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ORIGINAL RESEARCH ARTICLE

Assessment of Plastic Distribution and Nutrient Flux in Kandolla Shella Stream at Usmanu Danfodiyo University, Sokoto State, Nigeria

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ABSTRACT
Plastic waste has emerged as a significant global pollutant in aquatic ecosystems, drawing increasing worldwide attention from the scientific community. However, its impact has received comparatively less attention in Nigeria. This study aimed to assess plastic distribution and nutrient flux in the Kandolla Shella Stream. The Kandolla Shella stream was divided into four sampling points for the study. Standard analysis methods were adopted to assess plastic distribution and nutrient flux. Plastic samples were classified by polymer type, revealing a total weight of 341.8 grams. Polyvinyl chloride (205 grams) was found at only location A due to a nearby construction site. Polyethylene (79.5 grams), Polypropylene (29.6 grams), and Polyethylene terephthalate (27.3 grams) were present across all locations. Water and sediment samples were also evaluated, in which surface water pH ranged from 6.91-6.95 while in sediment from 6.77-6.99. Electrical conductivity varied in surface water (420-434 µs/m) and sediment (31.1-105.9 µs/m). Nitrate-nitrogen concentration was higher in water (5.675 mg/l) than in sediments (1.5 cmol/kg), while phosphorus concentration showed the opposite trend (sediments: 0.535 cmol/kg; water: 0.094 mg/l). Other chemical parameters exhibited higher concentrations in water but lower concentrations in sediments, except for potassium (sediments: 21.5 cmol/kg; water: 11.25 mg/l). The study observed the accumulation of important nutrients, particularly phosphorus, in sediments, emphasising the role of mineralisation processes near or below the bedrock interface along stream bottoms. Finally, the article provides valuable insights into plastic pollution and nutrient dynamics in the Kandolla Shella Stream.

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Aquatic, Kandolla-Shella, Nutrient, Plastic, Sediments, Water.

INTRODUCTION
Plastics created by humans are the most common synthetic materials in the world, boasting lightweight construction, robustness, longevity, corrosion resistance, and electrical insulation, all while being cost-effective (Zhang *et al*., 2015; Soares *et al*., 2021; Pandey *et al*., 2023). With the invention of plastics, society entered a new era of limitless possibilities. Plastics experienced a surge in popularity throughout the twentieth century due to their advantageous properties such as affordability, endurance, lightness, abundance, and moldability, a trend that continues to this day (PlasticsEurope, 2022), with global production reaching 391 million tonnes (Mt) in 2021. Plastics were originally used for lasting goods but are now increasingly used in disposable objects (Geyer, Jambeck, & Law, 2017). Despite their numerous benefits in comfort, hygiene, and safety, eventually contributing to societal well-being, plastics' single-use nature and incorrect disposal outweigh these benefits unless managed carefully (PlasticsEurope, 2018).

Plastic materials have transformed industries such as food packaging (Leal *et al.,* 2021), drug distribution (Hogan & Mikos, 2020), fuel alternatives, disease prevention, and infrastructure like roads and pavements (Conlon, 2021). However, the proliferation of plastic trash results from illogical production, inappropriate disposal, and insufficient recycling methods. Plastic trash leakage into terrestrial and aquatic environments presents enormous waste management difficulties, especially in developing countries and areas with expanding populations (UNEP, 2018; Godfrey, 2019). Given their persistent character, the consequences of plastic pollution become more ostensible when plastic debris accumulates in the environment (Rochman, 2020). Ecosystems, human

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health, and aquatic life are all at risk from plastic pollution (Diarmuid *et al.*, 2019).

Nutrient exchange at the sediment-water interface is critical for changing aquatic ecosystems' chemical composition and trophic status, especially in shallow bodies like lakes and reservoirs (Chen *et al.*, 2016; Zhang *et al.*, 2021). The reproductive potential of water masses is determined by nutrient distribution (Feary *et al.*, 2021), with seasonal climate variations directly impacting environmental parameters and, hence, planktonic populations (Magami and Balarabe, 2014). The nutrient cycle is impacted in different aquatic habitats by seasonal variations, biotic and abiotic processes, and both (Smith *et al.*, 2021).

Shallow waters are very productive, causing sediment particles and dissolved nutrients to accumulate. These are then quickly discharged through bacterial decomposition, mineralisation, autolysis, and desorption (Magami and Balarabe, 2014). This nutrient exchange between sediment and water greatly impacts the lateral transfer of nutrients to deeper waters and the local primary productivity (Lee *et al.*, 2021). Given that rivers, lakes, and streams are essential water sources for domestic, commercial, and agricultural use, it is imperative to monitor physiochemical parameters to guarantee high-quality water (Sharma *et al.*, 2020). (Patel, Kumar and Singh, 2021). The general goals of limnological investigations are to determine the ideal water quality, pinpoint the variables affecting water systems, and isolate particular effects (Ovie, Bwala, and Ajayi, 2011). In light of these factors, this article examined the distribution of plastics and the physicochemical parameters of surface water and sediment in the Kandolla Shella Stream.

