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Spatial distribution of microplastic contamination in Sunyani municipal Rivers, Ghana: Insights into environmental persistence and ecological impact

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ABSTRACT

Microplastics are gradually becoming emerging contaminants worldwide. This is mostly due to the improper disposal of plastic waste. However, comparative data on microplastic levels in freshwater systems is still scarce for most developing countries. Therefore, this study aims to determine the presence of microplastics in selected rivers in Sunyani, Ghana. Also, forty questionnaires were administered to residents around the river banks to ascertain their knowledge of microplastics. The responses revealed that the residents had limited knowledge about the pollution of the rivers with microplastics. The study further investigated the abundance of microplastics in the water. The number of particles was estimated to be 220, 215, 280 and 120 per mL of the water sample.

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Capsule Summary: This study investigates the awareness among residents regarding microplastic pollution. By examining both public understanding and environmental realities, this research aims to provide comprehensive insights into the prevalence and implications of microplastic contamination in the Ghana River ecosystem.

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INTRODUCTION

Plastics were considered one of the greatest inventions of the 20th century. They gained widespread applications due to their properties such as relatively low weight and durability. This has corresponded to their exponential production (Shen et al., 2020). However, their improper disposal has caused more harm than good. The worst part is that a greater percentage of these plastic wastes find their way into water bodies. It has been estimated by an earlier report that a total of 250 million tons of plastics will be discharged into waterbodies by 2025 (Jambeck et al., 2015). Plastics have service lives ranging from 1 to over 50 years depending on their use before disposal (Enfrin et al., 2019). This implies that they can stay in the environment for years without much degradation. However, under favorable conditions, plastic undergoes chemical, physical and biological modification leading to fragmentation into smaller pieces referred to as microplastics (Julienne et al., 2019). These have dimensions between 1 µm to 5 mm (Thompson et al., 2004). Microplastics can be classified into primary (originally produced as micro-sized polymers) or secondary (caused by fragmentation of larger plastics) depending on their sources. The major processes that have been reported to aid plastic fragmentations are photo-oxidation and hydrolysis (Enfrin et al., 2019).

