Bharatpur Pragya : Journal of Multidisciplinary Studies
ISSN : 2990-773X (Print); ISSN : 2990-7748 (Online)
Published by Bharatpur Academy, Chitwan, Nepal
https://www.bharatpurmun.gov.np

An Evaluation of Microplastics Contamination in Narayani River

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Article History : *Submitted : 21th Nov. 2024; Reviewed : 15th Jan. 2025; Revised : 6th Feb. 2025*
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DOI : *https://doi.org/10.3126/bpjms.v3i01.76241*

Abstract

Plastic pollution has emerged as one of the growing challenges due to their relatively low production cost, unique physiochemical properties, ease in access, and little or no alternatives to its use and its use are not only limited to domestic, institutional, and industrial purpose. This study is conducted to examine the microplastics (MPs) contamination in the Narayani River - one of the major drainage systems of Nepal. The water samples from the Narayani River were taken from five different location in the first half of June 2023 covering around seven kilometer (km) of river stretch starting from the upstream of Devghat cremation site, to the downstream near the landfill site. Microplastics extraction from surface water was be performed with reference to National Oceanic and Atmospheric Administration (NOAA) and criteria described by (Hidalgo-Ruz et al., 2012) was followed to identify microplastics. In addition, hot needle tests were conducted to confirm whether the suspected particles were plastic or non-plastic. Results indicate, five different types of MPs namely, fiber, pellet, film, foam and fragment. A total number of 81 particles throughout the surface water samples of Narayani River. On average 0.53 particle per liter of fibers were found followed by film, fragments, foam and pallets with value of 0.16, 0.08, 0.03 and 0.01 particle per liters respectively. Lack of awareness, inefficient waste management, and municipal solid waste dumping together with increased urbanization were some of the major contributors to the MPs pollution in Narayani River.

Keywords: Aquatic ecosystems, fibers, religious site, urbanization, waste dumping.

Introduction

Plastic pollution has emerged as one of the growing challenges of the 21st century. Due to their relatively low production cost, unique physiochemical properties, ease in access, and little or no alternatives to its use; the use of these materials are not only limited to domestic, institutional, and industrial purpose. Globally, plastic waste is expected to surge from 353 Metric tons (Mt) in 2019 to 1,014 Mt by 2060 (OECD, 2022). The disturbing problem of plastic use is affecting the environmental health which is due to their high persistence nature. Plastics are primarily composed of hydrocarbon polymers like polyethylene $(C_2H_4)n$, polypropylene $(C_3H_6)n$, and polyethylene terephthalate $(C_{10}H_8O_4)n$, often with additives to enhance properties (Hopewell et al., 2009; Andrady & Neal, 2009). Plastic when dispersed in the surroundings alters water and soil quality and are estimated to last for hundreds to thousands of years (Barnes et al., 2009). Persistent nature of plastic pollution poses a significant threat disrupting environmental health for generations to come.

Microplastics (MPs) are tiny plastic particles that are either manufactured at a small scale or derived from the degradation of larger plastic items (Du et al., 2021) with diameter less than 5mm (Ding et al., 2020; Cole et al., 2015). Different sources of microplastics cause them to occur in diverse shapes such as fiber, fragments, film, pellets and foam in environmental samples (Klein et al., 2015). On land, they originate from sources such as agricultural runoff (Akdogan & Guven, 2019), plastic mulch degradation (Sajjad et al., 2022), and tire wear (Sommer et al., 2018; Kole et al., 2017). Studies have reported that these tiny particles are deposited to agricultural settings and transported to river network by various measures thereby altering soil and water chemistry and biological health.

Microplastics enter freshwater bodies through runoff from agricultural land (Akdogan & Guven, 2019), urban sewage drainage (Qaiser et al., 2023), solid waste disposal (Horton et al., 2017), overflow of drains during storm or rain event (Ochoa et al., 2024), and laundry activities (Browne et al., 2011). Once plastics reach the aquatic environment, their fate relies on many factors and they can be found in diverse shapes and sizes (Li et al., 2018). Schell et al. (2021), reported there is a link between rainfall and microplastics concentration. They affect the soils water infiltration rates and affecting plant growth and soil microorganisms (Liu et al., 2022) and are also transported the marine environment by river network (Jiang et al., 2018). Because of their ubiquitous presence and morphological features in aquatic ecosystem, life and development of biota is likely to be threatened via direct and indirect pathways, including contact, uptake and digestion (Farrell and Nelson, 2013; Long et al., 2015). Polypropylene (PP), Polyethylene terephthalate (PET) and Polyethylene (PE) are the most dominant polymer types found in river (Zhang et al., 2015). Studies have shown that the ingestion of microplastics can block and damage the digestive organs of invertebrates, resulting the reduction in reproductive as well as feeding capacity and their survival rate (Cole et al., 2015; Wright et al., 2013). Further studies revel that intake of microplastics can leach out toxic chemicals used as additives in the production process (Yang et al., 2021) as well as absorb variety of heavy metals and organic pollutants from the environment (Guo et al., 2018; Ding et al., 2020). In addition, microplastics have capacity to adsorb toxic hydrophobic contaminants that leads to the question of what risk of chemical exposure is faced by the aquatic biota (Beckingham and Ghosh, 2017). Several researchers have emphasized the issue of microplastics infiltrating the food web, bio-accumulation and amplification across the food chain, which poses significant risks to both the environment, ecological and human health.

The study of microplastics pollution in Nepal began from 2020, revealing microplastics in rivers, lakes, snow, and sediments (Maharjan, 2024). However, till date the study is very much limited (Amrutha et al., 2021; Bayar et al., 2022; Maharjan, 2024). Yang et al., (2021a) have identified atmospheric transport and deposition, urbanization, agriculture, tourism, traffic, and fishing as a major contributor to the MPs pollution in the sediments of Koshi River system. Furthermore, Guheshwori WWTP located at the bank of the Bagmati River identified fiber, fragments, foam, and pellets as the major form of MPs in Kathmandu valley. Among the lotic water system, traces of fibers as MPs has been identified in Phewa lake sediments (Malla-pradhan, 2022). Furthermore, anthropogenic and potential airborne sources were identified to be contributing factors of MPs pollution in the remote region of Sagarmatha National Park (Han et al., 2023). Kandel et al., (2023), have reported significant contamination of MPs in the Saptagandaki river system.