MATERIALS AND METHODS

Study Area

This study was conducted at Usmanu Danfodiyo University, Sokoto, in Wammako Local Government Area of Sokoto State, Nigeria (SERC, 2014), in the Kandolla Shella stream behind the Biological Sciences Garden. The location of the study area is between Longitude 5º 11" 30'E and 5º 14" 30'E and Latitude 13º 8" 30'N and 13º 7" 0'N (Arc GIS, 2016). Sokoto is located in the Sudan Savanna Region of Nigeria, between latitudes 12°N and 13°58'N and longitudes 4°8'E and 6°54'E. It is 351 metres above sea level. The region has a tropical climate that is hot and semi-arid. It is distinguished by a brief but intense wet season from May/June to September and a long and harsh dry season from October to May. August marks the climax of the rainfall pattern, which is characteristically spread. In North-Western Nigeria, Sokoto is located in the Sudan savanna agroecological zone. Around April, the region has mean annual temperatures of 38 °C to 42 °C or higher, with an annual rainfall range of 550–700 mm. January and December (the Hartmattan period) have the lowest mean temperature between 13 and 15 °C. From Mach to June, the mean maximum temperatures are at their highest. December and January have the lowest mean relative humidity (10–30 %), whereas August sees the highest relative humidity of over 90 % (SERC, 2014). Adejuwon (2016) notes that there are hot, muggy days when it rains. Sand-loam soil makes up the region. The wind blows northwest and southwest throughout the dry and wet seasons, respectively (SERC, 2014).

The Kandolla Shella Stream passes through the university and is essential to the residents' daily lives, economy, and ecology. The stream serves as a social and economic centre in addition to being a body of water. Its waters are an essential agricultural resource, supplying irrigation to the crops in the area. Communities use the stream's resources to irrigate their fields to guarantee abundant harvests. In addition to its benefits to agriculture, the stream offers water for washing and bathing and is an essential lifeline for daily tasks.

Sample Collection

Sampling was carried out at four points along the Kandolla Shella stream, from upstream to downstream. Gloves, nets, plastic bottles, digital scales, trash bags (polythene bags), and stationery were the instruments utilised in this investigation. The plastic debris in and around the stream was gathered using the garbage trap technique. The plastics were gathered from the streambank, sediment, and surface water. Every plastic garbage gathered, cleaned, and placed in a distinct polythene bag for every location was transported to the laboratory, where it was allowed to air dry at room temperature.

Water and sediment samples were collected during December 2023. As adapted by Magami and Balarabe (2014), in order to maintain sample homogeneity, water samples were taken from locations along rivers with laminar flow patterns. They were also taken between 10 and 15 cm below the surface to prevent floating debris, and they were then poured into 1-liter plastic containers. Samples of sediment were taken below the water's surface. Prior to laboratory analysis, the samples were placed in clearly labelled plastic bags. Samples of sediment were allowed to dry at room temperature in the laboratory, after which they were sorted by removing large debris and sieved using a 2 mm sieve.

Sample Processing

Plastic Characterisation

As Thompson et al. (2009) described, plastics were visually separated based on shape, size, colour, and type before being classified based on use and weight in the laboratory using a weighing balance.

Nutrient Flux Analysis

Standard procedures were followed to determine the chemical variables for the water and sediments. At 25 °C, the pH was measured using a JENWAY pH metre 3015 Model. A WINDAUS Electrical Conductivity Metre (Model 9008) calibrated at 35 °C was used to measure electrical conductivity (UNEP, 2014). Nutrient extraction from sediment samples was done according to the target analyte. Sodium bicarbonate was used to remove the available phosphorus from the sediment, and molybdenum blue was formed by combining ammonium molybdate with ascorbic acid (Oladosu *et al.,* 2016). The wavelength of the molybdenum blue was then measured using a spectrophotometer (JENWAY 6100) at 660 nm. Nitrate concentrations in the sediment were determined using the brucine colour development reagent, and the nitrate was extracted using 2M potassium chloride (Abayomi *et al.,* 2017). Calcium and magnesium were measured using the ethylenediamine tetraacetic acid (EDTA) titration method (UNEP, 2014), while potassium and sodium were measured using a flame photometer (Corning 400 Essex, England). The cadmium reduction method was used to test nitrate (Patel *et al.,* 2019).