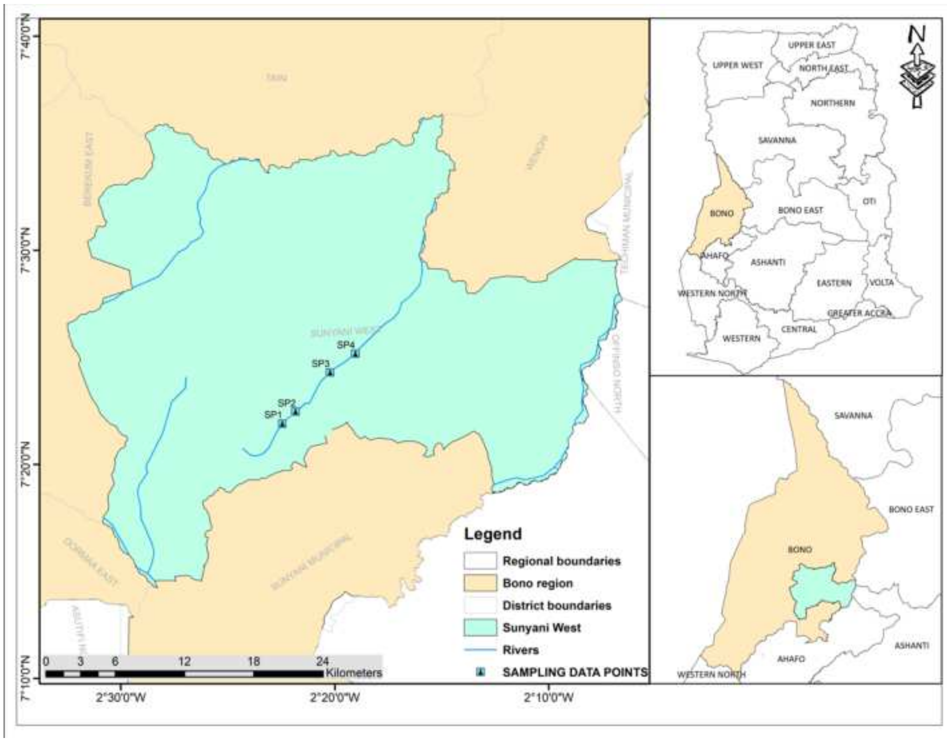

Fig. 1: Map of Ghana showing the study area

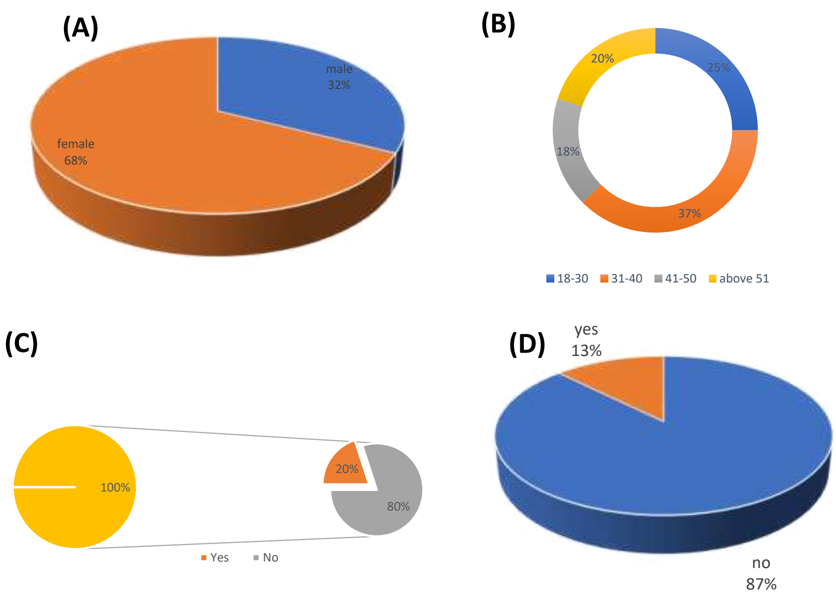

Fig. 2: Pie chart of the (A) gender (B) age (C) knowledge about microplastics and (D) presence of microplastics in the water bodies.

Microplastics have been identified in water bodies at least over the last five decades (Andrady, 2011) and are now being considered emerging contaminants globally. Improper disposal of plastics is a major contributor to the pervasive of these secondary microplastics in the environment. Previously, most researches on microplastics were centered around seas and oceans as reviewed earlier (Andrady, 2011), (Zobkov & Esiukova, 2018), (Guo & Wang, 2019). However, additional concerns have emerged upon the identification of microplastics in freshwater bodies (Chen et al., 2020). The reported high loads of microplastics in freshwater have raised the urgency to better understand their sources and the various anthropogenic impacts that may help improve pollution management practices (Su et al., 2020). A comparative assessment of microplastic in sediment and water of the Elbe River (Europe) revealed that the sediments had over 600,000-fold contamination as compared to the water sample (Scherer et al., 2020). Much recently, reports on the identification of microplastics in drinking water are even more alarming although their levels are relatively low (Mintenig et al., 2019, Schymanski et al., 2018, Tong et al., 2020).

The occurrence of these microplastics in the environment has been reported to have several negative impacts. For instance, microplastics can adsorb and accumulate metals and organic pollutants onto their surfaces. Also, due to their small sizes, they can be mistakenly ingested as food by aquatic organisms. This can cause negative effects on the growth, survival, metabolism and general wellbeing of aquatic organisms. Furthermore, microplastics have been reported to cause blockage of the gastrointestinal system of animals. Lastly, microplastics can also enter humans through the food chain (Du et al., 2020). A recent review has reported the detection of microplastic in fecal matter of lower to higher trophic organisms (Pérez-Guevara et al., 2021).

