities such as growth, differentiation, damage-repairing processes, and apoptosis (Baguma et al. 2022). These may be mediated through the generation of reactive oxygen species (thus causing oxidative stress), weakening the organism's antioxidant defense system, complexation or ligand-formation with organic compounds, and the active sites of enzymes. Their toxicity is contingent on the exposure route, dose, chemical form, and the age, gender, and nutritional status of the individual in question (Balali-Mood et al. 2021).

Additionally, heavy metals, as persistent toxicants, are deposited in the ecosystem and subsequently get absorbed in food chains (Kumar & Khan 2020). Pollution of aquatic ecosystems with heavy metals can lead to environmental problems hence adverse ecological impacts. In aquatic macrophytes, growth inhibition has been observed to occur in duckweed and algae, whereas in benthic invertebrates and freshwater fingerlings, reductions in fecundity, growth, and survival of these organisms have also been reported (Vera-Candioti et al. 2011).

Microplastics

Microplastics (MPs) are synthetic polymeric compounds on a microscopic scale (<5 mm). Microplastic contaminants originate from the breakdown of larger plastics by agents like wave action, temperature, and radiation (Li et al. 2021). Microplastic fragments even break down further to form smaller particles (< 0.1 micrometers) called nanoparticles (Danopoulos et al. 2020). More than 45 plastic compounds are in commercial use currently. These include polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polystyrene (PS), polyurethane (PU), polyvinyl chloride (PVC), and polycarbonate (PC) (Kannan & Vimalkumar 2021). Most of the microplastic waste ends up in soils and freshwater bodies. Their small size, coupled with resistance to microbial degradation, renders them potential contaminants to water and soil ecosystems (Issac & Kandasubramanian 2021).

Despite the occurrence of microplastics in most aquatic environments such as underground water systems, rivers, lakes, estuaries, shorelines, and domestic tap water systems, existing research on MP contamination has majorly focused on marine water systems (Danopoulos et al. 2020, Lamm et al. 2021) thus creating a knowledge gap on the potential contamination of MPs in freshwater systems. Human exposure to microplastics is mainly through contaminated drinking water, ingestion, and inhalation (Kannan & Vimalkumar 2021). Although limited knowledge has been established on the human health impacts associated with exposure to microplastics, the potential effects of microplastic exposure to aquatic biota are well documented. These include intestinal obstruction, reduced energy metabolism, and reproductive malfunction. In addition, exposure to MPs enhances the absorption of hydrophobic organic contaminants (HOCs) from the environment into living systems (Lamm et al. 2021). As a result of the widespread existence of MPs, their absorption, distribution, metabolism (along with the potential toxicity), and excretion processes in humans have drawn increasing attention (Dick-Vethaak & Legler 2021). These MPs may affect human health by interfering with metabolic processes (Vaughan et al. 2017).

Even though the effects of exposure to microplastics on human health are still not fully understood, continuous exposure to microplastics is documented to cause inflammation in body systems (Wu et al. 2021). MP ingestion not only poses physical impacts by internal abrasions and blockages but also provides a possible pathway of exposure to the respective organisms via adsorbing organic contaminants and metals from the ambient environment (Zhao et al. 2015).

Although some studies have been conducted to assess the potential of heavy metal (Basooma et al. 2021; Egesa et al. 2020; Mbabazi et al. 2010, Sekabira 2010) and microplastic contamination (Egesa et al. 2020), knowledge of heavy metals and microplastic contamination in Ugandan river ecosystems is still scanty. Knowledge of heavy metal and microplastic concentrations in aquatic environments and commercial water systems is essential for monitoring water quality, controlling pollution, protecting aquatic ecosystems, and safeguarding human health. The study, therefore, focused on assessing the potential of microplastics and heavy metals (As, Cd, Cu, and Pb) contamination in River Mpanga. These metals have been documented as prime heavy metals of concern to human health owing to their high levels of toxicity (Balali-Mood et al. 2021).