Narayani River which originates on the Tibetan Plateau is one of the main tributary of the Gandak river basin, and is a holy site for Hindu. Devghat located at the bank of the Narayani River, is one of the dispersed source of religious waste including plastics around its arena. Improper waste management, lack of awareness in waste dispose among the visitors are some of the contributors of the plastic waste in the river. The Narayani River which also serves as the major river that supports the wildlife habitat of the Chitwan National Park (CNP) if contaminated with MPs can disturb the ecosystem of the protected areas leading to further environmental disruption. This study aims to explore the types and the status of microplastics contamination in different sites of the Narayani River.

Limitations

The study focused on a seven-kilometer stretch of the Narayani river form Devghat to Nagarban area in the first weeks of monsoon season, thereby it may not fully reflect the overall pollution levels of the Narayani River. Furthermore, due to the unavailability of FT-IR technology, microplastics were examined using a digital microscope, thereby additional properties of identified MPs could not be further examined.

Materials and methods

Study area

The Narayani River, which marks up the boundary between the Nawalparshi-East and Chitwan is one of the major drainage systems of Nepal. The Chitwan District, situated in Nepal's Bagmati Province, is located between latitudes 27°21' and 27°46' and longitudes 85°55' and 85°35' and experiences a subtropical climate. The Kaligandaki River, the primary tributary, merges with the Trishuli (also known as Trisuli) River at Devghat in Chitwan District, where it is renamed the Narayani. This river system eventually flows southward into India, where it becomes the Gandak River before merging with the Ganges River system (Bohora et al., 2022).

The Narayani River borders Bagmati province in the east and Gandaki province in the west. Before entering to the CNP, divides in two main branches both of which supports the biodiversity of this protected areas.

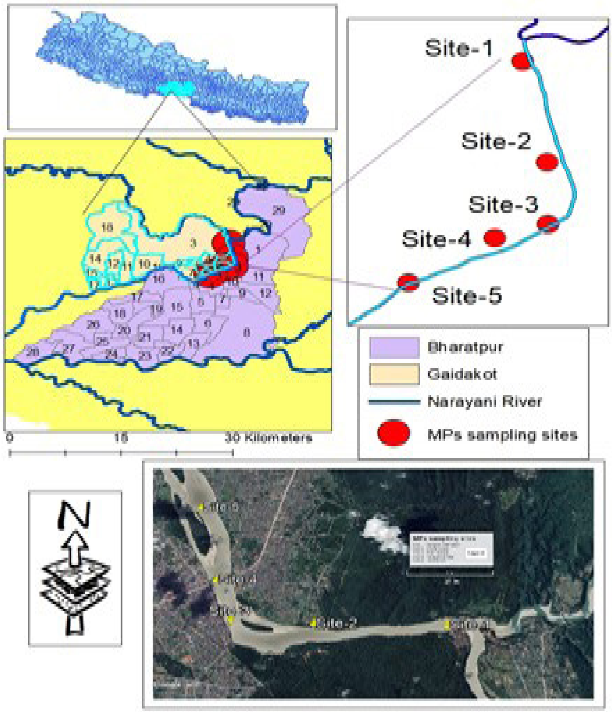

Figure 1: Study area showing sampling points

Sample collection

The water samples from the Narayani River were taken from five different location covering around seven kilometer (km) of river stretch starting from the upstream of Devghat cremation site, to the downstream near the landfill site. This distance covered along the river section is one of the most disturbed area of the Narayani River as the river enters around the urban areas of central Nepal. Four samples were collected towards Chitwan side of Narayani located in Bharatpur Metropolitan City whereas a single sample was collected from the Nawalpur side of the Narayani River of the Gaidakot Municipality (Table 1).

Table 1: Site details

Site	Location	Local level	Latitude	Longitude	Elevation (masl)	Site description
Site 1	Devghat Cremation	Bharatpur-1	27.737108	84.424056	169m	Holy site and Cremation area

Site 2	Near British Camp	Gaidakot-1	27.716139	84.428725	164m	Less settlement area, Forest area
Site 3	Near Ram Mandir	Bharatpur-3	27.703378	84.428742	167m	Rituals and residential area
Site 4	Narayani Bridge	Bharatpur-3	27.700631	84.418681	164m	Highway, core area
Site 5	Near Landfill Site	Bharatpur-3	27.691267	84.402097	168m	Municipal solid waste dumping site

The first site of observation was in the Devghat cremation area. The distance form this site-1 to site-2 had the stretch distance of 2400 meters. Similarly, the stretch form the site-2 to site-3 was 1500 meters, and that from site 3 to site-4 was around 1000 meters, whereas the stretch form the site-4 to the last site was 2000 meters, covering a total of 7km of river stretch form North-South.

The surface water samples was taken from two sampling sites in each location (Table-1) in the first half of June 2023, after the onset of the monsoon season in Nepal. A composite sample form each location was used to calculate the onsite parameters of the water sample. At each location, five liters (ltrs) of surface water (0-20cm in depth) was collected by using a steel bucket (Negrete Velasco et al., 2020; Su et al., 2016) at the distance of five meters form the water shoreline which was carefully transferred into glass bottle. This sample was filtered through a standard brass sieve at laboratory (Mao et al., 2020) using HPLC water. Similarly, one replica of sample was collected each at the distance of 5 meters and stored before analysis from each site. Furthermore, composite sample of one liters of surface water was collected to study some physio-chemical properties of water, making a total of three samples from each site.

The onsite parameters including the temperature pH and turbidity were taken each locations after the calibration of the instruments. Water temperature was measured by using alcohol thermometer and digital pH meter was used to measure the pH of the composite water sample of each site. For measuring the turbidity, circular Secchi disc attached to a rope was used and was lowered into the water and depth (cm) where its disappearance and reappearance figures were noted.