Although there is a growing number of studies on the occurrence of microplastic in the environment, the challenge however is that most of these researches are centered around developed countries with little or no attention on developing countries (Koelmans et al., 2019), (Scherer et al., 2020), (Tong et al., 2020). This may partly be due to the sophisticated and expensive instrument used for microplastic detection. These instruments include a scanning electron microscope, atomic force microscope, gas chromatography-mass spectrometer, and Raman spectrometer (Schymanski et al., 2018, Tong et al., 2020). This leaves the light microscope as the most commonly used instrument for microplastic identification in environmental samples. Hence, this research investigates the occurrence of microplastics in selected rivers in the Sunyani municipal using a light microscope.

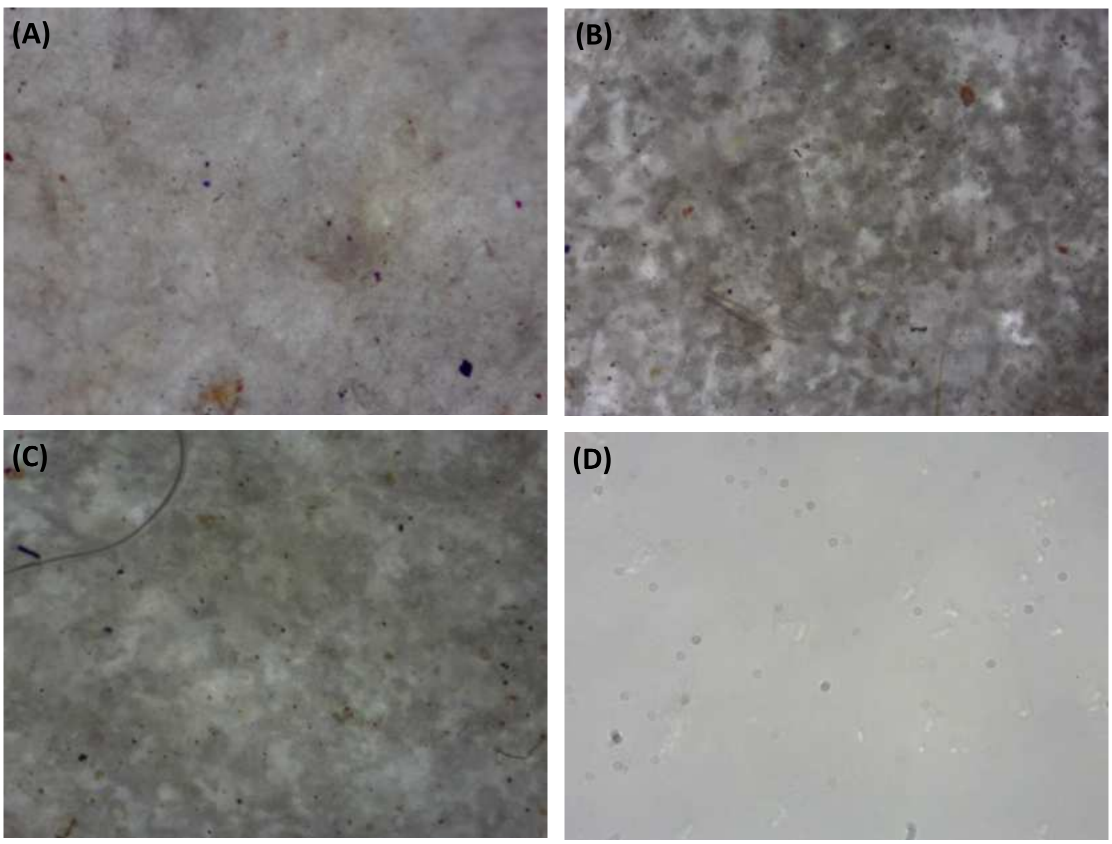

Fig. 3: Microscopic images showing the microplastics

MATERIAL AND METHODS

Sampling area

The study was conducted in Fiapre**,** a suburb of Sunyani. Fiapre shares a boundary with Berlin's top to the north, Odumasi to the south, Dumasua to the east, and Sunyani to the west within the Sunyani West Municipality. The vegetation of this locality consists of grasses with scattered low trees. The climate is tropical with an average temperature of 25.7 °C. Sunyani had about 1,208,649 residents as of 2021, and its coordinates are 7°20′N 2°20′W, with a Latitude: of 7°20′23″ N and Longitude: of 2°19′36″ W. Sunyani is surrounded by a forested uplands with approximately 48% of the population engaged in agriculture. The physiography of the Sunyani area is mainly a dissected Plateau. Its ground elevation rises to between 240 m and 300 m above sea level.

Sampling and sample preparation

This study used a mixed-method approach. Typically, laboratory analyses of water samples from 4 sampling points along River Atadea (Fig. 1) and responses to questionnaires from 40 respondents (10 around each sampling site) made up the data for this study. The 4 sampling points were chosen based on the ease of sample collection and the river's geography. The points were approximately 2 km apart.