MATERIALS AND METHODS

Description of the Study Area

The study was carried out on the section of River Mpanga, which is within the geographical confines of Fort Portal City, Kabarole District. River Mpanga is a lifeline for an estimated 1.2 million people in Uganda. From its origin in the Rwenzori Mountains, the river flows 250 km through the Kabarole, Kamwenge, and Kyenjojo districts before reaching Lake George. Three georeferenced locations of the river: Kazingo (36 N 185263E 72611N), Kabandaire (36 N 196628E 72699N), and Nyamigira (36 N 207662E 73601N) were selected and referred to as upstream, midstream and downstream sites (Fig. 1).

Sample Collection

Triplicate water samples were collected from each of the three sites in the river using a 10 L sterile plastic container and filtered through a 63 µm neuston net. The final concentrates were kept in sterile glass bottles, preserved in 70% ethanol, and kept in cool boxes before analysis for four heavy metals, namely arsenic, cadmium, copper, and lead.

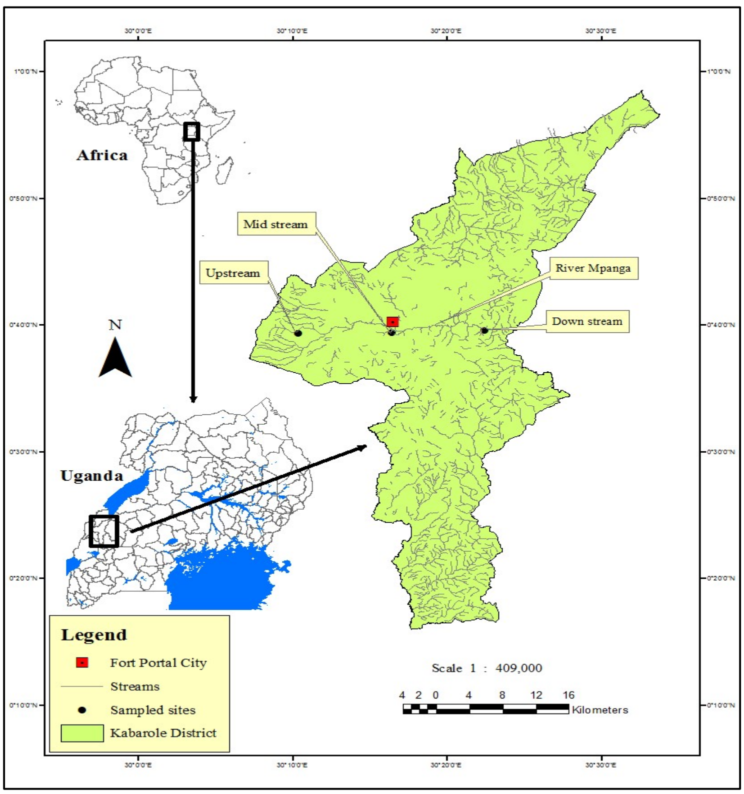

Fig. 1: Location of the study sites.

Sediment samples were collected from each of the three locations of the river using an Ekman sediment grab from which sub-samples were obtained for analyses. Sediment samples were prior kept in a cool box before delivery to the laboratory for further sample processing and analysis.

Additional information about each sampling area was also obtained, i.e., approximate width of the river, land use pattern, type of shoreline materials, river velocity and factors that affect it, topography, river use, distance from the nearest population center, any development nearby, industrial complex, wastewater discharges, and other pollution sources.

Sample Analysis

Water sample analysis for heavy metals: Water samples for heavy metal analyses were subjected to hot peroxide digestion to break down any organic matter. The samples were filtered through a 0.45 µm pore size Whatman glass fiber filter paper. The filter paper was then placed into a glass petri dish and kept in a desiccator. Sample digestion and filtration were conducted following the protocols provided by Masura et al. (2015). Negative controls comprising tap and deionized water were used as quality control measures of the laboratory analysis procedures.