Extraction methods for MPs

Microplastics extraction from surface water was be performed with reference to National Oceanic and Atmospheric Administration (NOAA) (Masura et al., 2015). The sample was treated with saturated NaCl solution of 1.2mg/liter for density separation and stirred with the help of glass rod for a minute (Kunz et al., 2016). Then, to remove the influence of the organic matter, all water samples placed in glass bottles were treated with 20 ml of 30% Hydrogen Peroxide. After 5 minutes, it was heated on a hot air oven at 150°C for 20 minutes. This sample was allowed to cool and were stored for five days at room temperature. The sample was then filtered through 1mm sieve and filtrate were collected in a glass beaker and was carefully filtered through microfiber filter with diameter of 47-mm under a vacuum (Malla-Pradhan et al., 2022). The beaker was rinsed 2-3 times with HPLC water to ensure complete removal of microplastics. The filter papers were placed in clean petri dishes and were dried at room temperature for 24 hours. In the process of sampling and testing, any contact between samples and plastic products was avoided.

Identification of microplastics

The petri-dish along with filters were visually inspected under a digital microscope at 40x magnification in slides. Microplastics were identified according to their morphological characteristics into shape and color (Liu et al., 2019) and were classified into five types: fiber, pellet, film, foam and fragment. Criteria described by (Hidalgo-Ruz et al., 2012) was followed to identify microplastics.

Microplastics as fibers were identified consisting slender and greatly elongated appearance; pellets were round with spherical shape; a film was a very small and very thin layer or pieces of plastic debris; a fragment was an isolated or incomplete part of plastic debris; whereas foams were in its fluffy form. Any samples of MPs were classified as fragments when they couldn't be classified as film, fiber or pellets (Su et al., 2016).

Hot needle test

In addition, hot needle tests were conducted to confirm whether the suspected particles were plastic or non-plastic (De Witte et al., 2014). This test was done when MPs were confused with algae or any other substance in the water sample. After the preparation of slides, they were observed under microscope and incase of confusion with any other particles, the needle was used after heating and touched with the particle when under microscopic observation. If the suspect particles were microplastics, the hot needle would melt the MPs to confirm the substance under observation.

Control of contamination

A series of efforts were made to avoid contamination during sampling and laboratory analysis. A laboratory protocol were followed when inside the lab. The working environment was cleaned using 99% ethanol and apparatus used in the laboratory during analysis were rinsed with distilled water. Samples and glassware were covered with aluminum foil to minimize contamination. Water samples were processed inside the Laminar Air Flow Cabinet for further precaution. To find out airborne contamination, filter paper was kept open on a petri dish in the working environment for 24 hours. Filed blank test was also conducted analyze any contamination with the working environment.

Results

The average water temperature of the collected water was found to be 23 ˚C which ranged from 21˚C to 24.5˚C. Highest temperature was found in site 4 whereas lowest water temperature was found in Devghat cremation area (Site 1). Similarly, pH of the water samples ranged from 6.7 to 7.7 whereas the average pH was found to be 7.26. Lowest pH was found to be on the last site near the landfill area whereas the water sample has highest pH near the British camp (Site 2).

Table 2: Site specific physical parameters of Narayani water sample

S.N.	Site No.	Location	Temperature (˚C)	pH	Transparency (cm)
1	Site 1	Devghat Cremation	21	7.6	13.83
2	Site 2	Near British Camp	22	7.7	18.42
3	Site 3	Near Ram Mandir	23.5	6.8	6.22
4	Site 4	Narayani Bridge	24.5	7.5	19.05
5	Site 5	Near Landfill Site	24	6.7	5.63
Average			**23**	**7.26**	**12.63**

Also, the water sample has high turbidity around the landfill areas (site 5) whereas the transparency of water was high around the site of Narayani Bridge (Site 4), whose value ranges from 5.63 cm and 19.1 cm respectively. The average transparency of water was found to be 12.63 cm.

MPs contamination

Results illustrated that MPs were evident at all sampling sites with a total count of 81 particles throughout the surface water samples of Narayani River. The microplastics was highest (34.6%) in the site near the landfill with a total of 28 MPs count whereas, least number of MPs (6.2%) was found in the similar volume of water in site-2 i.e. the area around the British Camp. The 10 liters of sample form each location had 23.5%, 21%, and 14.8% of MPs count in site-4, site-3 and site-1 respectively.

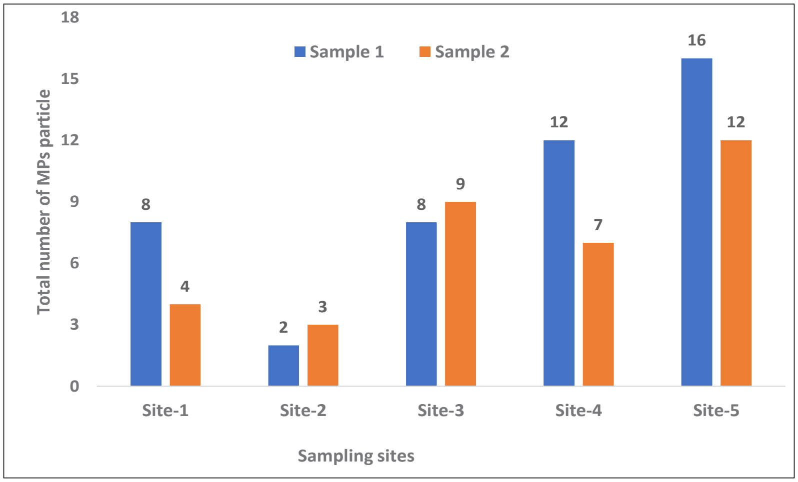

Figure 2: Total number of MPs on each sample of different location

More number of MPs were present in the first sample of the water compared to its replica (Figure 2). A total of 46 MPs were present in 25 liters of water collected as first sample in each site whereas, a total of 35 samples were recorded in rest of the 25 liters of water taken as sample-2 or replica. Five different types of MPs were observed form the collected volume of sample (Figure-3) were fiber, film, fragments, pellets and foam. Fiber and Films were the major microplastics recorded in all of the sites. Fiber constituted of 65.4% of the total MPs recorded and the average number of fiber particles was found to be 0.53 particles per liter (Figure 3).