Statistical Analysis

Following statistical data analysis, analysis of variance (ANOVA) was used, and the significant difference probability at $P<0.05$ was acceptable (Motulsky, 2007).

RESULTS AND DISCUSSION

The study of plastic distribution in Kandolla Shella Stream found four types of polymers: polyethylene terephthalate (PET), polyethylene (PE), polypropylene (PP), and polyvinyl chloride (PVC) (Table 1). A total of 27.3 grams of PET was detected, with the highest concentration at Point C (16.7 grams), lowest at Point D (5.0 grams), and nonexistent at Point B. This polymer is extensively used in beverage and food containers due to its transparency, lightweight nature, and recyclability. A mean weight of 29.6 grams was obtained by comparing the concentrations of polypropylene at different sites. The highest concentration was found at Point A (10.2 grams), while the lowest was at Point D (2.9 grams). Polypropylene makes packaging, textiles, automotive components, medical equipment, and other products. PVC, weighing 205.4 grams, was only discovered at Point A because of its nearness to a building site and density. PVC is used in a variety of products, including cleaning solution containers, water and sewage pipes, garments, water bottles, medical containers, signage, furniture, tubing, flooring, electrical conductors and cables. The most prevalent polymer was polyethylene, which had a mean weight of 79.5 grams, the highest (53.2 grams) at point A and the lowest (4.5 grams) at point B. Owing to its flexibility, durability, and moisture resistance, this multipurpose polymer is frequently used to manufacture plastic bottles, bags, and other packaging. According to Ibrahim *et al.* (2023), all forms of plastic have detrimental effects on freshwater bodies and the environment, including lowered water quality, disturbed aquatic ecosystems, risks to fish and wildlife, bad health effects on humans, and financial implications.

Table 1: Plastic Distribution in Kandolla Shella Stream at Various Locations

Sample Points	Weight of Plastics (grams)				
	PE	PP	PET	PVC	Mean
Point A	53.2	10.2	5.6	205.4	68.6
Point B	4.5	7.4	_	_	2.97
Point C	6.5	9.1	16.7	_	8.07
Point D	15.3	2.9	5.0	_	5.80
Total	79.5	29.6	27.3	205.4	

Key: PE = Polyethylene, PP = Polypropylene, PET = Polyethylene Terephthalate, PVC = Polyvinyl Chloride

Furthermore, the data from each location were displayed in a pie chart (Figure 1), with Point A having the highest distribution of plastic (80.29 %), Points C and D recording 9.45 % and 6.79 %, respectively, and Point B had the least (3.48 %).

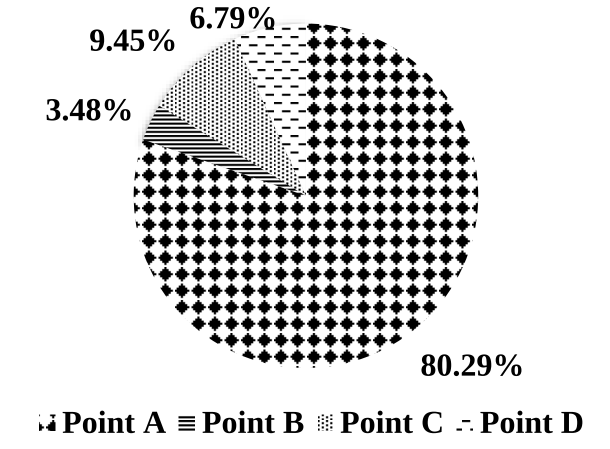

Figure 1: Average Values of Plastic Distribution from different Locations

As shown in Tables 2 and 3 below, the nutrient flux analysis results revealed variable quantities in water and sediment at different locations, with $p<0.05$ significance level. Variations were seen in the comparison of results between water and sediment (Table 4). With minimum values of 6.91 for water and 6.77 for sediment and maximum values of 6.95 for water and 6.99 for sediment, pH levels in water were higher (6.93) than in sediment (6.86). The pH values fit the conclusions made by Magami and Balarabe (2014). The electrical conductivity was 428.75 µs/cm for water and 67.3 µs/cm for sediment. These results fell within the usual range for freshwater, where most freshwater has conductivity levels between 0.1 and 1000. Also, according to Vajrapp and Singh (2005), aquatic biota can survive in water with a conductivity of less than 750 µs/cm. Based on the maximum recorded values of 434 µs/cm for water and 105.9 µs/cm for sediment, it can be concluded that Kandolla Shella Stream is suitable for aquatic biota.