Sediment sample analysis for heavy metals: Sediment samples were oven-dried at 105°C overnight before grinding them to fine powder, of which 1 g was mixed with 50 mL of deionized water in a conical flask. To each mixture, 3 mL of HNO_3 was added, and the mixture was heated slowly to concentrate the sample to 5 mL, to which 5 mL of HNO_3 acid was added. The conical flask was covered with a watch glass and heated. Heating was continued until a light-colored solution was realized, indicating the completion of the digestion process. This was followed by the addition of 10 mL of 1 + 1 HCl and 15 mL of deionized water per 100 mL. This was followed by an additional 15 minutes of heating to dissolve any precipitate or residues. The digested sample was cooled and filtered through a GF/C Whatman filter paper (0.45 um pore size, 47 mm diameter) to remove insoluble material that could clog the nebulizer (EPA 1996). The concentrations of the heavy metals were determined in ppm (parts per million) by using the atomic absorption spectrophotometer (AAS).

Water sample analysis for microplastics in water: Microplastic analyses were conducted using a stereomicroscope (×50 mag) scanning through each petri dish for physical characterization of any observed microplastic particles based on morphological and visual guidelines (Branch et al. 2022). The key morphological descriptors used were fragments for broken-off plastic pieces, foam for all particles that are easily deformed under pressure and exhibit elastic characteristics, film for all particles with smooth, angular edges, flat and flexible, pellet for particles that are harder than foam and lastly filament for particles that are long, or fibrous (Branch et al. 2022). All the observed microplastics were recorded by use of photographs, and each particle type was tallied and the counts summed up.

Data Analysis

Data analysis involved the use of descriptive statistics to indicate proportions, distribution, and counts for microplastic data. On the other hand, means and standard deviations were used to indicate different heavy metal concentrations.

Table 1: Field information obtained during sampling of River Mpanga water and benthic sediment.

River Properties		Sampling points		
		Upstream	Midstream	Downstream
	Site location	36 N 185263E 72622N	36 N 196628E 72699N	36 N 207662E 73601N
Catchment information	Topography	Slope	Gentle slope	Gentle slope
	Land use	Farming	Market, car wash, laundry	Tea plantation
	River use	Domestic use	Laundry & commercial car washing	Domestic use
River physical properties	Mean river width [m]	1.9	4.4	7
	Mean river depth [cm]	38.7	46.3	88.7
	Shoreline/benthic type (sand, gravel, clay)	Rock	Clay + sand	Rocks
	River bed type (sand,gravel, clay)	Gravel	Gravel	Rocks
	Objects affecting current	Boulders	Plastic debris & plant materials	Stones
River hydraulic properties	Velocity [$m.sec^{-1}$]	0.47	0.68	1

Table 2: Concentrations (ppm) of heavy metals in water samples from River Mpanga.

Location along the river	Heavy metal concentration in 10 L water sample			
	Mean [PPM]			
	As	Cu	Pb	Cd
River upstream (n =3)	12.67±2.43	0.05±0.06	0.01± 0.00	0.00± 0.001
River mid stream (n=3)	13.13±0.58	0.04±0.01	0.03 ±0.01	0.002±0.00
River downstream (n =3)	13.80±3.00	0.03±0.02	0.00±0.00	0.001±0.00
Background	10	1	0.026	1
Mean along the river	13.20±0.57	0.04±0.01	0.01± 0.01	0.0013±0.001
WHO (2017) limit	0.05	1.5	0.05	0.005
EPA (2018) limit	0.01	1.3	0.015	0.005

Table 3: Concentration of heavy metals in River Mpanga bed sediment.