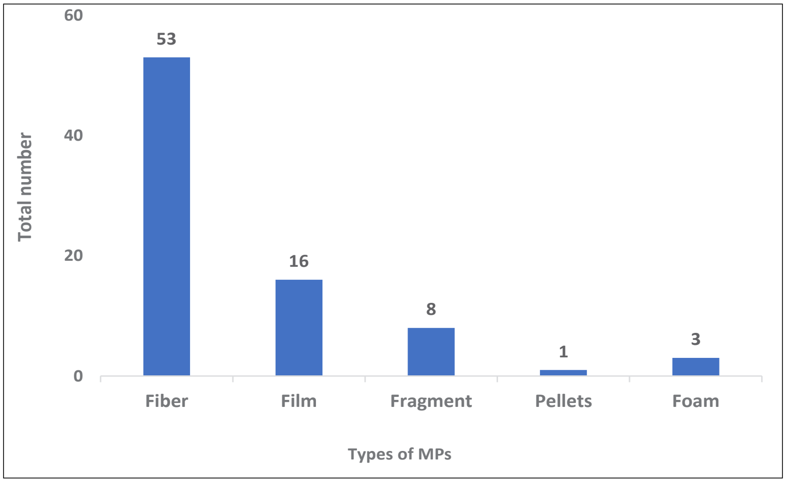

Figure 3: Types of MPs in the water sample

Similarly, film with the total MPs count of 19.8% was present at an average of 0.16 particles per liter. Least number of MPs was pellets comprising of a total of 1.2% count was recorded in a single location at an average of 0.01 particle per liter. Also, fragments comprising of 9.9% of MPs particle count was present at an average of 0.08 particle per liters. The count of foam was 3.7% and was present at an average of 0.03 particle per liters (Figure 3 & Table-3).

The fiber particle ranged from 0.2-0.8 particles per liters, which was the dominant MPs among all of the sample. Film with an average of 0.16 particle per liter was present at a range form 0.05-0.3 particle per liters in the water body. Similarly, fragments was present at an average of 0.08 particle per liters which ranged from 0.05-0.15 particle per liters. Whereas, pallets was present at a single site whose constituent was 0.05 particle per liters. At the last, foam was present in two of the study site and was detected at an amount of 0.05-0.1 particle per liters.

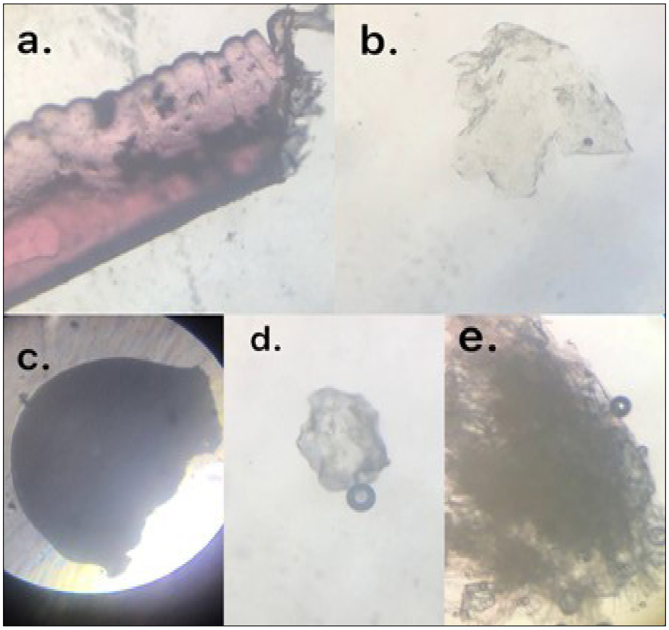

Figure 4: Microplastics under microscope (a. fiber, b. film, c. fragment, d. pellets, e. foam)

Table 3 shows that the stretch of the Narayani River contained an average of 0.162 particles per liters of MPs which varied form as high as 0.28 particles per liters in site-5, whereas a least of 0.05 particles per liters of MPs in site-2. The MP particles has increased form the upstream i.e. site-2 towards downstream.

Table 3: Average MPs in each site (particle per ltrs)

S.N.	Location	Fiber	Film	Fragments	Pellets	Foam	Average
1.	**Site-1**	0.4	0.15	0.05	0	0	0.12
2.	**Site-2**	0.2	0.05	0	0	0	0.05
3.	**Site-3**	0.55	0.1	0.15	0	0.05	0.17
4.	**Site-4**	0.7	0.2	0.05	0	0	0.19
5.	**Site-5**	0.8	0.3	0.15	0.05	0.1	0.28
Average		**0.53**	**0.16**	**0.08**	**0.01**	**0.03**	**0.162**

Furthermore, Table 3 shows that, the volume of water sample collected form the landfill site contaminated by all of the five types of MPs particles, followed by the sample of water collected form the Ram mandir which was contaminated by four categories of MPs particle. The sample of water collected from this area did not contain pallets. . The water sample other two location i.e. Devghat cremation and Narayani bridge contained the three types of MPs namely, fiber, film and fragments. The water sample near the British camp had only two types of MPs namely, fiber and film

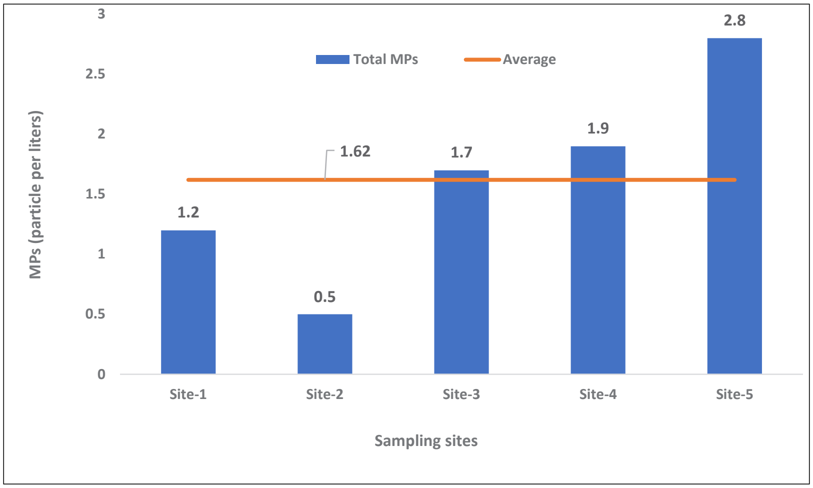

Figure 5: MPs particle per liters in Narayani River

Figure 3 shows that MPs in the water sample of the Narayani River contained 1.62 particle per liter which varied in different sites. The MPs particle present in site-1 and site-2 was below the average value, whereas site-3, site-4 and site-5 contained the MPs more than the average particle per liter. The MPs particle around the Narayani River varied form a minimum of 0.5 particle per liter to as high as 2.8 particle per liters.