Phosphorus, a crucial component for the growth of both plants and animals, was found in the sediments at higher concentrations than in the water, with mean values of 0.535 cmol/kg in sediments and 0.094 mg/l in water. This could be explained by the buildup and breakdown of organic materials in the sediment that serves as streams' primary source of nutrients. According to Magami *et al.* (2014), the mean phosphorus values in the water and sediments of Shagari Reservoir, Sokoto, Nigeria, were reported to be 0.18 mg/l and 2.31 g/kg, respectively, and these results correspond with their findings. Calcium was found to be 6.50 mg/l in water and 0.25 cmol/kg in sediment, with minimum values of 5.4 mg/l and 0.15 cmol/kg, respectively, and maximum values of 6.6 mg/l in water and 0.4 cmol/kg in sediment. These findings are inconsistent with those of Magami and Balarabe (2014), who found that sediment had a higher calcium content than water.

Nitrogen, as a key nutrient, showed varying quantities in water and sediment, with mean values of 5.675 mg/l and 1.5 cmol/kg, respectively. Surface water had higher nitrogen concentrations than sediment, as evidenced by the minimum values of 4.1 mg/l in water and 1 cmol/kg in sediment. This suggests that nitrates and ammonia are dietary requirements for plankton in freshwater, causing nitrogen concentrations to be higher on the surface than in the sediment. Nitrogen concentrations were lower in sediment than in water, possibly due to limited major nitrogen sources, such as sewage discharge and organic waste discharge.

All other elements varied in water and sediments like Sodium (3.0–8.0 mg/l and 3.0-8.0 cmol/kg), Potassium (8.0–15.0 mg/l and 11.0-42 cmol/kg) and Magnesium (7.68–9.96 mg/l and 0.75-0.90 cmol/kg) remained within the acceptable limits of APHA, AWWA, and WEF (2017), indicating minimal discharges from homes, businesses, and agriculture into Kandolla Shella Stream. However, Zhang *et al.* (2021) observed that alterations in sediment composition could also result from increased sediment transport in streams due to soil erosion and sediment retention within the stream.

Table 2: Physicochemical Parameters of Water at Kandolla Shella Stream

PARAMETERS	POINT					
	A	B	C	D	MEAN	SD
pH	6.93	6.91	6.92	6.95	6.93	0.014
EC (µs/cm)	434	431	430	420	428.75	5.26
Calcium (mg/l)	6.2	5.4	6.4	6.6	6.15	4.55
Magnesium (mg/l)	7.8	8.16	9.96	7.68	8.4	9.178
Phosphorus (mg/l)	0.097	0.1	0.096	0.082	0.094	0.006
Potassium (mg/l)	8	10	15	12	11.25	2.58
Sodium (mg/l)	7	6	7	8	7	0.707
N-N (mg/L)	4.2	6.8	4.9	6.8	5.675	1.151

Keys: EC = Electrical Conductivity, SD = Standard Deviation, N-N = Nitrate-Nitrogen

Table 3: Physicochemical Parameter of Sediment at Kandolla Shella Stream

PARAMETERS	POINT					
	A	B	C	D	MEAN	SD
pH	6.99	6.79	6.87	6.77	6.86	0.086
EC (µs/m)	31.1	87.9	44.3	105.9	67.3	30.633
Ca (cmol/kg)	0.2	0.15	0.25	0.4	0.25	0.093
Mg (cmol/kg)	0.75	0.9	0.85	0.85	0.84	0.054
P (cmol/kg)	0.48	0.569	0.561	0.529	0.535	0.034
K (cmol/kg)	11	42	16	17	21.5	12.051
Na (cmol/kg)	3	8	6	6	5.75	1.785
N-N (cmol/kg)	1.4	1.6	1	2	1.5	0.360

Keys: EC = Electrical Conductivity, SD = Standard Deviation, N-N = Nitrate-Nitrogen.

Table 4: Comparative Statistical Summary of Nutrient Flux of Kandolla Shella Stream

PARAMETERS	MEAN		MINIMUM		MAXIMUM	
	Water	Sediment	Water	Sediment	Water	Sediment
pH	6.93	6.86	6.91	6.77	6.95	6.99
EC	428.75	67.3	420	31.1	434	105.9
Calcium	6.15	0.25	5.4	0.15	6.6	0.4
Magnesium	8.4	0.84	7.68	0.75	9.96	0.9
Phosphorus	0.094	0.535	0.082	0.48	0.097	0.569
Potassium	11.25	21.5	8	11	15	42
Sodium	7	5.75	6	3	8	8
Nitrate-Nitrogen	5.675	1.5	4.2	1	6.8	2

Key: EC = Electrical Conductivity (µs/m), Water (mg/l) and Sediment (cmol/kg)