Location along the river	Heavy metal concentration in riverbed sediment			
	Mean [PPM]			
	As	Cu	Pb	Cd
River upstream (n =3)	1838 ±14.6	54.3± 7.6	32.3± 5.5	0.11± 0.02
River mid stream (n=3)	2113± 10.26	29.3± 7.0	31.3± 3.05	ND
River downstream (n =3)	2808 ±15	41.9± 6.4	27.3± 6.02	ND
Mean along the river	2253 ±499	41±12	30.3 ± 2.64	0.11 ± 0.02
Background	0.1 - 10	5 -50	15 - 40	0.01 - 1

Additionally, analysis of the heavy metal pollution index in the river bed sediments was established using a geoaccumulation indexing approach (Igeo index) using equation (1) (Muller 1969).

$$Igeo = \ln (Cn/1.5 \times Bn) \quad \ldots(1)$$

Where Cn = measured concentration, mg.kg^{-1}, and Bn = geochemical background value, mg/kg. In equation 1, average values were used and 1.5 was the factor used for lithologic variations of trace elements and the resulting findings compared to the permissible limits as provided by the World Health Organization (2018) and the Environmental Protection Agency (2017). All the analysis was conducted using SPSS version 15.0, and the results were presented in tables and figures.

RESULTS

Description of the River Characteristics

Samples were collected from three points with varrying gradients, that is Kazingo (sloping), Kabundaire and Nyamigira (gently sloping). The dominant land use type is agriculture, while the river water is being exploited for various domestic uses. The width of the river ranged between 1.9 to 7 m while the depth ranged from 38 to 9 cm. The riverbed was dominated by gravel, although parts of it were rocky. The velocity of the river, as expected, decreased downstream, with river flow being under the influence of variously-sized stones and foreign material (Table 1).

Heavy Metal Concentration in Mpanga River

Heavy metal concentration in water samples: Analysis of heavy metal concentrations indicated varying results for the three sections of the river. The mean concentration of arsenic, 13.2 ppm, was greater than the permissible maximum concentration (0.05 ppm) as provided by WHO (2018). The highest concentration of 13.8 ppm was detected at the river downstream, whereas the lowest concentration of 12.7 ppm was detected at the river upstream (Table 2). The mean concentrations (ppm) of copper, lead, and cadmium were 0.01, 0.01, and 0.001, respectively, and within the permissible maximum limits of WHO.

Heavy metal concentration in water sediments: The study findings revealed varying and high concentrations of arsenic in the river bed sediment. While the background arsenic concentration is between 0.1 to 10 ppm, an average concentration of 2253 ppm was detected along the river. The highest arsenic concentration of 2808 ppm was recorded at the downstream site, while the lowest value of 1838 ppm was recorded at the upstream site. Except for the copper concentration of 54.3 ppm upstream, the overall concentrations of copper, lead, and cadmium were below the background limits (Table 3).

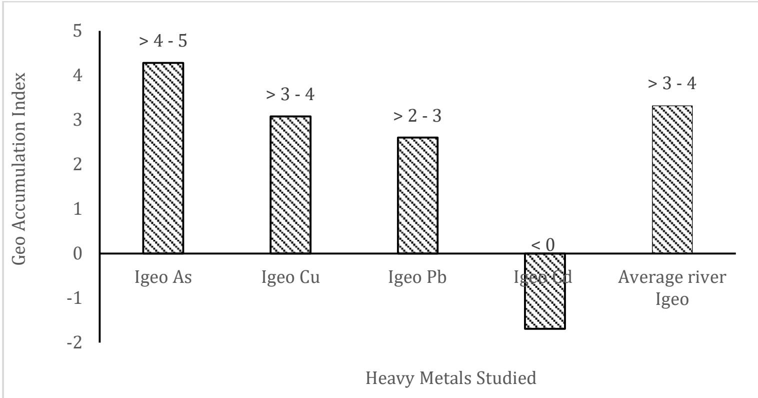

Fig. 2: Geoaccumulation index of heavy metals in River Mpanga sediment

Key: >4-5 strong to very strong contamination, >3-4 strong contamination, > 2- 3 Moderate to strong contamination, < 0 practically uncontaminated.