Discussions

In the Devghat cremation area water sample was contaminated with three types of MPs (fiber, films and fragments) in the water sample (Table 3) that can be linked with the religious pollution together with inefficiency in waste management (Jiang et al., 2019). This section is nearly half kilometers downstream from the river confluence of the Kaligadaki and the Trishuli River known as the Devghat *Beni Sangam* and is a recognized place for spiritual bath. Hindu devote bath for spiritual purification, perform rituals, worship etc. in the rivers (Narayanan, 2001) where the practice of haphazard disposal of waste including plastic products is common (Sen, 2019). Waste are also transported form upstream to downstream by the rivers (Nel et al., 2018). It can be expected that, the plastic waste disposed around *Beni Sangam* is transported towards downstream cremation site which is within 500 meters distance. The haphazard disposal of plastic products and microplastics waste transport by the rivers form upstream to downstream are the two combined reasons for detection of MPs form the sample form the cremation area.

Similarly, the lowest number of microplastics was found at British Camp i,e. site-2, which was contaminated with fiber and films. Most of the area this stretch of the river passes from forest area, and water remains undisturbed as human activities are relatively low. Furthermore, rapid water flow and sedimentation in certain sections may lead to the deposition and accumulation of microplastics in sediments, resulting in lower counts in the water column (Matjašič et al., 2023). River's hydrological dynamics, including flow rates and sedimentation processes, might have contributed to reduced microplastics counts around this area.

The Narayani River flows through urban areas before reaching the Ram Mandir (site-3), where ritual activities are held and the area is disturbed. At this site, fibers, films, fragments, and foam have all been recorded. Urban sewage systems and solid waste disposal practices are significant sources of MP pollution in the river (Horton et al., 2017). Domestic sewage is directly discharged into the river before it reaches this location. Studies have recorded the MPs abundance higher at sites which are in close proximity to urban areas compared to remote ones (Mani et al., 2015; Yonkos et al., 2014). As the Narayani River passes through the urban area of BMC, where sewage and drainage systems are mixed with the river water, these factors further contribute to the microplastic contamination to the Narayani water samples at the Ram Mandir site.

Fiber, films and fragments were recorded as the major MPs around the Narayani Bridge segments of the river. More people visit these areas for aesthetic pleasure and is one of the tourism hotspots of Bharatpur Metropolitan city (BMC). Furthermore, BMC also organizes the *mathosab* in this section once in a year, which attracts more business hubs and visitors. Behmanesh et al. (2023), in their study in Iran have shown that tourism activities is one of the major contributors to MPs contamination in Zayandeh-rood river water. This section in Narayani further supports small business houses, hotels, recreational activities including boating, foot trails and other commercial activities such as laundry, carwash etc. Laundry activities are the sources from which MPs are introduced into freshwater environment (Browne et al., 2011). Furthermore, in the second half of 2022, Bharatpur Metropolitan city (BMC) had dumped the municipal plastics waste together with river sediments to organize a public event (i.e. *mahotshab*) in between the site-3 and site-4 section of the river channel. These activities could have triggered for more plastic waste pollution in this area compared to the previous three sites.

The Landfill site which is located at the downstream site was highly affected by the MPs and all of the types of the MPs were recorded. Municipalities dump municipal solid waste on the bank of the river (Khadka, 2020), and BMC is not exception to it. *Nagarban*, located at the mid of the two branches of Narayani River is a place where BMC has practiced open dumping of its municipal waste. Both of these branches of Narayani River enters the CNP and is buffer zone which is a major water source that supports its biodiversity. Presence of all five types of MPs and highest number of microplastics particle per liter indicated that open waste dumping in *Nagarban* have contaminated Narayani River with MPs. Such small fragments of MPs can be ingested aquatic life including fish (Neves et al., 2015; Hermsen et al., 2017; Jabeen et al., 2017) due to misidentification for feeding (Ory et al., 2017) or indirectly as a result of trophic transfer along the food web (Nelms et al., 2018).

A study by Patidar et al. (2024), in the two Indian rivers found that fiber and films were the predominant microplastics recorded due to their widespread sources and persistence in aquatic environments. Sample of water form Narayani River indicates the similar findings as higher number of fibers (65.4%), followed by films (19.8%) were evident in all of the sites which make up more than three-four quarters of total MPs recorded. Studies have shown that the presence of fibers can be attributed with domestic laundry discharges, washing of textiles, solid wastes and high fishing activity (Browne et al., 2011; Yuan et al., 2019). Degradation of synthetic textiles is also a major contributor to fiber pollution (Silva & Nanny., 2020; Patidar et al., 2024). Microplastics films found in river water was the second most common type after fibers (Patidar et al., 2024), and is supported by the findings of this study. Similarly, the high occurrence of films can be attributed to their lightweight nature, which facilitates their dispersion and accumulation in river systems, particularly in areas influenced by urbanization and industrial activities (Karing et al., 2023). Additionally, the presence of film can be associated with various anthropogenic factors such as plastic waste disposal, urban and industrial runoff, and plastic degradation in the environment (Eerkes – Medrano et al., 2015). Degradation of larger plastic debris into smaller film particles contributes to their abundance in freshwater ecosystems (Saputri et al., 2023). There is an increasing pattern in distribution of MPs towards the downstream from urban areas (Silva & Nanny, 2020). The Narayani River water samples exhibited a similar trend, as the water passes form relatively less disturbed area (site-2), the presence of fibers and films as the major constituents of MPs had increased in the downstream of the river section (Table-3).

Fragments were presents in four of the sampling sites in the water sample of Narayani River. The generation of small fragments from the environmental ageing of microplastics (MPs) is still a poorly known process (Sorasan et al., 2022). However, studies have shown that, larger plastic items, including fragments, can degrade into smaller microplastics due to weathering processes, exposure to sunlight, and mechanical action (Andrady & Koongolla, 2022). As a result, the original fragments may have broken down into smaller particles, leading to lower counts of visible fragments and pellets in the river (Horton et al., 2017).