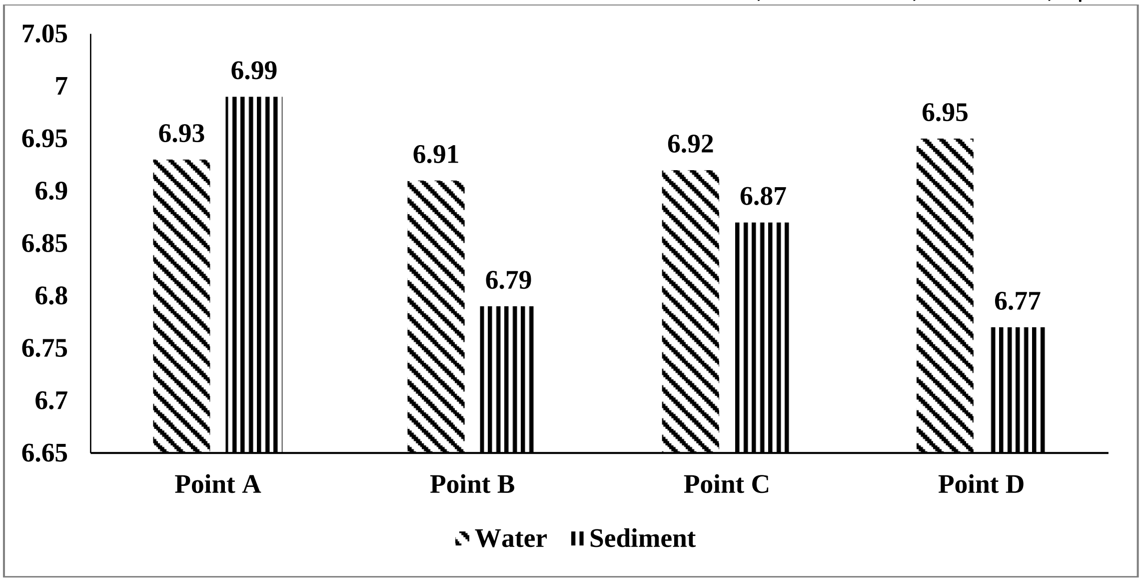

Figure 2: Mean Values of pH of Water and Sediment

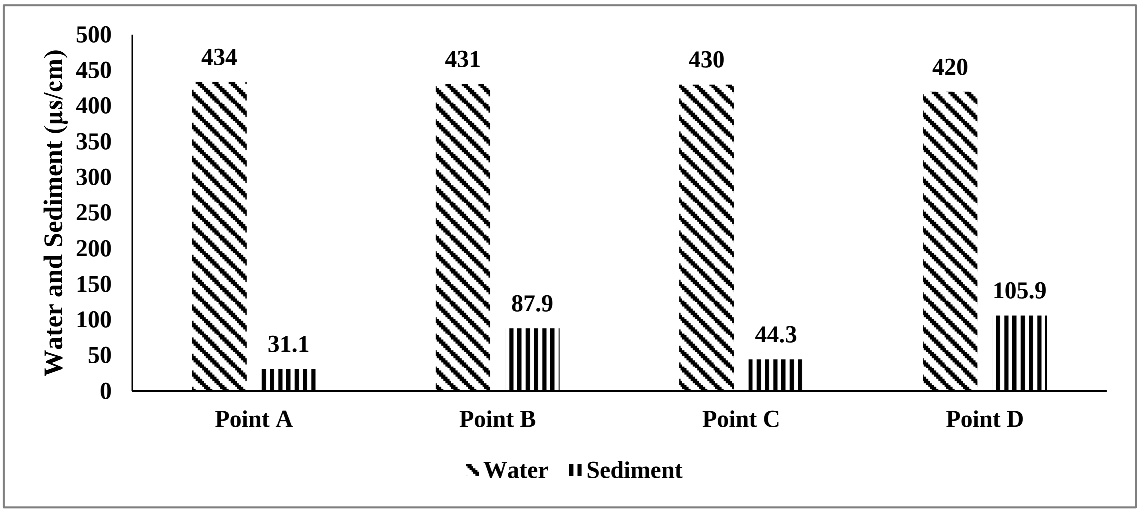

Figure 3: Mean Values of Electrical Conductivity of Water and Sediment

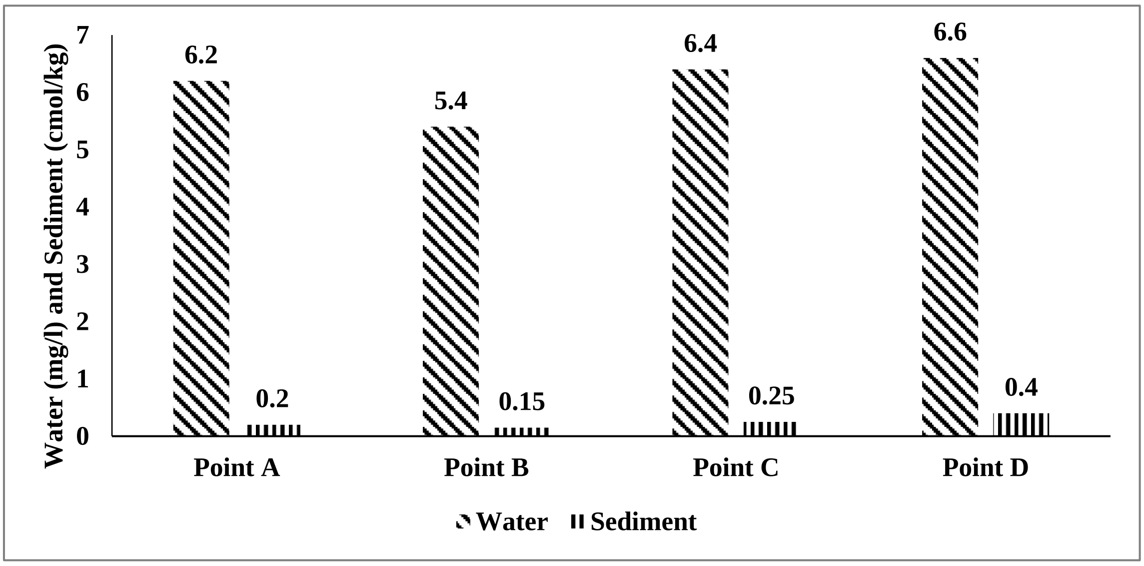

Figure 4: Mean Values of Calcium in Water and Sediment

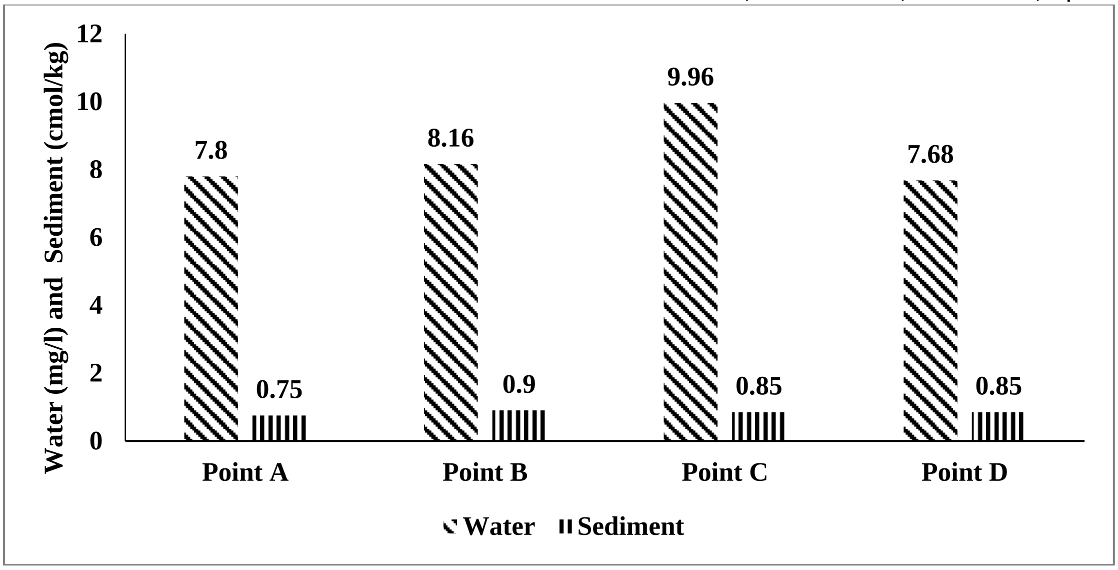

Figure 5: Mean Values of Magnesium in Water and Sediment

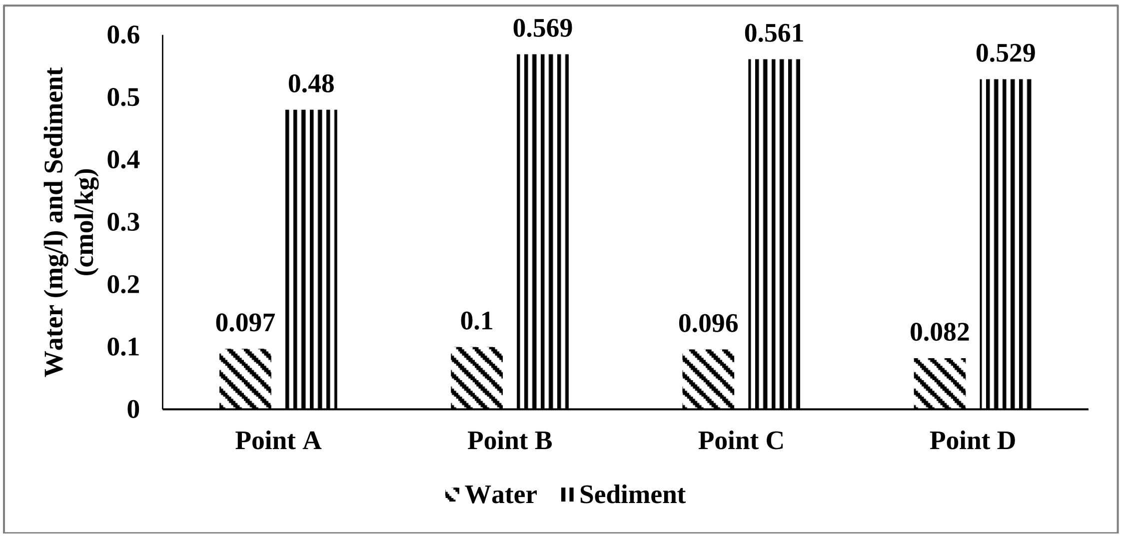