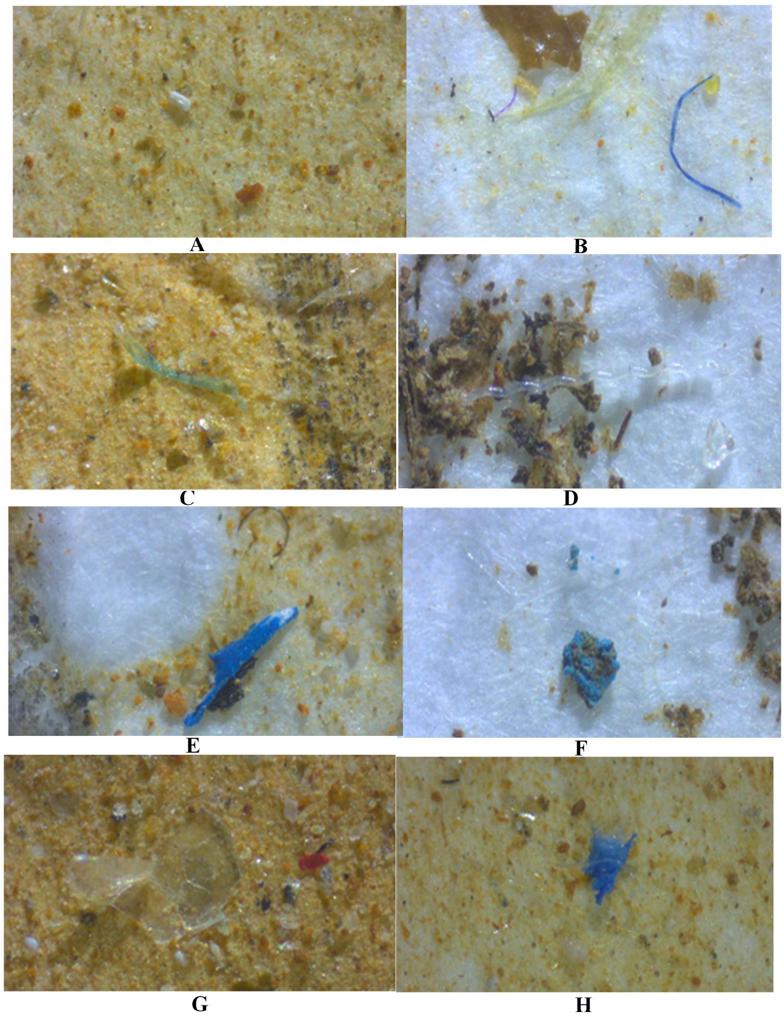

Fig. 3: Microplastics (mag ×50) in River Mpanga

A = Pellets, B - D = Filaments, E - G = Fragments, H = Film

Description: Foam = near spherical or granular particles, Pellet = resin bead, granular shape, Filament = long fibrous material, Fragment = granular, irregularly shaped hard particles, Film = sheet, flat and flexible.

Heavy metal geoaccumulation index (Igeo) in the river bed sediment: The heavy metal accumulation in the sediments showed varying indices. Analysis of the river Igeo (> 3-4) indicated a strong level of contamination. The order of Igeo indices for the four metals was -1.69 for cadmium, 2.6 for lead, 3.08 for copper, and 4.28 for arsenic. Compared to the Igeo classification scale, findings from the study indicate a strong to very strong arsenic contamination, strong contamination for copper, moderate to strong contamination for lead, and a potential lack of contamination for cadmium. Therefore, the average bioaccumulation index of heavy metals in the river bed sediment was in the order of As > Cu> Pb > Cd (Fig. 2).

Characterization and Concentration of Microplastics in Water

Water analysis for microplastic contamination revealed six types of microplastics: fragment, film, pellet, form, fiber, and filament (Fig. 3).