Data indicate that the MPs contamination due to foam and pallets were the lower in the sample of Narayani River. Pellets may derive from the breakdown of larger plastic debris or be directly introduced as industrial granules or cosmetic microbeads (Frère, 2017). These particles are extensively used across industries such as textiles, construction, electronics, and healthcare which persist in the environment in a long run due to their slow degradation (An et al., 2020). Furthermore, Pellets and foam can enter rivers during heavy rainfall, which transports them from residential areas (Malla-Pradhan et al., 2022). These findings illustrate that MPs particles are found around the urban areas and landfill sites.

At the last, the samples form the Narayani River indicate that water is not free form MPs contamination, however has varied in concentrations form place to places. Some of the causes of MPs pollution includes, human activities, around the river and river channel, urbanization, and urban runoff, and unmanaged solid waste dumping inside the river channel. Lack of awareness among the visitors, inefficiency in waste management together with urban environment can be the causes of increased MPs particle in this area. Human activities such as bathing, cremation, aesthetic purpose, laundry, vehicle wash etc. have all contributed to the MPs contamination to this river system.

MPs contamination of the Narayani River can lead to the serious concerns as this river is also the heart of the CNP, which supports diverse life forms including aquatic and terrestrial ecosystems. These micro particles can be easily ingested by the aquatic animals which inurn not only disrupts the ecosystem but also can pass to the higher tropic level of the food chain. The worsening scenario is that the local government itself have not identified the consequences of MPs but is itself responsible for adding up piles of microplastics as the river is itself the primary dumping site of its municipal waste. These MPs can easily transfer to the river when the level of water is high and the landfill wastes are washed during the peak flood levels of the Narayani River.

Conclusion

Five types of MPs were identified along the seven kilometers stretch of Narayani River section, out of which the fiber was found in every sample of river water. Whereas, pellets was identified in a single downstream section of river. On average 0.53 particle per liter of fibers were found followed by film, fragments, foam and pallets with value of 0.16, 0.08, 0.03 and 0.01 particle per liters respectively. Some of the causes of MPs contamination of Narayani River are worships and rituals around the banks, unregulated waste collection and management system, haphazard disposal of solid waste, increased urbanization around the river banks, dumping of sewerage into the river, practice of open disposal of municipal solid waste within the river channel, recreational tourism activities around the river bank, lack of awareness of visitors, small scale business activities including laundry, carwash etc.

Recommendations

To address microplastic (MP) contamination, it is recommended that local and provincial governments must enforce effective regulations and develop comprehensive plans. Visitors must be aware and encouraged to use waste collection arrangements. Plastics can be replaced by biodegradable paper bags. Regular river-cleaning campaigns and initiatives can be launched at regular intervals to minimize MPs pollution of river. BMC should improve the waste collection and recycling systems and primarily focus on construction of sanitary landfill and should be established far from river sources. Ensuring the treatment of domestic and municipal wastewater before discharge are essential. Additionally, activities such as car washing, laundry, and tourism near the river should be strictly regulated to minimize their impact.

References

Akdogan, Z. & Guven, B. (2019) Microplastics in the environment: a critical review of current understanding and identification of future research needs. *Environmental Pollution, 254, 113011*

Amrutha, K., Unnikrishnan, V., Shajikumar, S., & Warrier, A. K. (2021). Current State of Microplastics Research in SAARC Countries—A Review. In *Sustainable textiles* (pp. 27–63). https://doi.org/10.1007/978-981-16-0297-9_2

An, L., Liu, Q., Deng, Y., Wu, W., Gao, Y., Ling, W. (2020). Sources of Microplastic in the Environment. In: He, D., Luo, Y. (eds) Microplastics in Terrestrial Environments. The Handbook of Environmental Chemistry, vol 95. Springer, Cham. https://doi.org/10.1007/698_2020_449

Andrady, A. L., & Koongolla, B. (2022). Degradation and fragmentation of microplastics. *Plastics and the Ocean: Origin, Characterization, Fate, and Impacts*, 227-268.

Andrady, A. L., & Neal, M. A. (2009). Applications and societal benefits of plastics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 1977-1984.

Baburam, Kandel., Nabin, Adhikari., K., Anuradha., Asmita, Karki., Hari, Paudyal., Khaga, Raj, Sharma., Basant, Giri., Bhanu, Bhakta, Neupane. (2023). 4. Distribution of Microplastic Contamination in Sapta-Gandaki River System, Nepal. https://doi.org/10.31219/osf.io/5s7wm

Barnes, D.K., Galgami, F., Thompson, R.C., Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. Philosophical transactions of the royal society biological sciences, 364(1526), 1985-1998.

Bayar, J., Hashmi, M. Z., Khan, M. A., Pongpiachan, S., Su, X., & Chakaraborty, P. (2022). Emerging issue of microplastic in sediments and surface water in South Asia: A review of status, research needs, and data gaps. *Emerging Contaminants and Associated Treatment Technologies*, 3–19. https://doi.org/10.1007/978-3-030-89220-3_1

Beckingham, B. and Ghosh, U. (2017). Differential availability of polychlorinated biphenyls associated with environmental particles: Microplastic in comparison to wood, coal and biochar. *Environmental pollution*, *220*, 150-158.

Behmanesh, M., Chamani, A., & Chavoshi, E. (2023). Sedimentary abundance and major determinants of river microplastic contamination in the central arid part of Iran. *Applied Water Science*, *13*(12), 239.

Bohara, S., Joshi, R., & Poudel, B. (2022). Population Status, Distribution and Threats of the Critically Endangered Gharial (Gavialis gangeticus) in Narayani River of Chitwan National Park, Nepal. *Journal of Animal Diversity*, 4(1), 1–17. https://doi.org/10.52547/jad.2022.4.1.1

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of microplastic on shorelines woldwide: sources and sinks. *Environmental science & technology*, *45*(21), 9175-9179.