Figure 6: Mean Values of Phosphorus in Water and Sediment

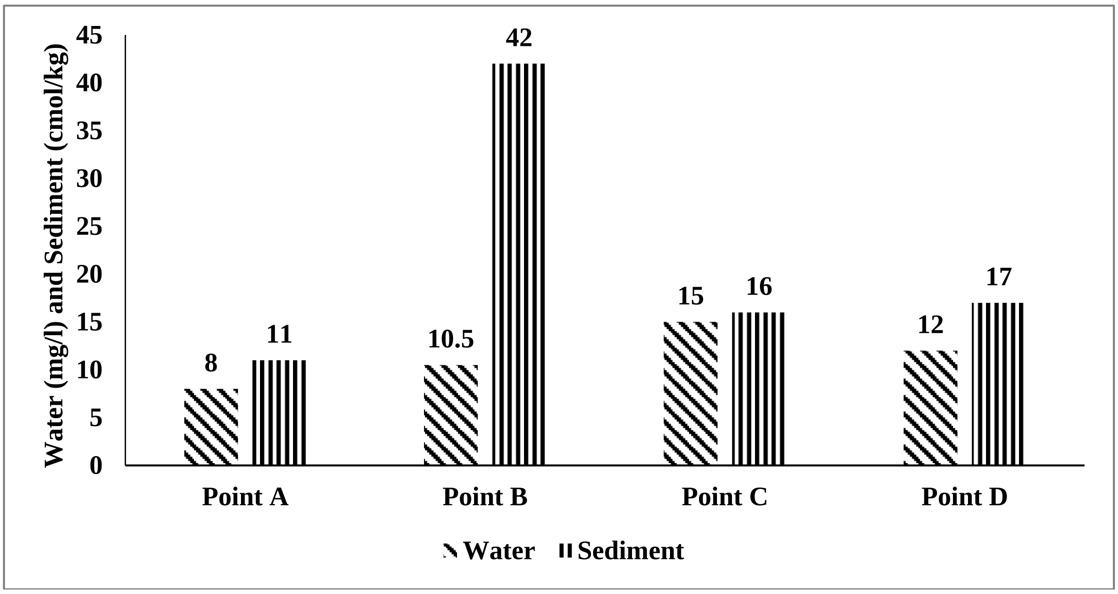

Figure 7: Mean Values of Potassium in Water and Sediment

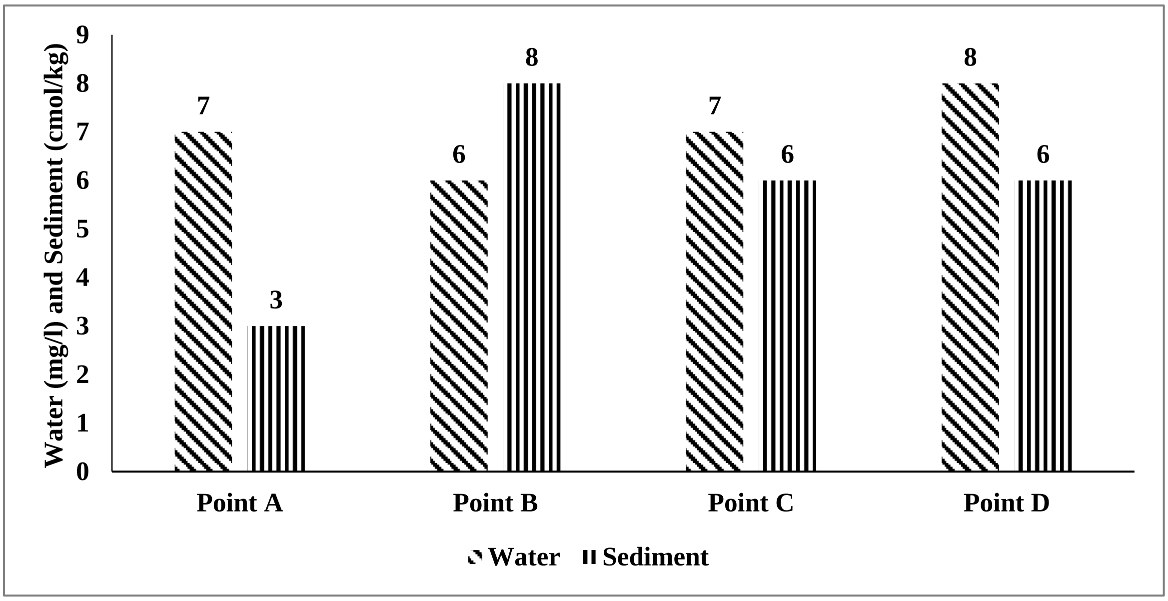

Figure 8: Mean Values of Sodium in Water and Sediment

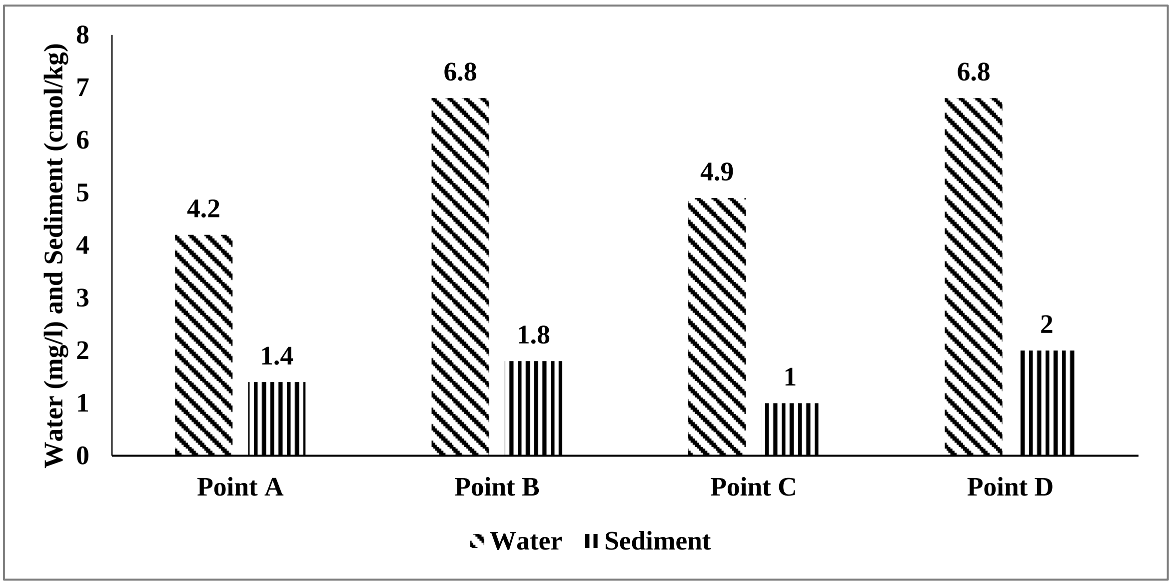

Figure 9: Mean Values of Nitrate-Nitrogen in Water and Sediment

CONCLUSION

The study reveals the widespread threat that plastics pose to biodiversity and nutrient dynamics, exposing the intricate links between human activities and the wellness of the environment. Microplastic breakdown and marine life entanglement are two issues caused by the dispersion of plastic in water bodies and terrestrial ecosystems, which raises worries about the short- and long-term effects on ecosystem stability.

The analysis of nutrient flux in the Kandolla Shella stream reveals higher concentrations of phosphorus, nitrogen, and other components, indicating possible human influence. The significance of sustainable land management is highlighted by the features of sediment that further impede the flow of nutrients. To handle the changing difficulties and maintain the ecological balance of the stream, ongoing monitoring and adaptive methods are essential.

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