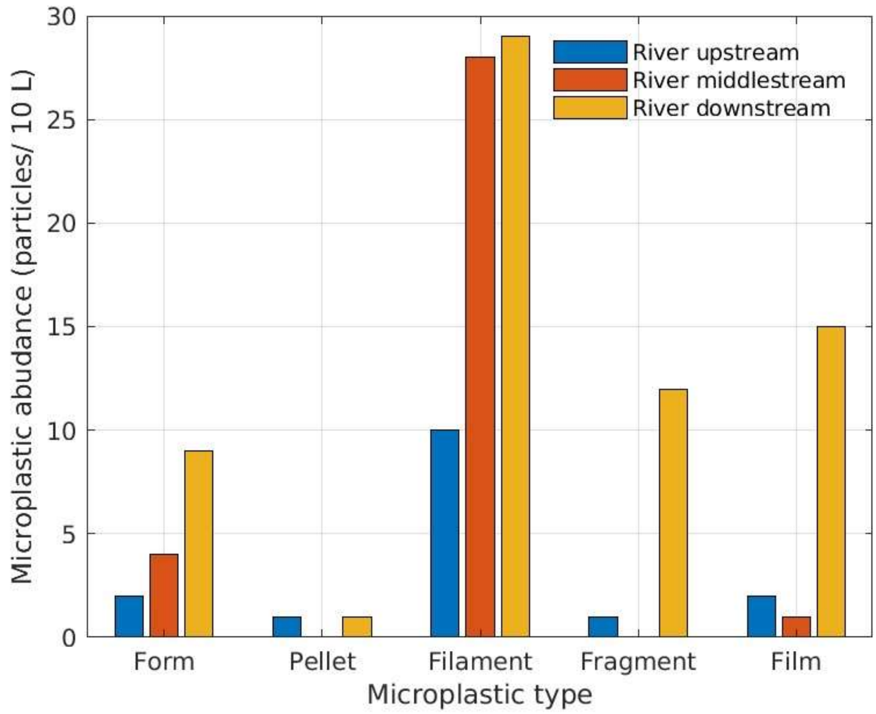

Fig. 4: Microplastic counts in the water samples.

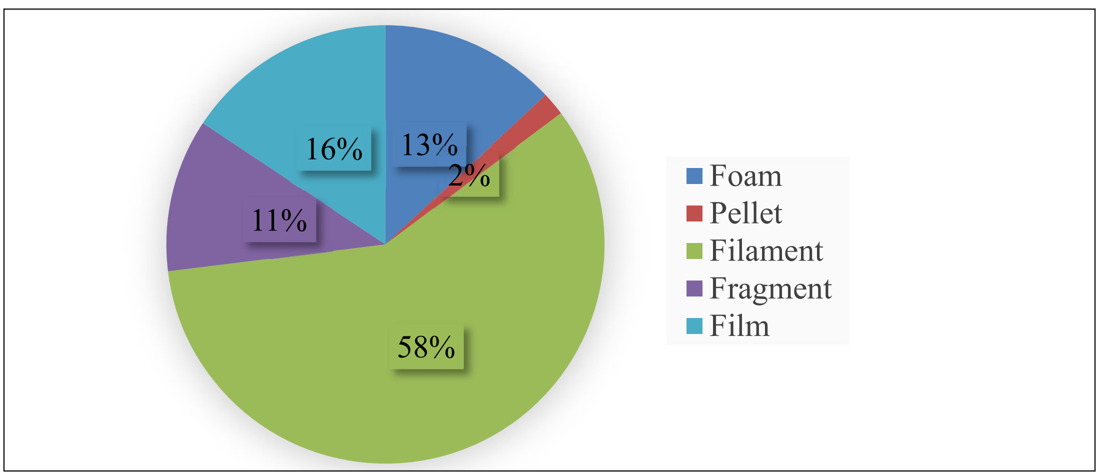

Fig. 5: Sediment microplastics characterization, composition and contribution of River Mpanga.

The study indicated a total microplastic of 115 particles per 10-L water sample in the river. Microplastic abundance increased from the upstream to the downstream section of the river. The total microplastic count was lowest at the river upstream (16), moderate at the river mid stream (33), and highest at the river downstream (66) (Fig. 3). The filament, form, and film types occurred across all sites, while the pellet and fragment foams were only recorded upstream and downstream. For all the three sites of the river studied, the most abundant microplastic was filaments (58%), followed by film (16%), foam (13%), fragments (11%), and pellets (2%). The filament type was represented more midstream and downstream (Fig. 4 & Fig. 5).