Cole, M., Lindeque, P., Fileman, E., Halsbad, C., Galloway, T.S. (2015). The impact of polystyrene microplastics on feeding, function and fecundity in the Marine Copepod *Calanus Helgolandicus*

De Witte, B., Devriese, L., Bekaert, K., Hoffmann, S., Vandermeersch, G., Cooreman, K., Robbens, J. (2014). Quality assessment of the blue mussel (*Mytilus edulis*): Comparison between commercial and wild types. *Marine Pollution Bulletin, 85*(1), 146-155.

Ding, L., Mao, R., Ma, S., Guo, X., & Zhu, L. (2020). High temperature depended on the ageing mechanism of microplastics under different environmental conditions and its effect on the distribution of organic pollutants. *Water Research*, *174*, 115634. https://doi.org/10.1016/j.watres.2020.115634

Du, S., Zhu, R., Cai, Y., Xu, N., Yap, P., Zhang, Y., . . . Zhang, Y. (2021). Environmental fate and impacts of microplastics in aquatic ecosystems: a review. RSC Advances, 11(26), 15762–15784. https://doi.org/10.1039/d1ra00880c

Eerkes – Medrano, D., Thompson, R.C., Aldridge, D.C. (2015). Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritization of research needs. *Water research*, *75*, 63-82.

Farrell, P, Nelson, K. (2013). Trophic level transfer of microplastics: *Mytilus edulis*(L) to *Carcinus maenns*(L). *Environmental Pollution* 177,1-3

Frère, L. (2017). *Les microplastiques: une menace en rade de Brest?* (Doctoral dissertation, Université de Bretagne occidentale-Brest).

Guo, X., Pang, J., Chen, S., & Jia, H. (2018). Sorption properties of tylosin on four different microplastics. *Chemosphere*, *209*, 240–245. https://doi.org/10.1016/j.chemosphere.2018.06.100

Hermsen, E., Pompe, R., Besseling, E., & Koelmans, A. A. (2017). Detection of low numbers of microplastics in North Sea fish using strict quality assurance criteria. *Marine Pollution Bulletin*, *122*(1–2), 253–258. https://doi.org/10.1016/j.marpolbul.2017.06.051

Hidalgo-Ruz, V., Gutow, L., Thompson, R.C., Theil, M. (2012). Microplastics in the marine environment: a review of the methods used for identification and quantification. *Environmental Science & Technology* 46,3060-3075

Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2115-2126.

Horton, A. A., Svendsen, C., Williams, R. J., Spurgeon, D. J., & Lahive, E. (2017). Large microplastic particles in sediments of tributaries of the River Thames, UK–Abundance, sources and methods for effective quantification. *Marine pollution bulletin*, *114*(1), 218-226.

Horton, A.A., Walton, A., Spurgeon, D.J., Lahive, E., Svendensen, C. (2017). Microplastics in freshwater and terrestrial environments: evaluating the current understanding to identify the knowledge gaps and future research priorities. *Science of the Total Environment* 586,127-141

Jabeen, K., Su, L., Li, J., Yang, D., Tong, C., Mu, J., & Shi, H. (2017). Microplastics and mesoplastics in fish from coastal and fresh waters of China. *Environmental Pollution*, *221*, 141–149. https://doi.org/10.1016/j.envpol.2016.11.055

Jiang, C., Yin, L., Wen, X., Du, C., Wu, L., Long, Y., Liu, Y., Ma, Y., Yin, Q., Zhou, Z., Pan, H. (2018). Microplastics in sediments and surface water of West Donting Lake and South Dongting Lake: abundance, source and composition. *Environmental Pollution* 244,958-965

Jiang, Changbo, Lingshi Yin, Zhiwei Li, Xiaofeng Wen, Xin Luo, Shuping Hu, Hanyuan Yang et al. "Microplastic pollution in the rivers of the Tibet Plateau." *Environmental Pollution* 249 (2019): 91-98.

Karing, D. J., Anggiani, M., Cao, L. T. T., & El-Shaammari, M. (2023). Occurrence of microplastics in Kemena River and Niah River of Sarawak, Malaysia. *Deleted Journal*, *1*(1), 1–13. https://doi.org/10.53623/tebt.v1i1.220

Khadka, S. (2020). Learning from River Cleaning Campaign: A Case Study of Bagmati River. *Asian journal of Social Sciences and Management*, *1*(1), 76-98.

Kishor, Kumar, Maharjan. (2024). 1. Microplastics research in Nepal: Present scenario and current gaps in knowledge. Heliyon, doi: 10.1016/j.heliyon.2024.e24956

Klein, S., Worch, E. & Knepper, T.P. (2015). Occurrence and spatial distribution of microplastics in river shore sediments of the Rhine – Main area in Germany. *Environmental science & technology*, *49*(10), 6070-6076.

Kole, P. J., Löhr, A. J., Van Belleghem, F. G., & Ragas, A. M. (2017). Wear and tear of tyres: a stealthy source of microplastics in the environment. *International journal of environmental research and public health*, *14*(10), 1265.

Li, J., Liu, H. & Chen, J.P. (2018). Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastics detection. *Water research*, *137*, 362-374

Liu, S., Jian, M., Zhou, L., Li, W. (2019). Distribution and characteristics of microplastics in the sediments of Poyang Lake, China. *Water Science & Technology* 79,1868-1877

Liu, Z., Cai, L., Dong, Q., Zhao, X., & Han, J. (2022). Effects of microplastics on water infiltration in agricultural soil on the Loess Plateau, China. *Agricultural Water Management*, *271*, 107818.

Long, M, Moriceau, B., Gallinari, M., Lambert, C., Huret, A., Raffray, J., Soudant, P.

(2015). Interaction between microplastics and phytoplankton aggregates: Impact on their respective fates. *Marine Chemistry* 175,39-46

Malla-Pradhan, R., Phoungthong, K., Suwunwong, T., Joshi, T. P., & Pradhan, B. L. (2022). Microplastic pollution in lakeshore sediments: the first report on abundance and composition of Phewa Lake, Nepal. *Environmental Science and Pollution Research*, *30*(27), 70065–70075. https://doi.org/10.1007/s11356-023-27315-4

Mani, T., Hauk, A., Walter, U., & Burkhardt-Holm, P. (2015). Microplastics profile along the Rhine River. *Scientific reports*, *5*(1), 17988.