Before the sampling, glass jars were acid-washed, rinsed severally with distilled water and air-dried. Onsite, sampling was done by venturing into the river to a depth of about 10–15 cm and gently submerging the glass jar to fill as reported earlier (Gbogbo et al., 2020). All samples were transported to the laboratory and kept at 4 °C until analyses. The water samples were prepared as reported earlier (Gbogbo et al., 2020). Typically, the samples were shaken to disperse all solid matter in them. About 10 ml of each water sample was digested with 6 ml of 30% H_2O_2 at 35 °C for 48 hours. The resulting solution was filtered using a glass funnel fitted with filter paper. A drop of the filtrate was then examined visually under a light microscope.

RESULTS AND DISCUSSION

This study provides an overview of knowledge on microplastic pollution in selected water bodies in Sunyani. The study also set a baseline for further research into the occurrence of microplastics in the aquatic environment in Ghana as a whole. The need therefore to develop efficient and cost-effective methodologies for analyzing microplastics cannot be overemphasized to fill the research gap.

Out of the 40 respondents interviewed, 68% were females which were expected because they usually fetch water for domestic use from the rivers (Fig 2A). A similar observation has been reported earlier (Adu-Boahen et al., 2020). Most of the respondents were between 31 and 40 years old (Fig 2B). Although all the respondents had heard about plastics, only 20% knew about microplastics (Fig 2C) confirming an earlier report on the Akora River in Ghana (Adu-Boahen et al., 2020). Out of 20% who had heard about microplastics, 75% of them had no idea of their health implications. Irrespective of their knowledge about microplastics, 87% of the respondent had no idea of their presence in the selected water bodies (Fig 2D). None of the respondents had any idea about how microplastics could be identified and removed from the water body. The responses present a huge knowledge gap about microplastics within the Sunyani municipality. And therefore, a need for immediate education.