DISCUSSION

The presence of arsenic above the maximum permissible levels by EPA and WHO poses serious potential health risks to the communities within the river vicinity. Arsenic exposures as low as 10ug/L have been linked to adverse health problems like cancer, neurological disorders, and skin lesions, whereas prolonged exposures result in genetic mutations (Lamm et al. 2021). Although arsenic has been recorded in other rivers (Liu et al. 2020) its concentrations are comparatively lower than in the River Mpanga case.

Elevated levels of arsenic could be due to deposition from agriculture through arsenic-containing agrochemicals, domestic sewage, arsenic laundry products, mining, and untreated effluent (Li et al. 2021). The activities evident in the Mpanga catchment near Fort Portal City included subsistence and commercial farming, untreated waste disposal, and commercial car washing. A higher water arsenic concentration at the river downstream site compared to the other sites could be attributed to likely contamination from adjacent tea plantations. Long-term use of agrochemicals like pesticides and fertilizers represents a significant anthropogenic factor contributing to the contamination of the environment with heavy metals (Kumari & Mishra 2021). In addition, river velocity of 0.47m/sec, 0.68 m/sec, and 1m/sec was recorded at the upstream, midstream and downstream, respectively. The relatively higher heavy metal concentration at the river downstream would be attributed to heavy metal resuspension attributed to the increasing velocity (Bao et al. 2023, Huang et al. 2012). On the other hand, the low concentration of copper and cadmium (below the permissible limit) in the water samples at all the sections of the river studied could be due to bioaccumulation in the sediments downstream.

The findings are in line with Astatkie et al. (2021), who indicated a reduction in heavy metal concentration in the Awetu watershed from upstream to downstream. This decrement of heavy metal in the downstream may be due to bioaccumulation, involving the adsorption of heavy metals into sediments and aquatic biota (Astatkie et al. 2021).

While arsenic contamination was above the background level in the river bed sediment, only the river upstream indicated copper contamination in the river sediment above the permissible level. Copper contamination in the water sediments could be attributed to the proximity of this river section to Mountain Rwenzori and the former Kilembe copper mines. Cases of environmental pollution arising from the Kilembe mines, even after its closure, have been reported widely in plants and the surrounding environment (Sarah et al. 2022). Additionally, the higher concentrations of the heavy metals in the sediments compared to water could be attributed to bioaccumulation, as evidenced by the high geoaccumulation values. River sediment contamination with arsenic has also been reported by Zhuang et al. (2018) but in lower concentrations compared to the Mpanga River.

The Igeo index of the Mpanga River sediment indicates moderate to very strong contamination with lead, copper, and arsenic. According to the classification of sediment pollution status based on the geoaccumulation index, Mpanga River falls within the scale of 3-4, which is an indicator of strong contamination and hence poor sediment quality (Goher et al. 2014, Wang et al. 2023). High accumulation of contaminants is a threat to the benthic biodiversity of the river, which may bioaccumulate and hence biomagnify them through trophic transfer and may eventually get into human food chains (Goher et al. 2014). They pose a potential health threat to the local communities because there is a likelihood of the heavy metals being reintroduced into the water column through geochemical cycles (Pierre & Karani 2016). Sediment heavy metal pollution in Ugandan rivers has also been reported by Baguma et al. (2022) and Sekabira (2010).

Overall, the contamination of the river could be attributed to the fact that the river is within the vicinity of garages, schools, markets, sewage plants, vehicle washing bays, and hospitals, which are likely to discharge heavy metal-laden waste into River Mpanga (Bentum et al. 2011, Singh et al. 2022).