Mao, R., Hu, Y., Zhang, S., Wu, R., Guo, X. (2020). Microplastics in the surface water of Wuliangsuhai Lake, northern China. *Water Science & Technology* 723, 137820

Masura, J., Baker, J., Foster, G., Arthur, C. (2015). Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments.

Matjašič, T., Mori, N., Hostnik, I., Bajt, O., & Viršek, M. K. (2023). Microplastic pollution in small rivers along rural–urban gradients: Variations across catchments and between water column and sediments. *Science of the total environment*, *858*, 160043.

Narayanan, V. (2001). Water, wood, and wisdom: Ecological perspectives from the Hindu traditions. *Daedalus*, *130*(4), 179-206.

Negrete Velasco, A. D. J., Rard, L., Blois, W., Lebrun, D., Lebrun, F., Pothe, F., & Stoll, S. (2020). Microplastic and fibre contamination in a remote mountain lake in Switzerland. *Water*, *12*(9), 2410.

Nel, H. A., Dalu, T., & Wasserman, R. J. (2018). Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. *Science of the Total Environment*, *612*, 950-956.

Nelms, S. E., Galloway, T. S., Godley, B. J., Jarvis, D., & Lindeque, P. K. (2018). Investigating microplastic trophic transfer in marine top predators. *Environmental Pollution*, *238*, 999–1007. https://doi.org/10.1016/j.envpol.2018.02.016

Neves, D., Sobral, P., Ferreira, J. L., & Pereira, T. R. (2015). Ingestion of microplastics by commercial fish off the Portuguese coast. *Marine Pollution Bulletin*, *101*(1), 119–126. https://doi.org/10.1016/j.marpolbul.2015.11.008

Ochoa, L., Chan, J., Auguste, C., Arbuckle-Keil, G., & Fahrenfeld, N. (2024). Stormwater runoff microplastics: Polymer types, particle size, and factors controlling loading rates. *The Science of the Total Environment*, *929*, 172485. https://doi.org/10.1016/j.scitotenv.2024.172485

Organization for Economic Co-operation and Development (2022). Global plastic waste set to almost triple by 2060. https://www.pna.gov.ph/articles/1175904

Ory, N. C., Sobral, P., Ferreira, J. L., & Thiel, M. (2017). Amberstripe scad Decapterus muroadsi (Carangidae) fish ingest blue microplastics resembling their copepod prey along the coast of Rapa Nui (Easter Island) in the South Pacific subtropical gyre. *Science of the Total Environment*, *586*, 430–437. https://doi.org/10.1016/j.scitotenv.2017.01.175

Patidar, K., Ambade, B., Younis, A. M., & Alluhayb, A. H. (2024). Characteristics, fate, and sources of microplastics contaminant in surface water and sediments of river water. *Physics and Chemistry of the Earth Parts a/B/C*, *134*, 103596. https://doi.org/10.1016/j.pce.2024.103596

Qaiser, Z., Aqeel, M., Sarfraz, W., Rizvi, Z. F., Noman, A., Naeem, S., & Khalid, N. (2023). Microplastics in wastewaters and their potential effects on aquatic and terrestrial biota. *Case Studies in Chemical and Environmental Engineering*, *8*, 100536. https://doi.org/10.1016/j.cscee.2023.100536

Sajjad, M., Huang, Q., Khan, S., Khan, M. A., Liu, Y., Wang, J., Lian, F., Wang, Q., & Guo, G. (2022). Microplastics in the soil environment: A critical review. *Environmental Technology & Innovation*, *27*, 102408. https://doi.org/10.1016/j.eti.2022.102408

Saputri, D., Hamdhani, H., & Suryana, I. (2023). Microplastic in Water and Sediment from the Middle Segment of Karang Mumus River, Samarinda City, East Kalimantan. *Jurnal Ilmu Perikanan Tropis Nusantara (Nusantara Tropical Fisheries Science Journal)*, *2*(2), 128–134. https://doi.org/10.30872/jipt.v2i2.679

Schell, T., hurley, R., Nizzeto, L., Rico, A., Vighi, M. (2021). Spatio-temporal distribution of microplastics in a Mediterranean river catchment: the importance of waste water as an environmental pathway.

Sen, S. (2019). *Ganges: The many pasts of an Indian river*. Yale University Press.

Sommer, F., Dietze, V., Baum, A., Sauer, J., Gilge, S., Maschowski, C., & Gieré, R. (2018). Tire abrasion as a major source of microplastics in the environment. *Aerosol and air quality research*, *18*(8), 2014-2028.

Sorasan, C., Edo, C., González-Pleiter, M., Fernández-Piñas, F., Leganés, F., Rodríguez, A., & Rosal, R. (2022). Ageing and fragmentation of marine microplastics. Science of The Total Environment, 827, 154438.

Su, L., Xue, Y., Li, L., Yang, D., Kolandhasamy, P., Li, D., Shi, H. (2016). Microplastics in Taihu lake, China. *Environmental Pollution* 216,711-719

Wright, S.L., Thompson, R.C., Galloway, T.S. (2013). The physical impacts of microplastics on marine organisms: a review. *Environmental Pollution* 286,483-492

Yang, L., Luo, W., Pin, Z., Zhang, Y., Kang, S., Giesy, J. P., & Zhang, F. (2021a).

Microplastics in the Koshi River, a remote alpine river crossing the Himalayas from China to Nepal. *Environmental Pollution*, *290*, 118121. https://doi.org/10.1016/j.envpol.2021.118121

Yonkos, L. T., Friedel, E. A., Perez-Reyes, A. C., Ghosal, S., & Arthur, C. D. (2014). Microplastics in four estuarine rivers in the Chesapeake Bay, USA. *Environmental science & technology*, *48*(24), 14195-14202.

Yuan, W., Liu, X., Wang, W., Di, M., & Wang, J. (2019). Microplastic abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake, China. *Ecotoxicology and environmental safety*, *170*, 180-187.

Zhang, K., Gong, W., Lv, J., Xiong, X., Wu, C. (2015). Accumulation of floating microplastics behind the Three Gorges Dam. *Environmental Pollution* 204,117-123