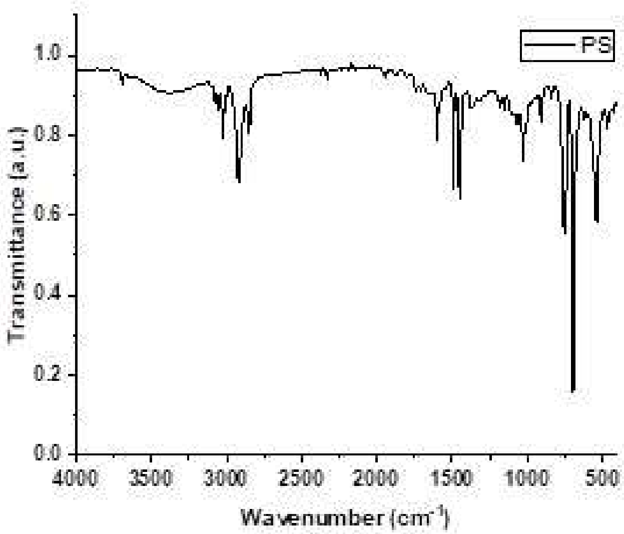

Fig. 4: FTIR spectrum of a representative microplastic

Although the visual identification of microplastics has been reported to have a potential for overestimation, it was considered ideal in this study because of the multicolored nature of the particles. An earlier report on the use of 1% Rose Bengal stain in distinguishing microplastics from environmental samples was discriminatory against red microplastics leading to an underestimation of the number of microplastics (Gbogbo et al., 2020). To reduce the overestimation of the amount of microplastics in the water samples in this study, the samples were first digested to reduce the organic matter content without affecting the properties of the microplastics. The microplastic content was then determined by visualization with the help a of a light microscope. This is one of the widely used approaches which is based on physical properties (Prata et al., 2019).

Therefore, with the aid of a microscope, microplastics were identified based on their color (black, white, transparent, grey, silver, brown, purple, blue, turquoise, green, yellow, orange, pink, red), size (particle diameter) and shape (fragment, sphere, fiber, foils). The microscopic approach provides quick and low-cost identification and quantification of microplastics (Li et al., 2018). Generally, except for image (D) which showed mostly black and white fragments, the others showed a variety of microplastic colors and shapes (Fig 3 A-D). Figure 3(A), showed particles that were mostly spheres with varying colors (mostly blue and brown). Figure 3 (B) was very similar to A although a few 1D structures were observed. A few more pronounced elongated structures were observed in Figure 3(C). The variety of colored microplastics observed in Figure 3 (A-C) presupposes that the microplastics may have possibly been formed from the breaking down of plastics disposed into the rivers because of the closeness to human settlement. The number of microplastics present confirmed their ubiquitous nature and therefore the urgency for such kind of studies. The fourth sampling site (Figure 3D) was located in a new site with fewer residents. The typical plastics found within the locality were mostly 'sachet water' rubber (linear low-density polyethylene) and 'take away' bowl (polystyrene). This might have contributed to the predominantly granular microplastics (Poerio et al., 2019). The Atadea River joins the Kuaso River and then joins the sea. And therefore, contribute significantly to the high levels of microplastics in the marine environment. Earlier studies on selected fishes along the coast of Ghana revealed that the fishes had ingested high levels of microplastics (Adika et al., 2020; Adu-Boahen et al., 2020). Microplastics cannot be digested by fish since there is no enzymatic breakdown process. This leaves the microplastic bio-inert (Andrady, 2011) and is stable for a long period.

After the visual studies, manual counting was performed to estimate the number of microplastics in the water samples whilst taking into account the guidelines proposed earlier (Noren, 2007). The number of particles was estimated to be 220, 215, 280 and 120 per mL of the water sample.

FTIR analysis was performed on a representative sample from the water. The major peaks identified from the spectrum (Figure 4) were at 3025 cm^{-1} (to =C-H from a phenyl group), 2916 cm^{-1} (C-H stretching), 1599 cm^{-1} (C=C stretching due to phenyl group), 1493 cm^{-1} (C-H bending from the ethyl group) and 1030 cm^{-1} (C-H bending from the ethyl group). The spectrum is consistent with what has been reported for polystyrene in the literature (Zobkov & Esiukova, 2018). Peaks at 534, 693 and 756 cm^{-1} in the fingerprint region could be from the additives added to styrene monomer to make the polymer.

CONCLUSIONS

The knowledge about microplastics in rivers within the Sunyani municipal was determined in the study. Although some of the respondents knew about microplastics, they had little or no idea about their presence in water and how they could be removed from the water. The study further investigated the abundance of microplastics in the water. The number of particles was estimated to be 220, 215, 280 and 120 per ml of the water sample. Although there is a possibility of overestimation due to a lack of confirmatory tests, the presence of microplastics in the water bodies cannot be overlooked.

DECLARATION OF COMPETING INTEREST

The authors declare no competing financial interest.

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