Study findings indicated an accumulating trend of microplastics from the river upstream to the downstream. Like other parts of the country, Fort Portal City is characterized by heavy dependence on a diversity of plastic items. This is because plastic items, namely household utensils and packaging materials, are cheap, durable, and have good thermal and electrical insulation properties (Singh et al. 2022). Formerly a municipality, Fort Portal was elevated to a tourism city status in 2020, and this is likely to lead to increased urban contamination. Due to insufficient solid waste management practices, a lot of plastic debris ends up in River Mpanga carried by wind, surface runoff after rain, or littering in water by the locals (Egessa et al. 2020).

Floating and deposited/trapped plastics are a common sight on the river. These macroplastics are broken down as the water moves downstream by natural processes like mechanical wear, weathering/aging, photolysis, hydrolysis, heat, and biological fragmentation into microplastics (Chen et al. 2023, Li et al. 2021). This probably accounts for the highest concentration of microplastics at the downstream Nyamigira site. The Kabundaire wastewater treatment plant could have also contributed to increased microplastic pollution because small microplastics like fibres may not be removed by treatment processes and thus end up in the effluent that enters the river (Liu et al. 2020). The microplastic load could also have formed from primary microplastics, which are manufactured intentionally for various domestic applications, like use in personal skin care products, toothpaste, etc. The foam, fibers, films, pellets, and fragments identified in this study were also reported by Singh et al. (2022). However, the foam, which is characterized by spherical or granular particles in River Mpanga, was absent in their study area.

Several studies have been conducted to assess the spatial variation, composition, and abundance of different types of MPs in different river systems (Li et al. 2021, Singh et al. 2022). The common finding is the dominant anthropogenic influence on the spatial distribution of microplastics, with higher concentrations in urban areas potentially due to factors such as poor waste management strategies. The predominance of fibers in water samples could be due to car washing and laundry (Gasperi et al. 2015). The occurrence of microplastics in all the sampling sites of the river concurs with the findings of Li et al. (2021). This poses a potential threat to the river ecosystem and the community because they are highly persistent, bioaccumulative, and toxic. Microplastic accumulation in aquatic organisms, especially fibers, has been reported in some aquatic organisms, including fish (Kumar & Khan 2020). They may ultimately enter humans through the food chain.

CONCLUSION

Heavy metal analysis revealed alarming concentrations of arsenic in water and river sediments. For the river water samples, arsenic concentration was above the WHO and EPA permissible limits for all sections of the river studied. This poses a serious concern to health and the environment as arsenic is a known carcinogen capable of causing health problems. The overall geoaccumulation index of the river was in the range of 3-4, also classified under strong contamination of heavy metals in the river bed sediment. A couple of activities, namely plantation agriculture, laundry, and commercial car-washing, evidenced along the Mpanga River, may be contributing to heavy metal contamination in the river. Additionally, the elevation of Fort Portal to a tourism city status in 2020 is likely to lead to an increased population and number of tourists, resulting in increased waste generation and thus increased heavy metal and microplastics contamination of River Mpanga.

RECOMMENDATIONS

Mpanga River is the main source of water for Fort Portal City. Besides its use by the National Water and Sewerage Cooperation of Fort Portal City, the river is also used directly by the communities within its vicinity without any prior treatment. This is a major concern, as the water is contaminated with heavy metals, microplastics, and other pollutants. The study recommends a stakeholder awareness campaign to educate the public about the contamination of the river water. In addition, the study recommends a thorough investigation of the possibility of the presence of heavy metals and microplastics in domestic piped water. The study also highlights the need to examine the influence of seasonality, precipitation, and flow rate on microplastic abundances.

Dumping of waste in the river is common. Activities observed on the river included commercial car wash, plantation agriculture and laundry. In addition, the river is in close proximity to Kabundaire Market, the Kabundaire Abattoir, and Buhinga Hospital, which are all likely to contribute to contaminated effluents in the river. The study recommends advocating for arsenic-free washing detergents and designating areas for commercial car wash. Additionally, the city council could put in place structures for solid and water waste management.

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