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Environmental Risk Assessment of Microplastics in Water and Sediments along Ibi Troughs North-East Nigeria

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Abstract

This study aimed to evaluate the risk associated with microplastics along river Ibi. Water and sediment samples were collected from five (5) sites each along river Ibi 100m apart. The surface sediment was sampled in all cases to approximately 5-cm depth using a Van Veen grab (25 cm^2). Microplastics particles were identified using Fourier Transform-Infrared Spectroscopy (FTIR). The FTIR spectra of the water and sediment showed bands and wave numbers of between 3275 cm^{-1} and 1033 cm^{-1} as the prominent peaks. The peaks at these frequencies were strong, broad and medium, which suggest the presence of compounds with the functional groups of alkanes, alkenes, alkynes, amines, alkyl halide, nitro compound, carbonyl bond, carboxylic acids and alcohols in the samples. The review analysis also shows that various polymer types have been covered in the studies polyethylene (PE), polypropylene (PP), polystyrene (PS), polyamide (PA), and polyethylene terephthalate (PET). Polyethylene (PE) and Polypropylene (PP) is the dominant polymer types found in all environmental matrices. Non-carcinogenic risk assessment shows hazard indices above one at every sampling location in river Ibi, indicating that drinking water from these water bodies may present serious health risks, including cardiovascular and non-carcinogenic health issues. The results obtained from this study showed that water from the sampling locations are not suitable for human consumption and also confirm the presence of microplastic in river Ibi.

Keywords: Microplastics, Water, Sediment, River Ibi, Risk Assessment

INTRODUCTION

As the global demand for plastic materials continues to rise, particularly in Nigeria, effectively managing plastic waste poses both local and global challenges. A significant portion of the plastic produced annually is non-biodegradable, leading to accumulation in marine and soil environments [1]. Plastics introduced into the marine environment can persist for extended periods, undergoing mechanical and photochemical processes that result in the formation of microplastics (< 5 mm) or nanoplastics (< 1 µm) [2]. Recent study has shown an increasing amount of microplastics in marine habitats, raising concerns about visible plastic litter.

Microplastics are categorized as "primary" When deliberately manufactured on a small scale, nanoparticles are frequently found in consumer products such as personal care items and industrial cleaners. Conversely, "secondary" microplastics are formed when bigger plastic objects, including plastic films, fishing nets, or home goods, break down, resulting in irregular forms [3,4]. Due to their tiny size, microplastics can be absorbed at various trophic levels, having severe consequences on organisms by influencing the gastrointestinal tract, causing sores, obstructions, malnutrition, and even death [5]. Additionally, microplastics can transport harmful compounds including persistent organic pollutants or metals. Given the growth in plastic manufacturing and the limited biodegradability of most released microplastics in the environment, their concentration is projected to rise in the near to medium-term future [6,7]. Therefore, it is necessary to focus efforts on ecotoxicological risk assessments to understand the possible dangers caused by microplastics to species [8].

The haphazard disposal of waste, encompassing both industrial and domestic sources, into water bodies stands out as a significant environmental challenge confronted by nations globally, including Nigeria. This reckless waste disposal contaminates aquatic environments, posing threats to both aquatic life and human well-being through the consumption of contaminated water. Each year, the Earth witnesses the addition of over seven million tons of plastic waste, contributing to the proliferation of microplastics. If this trend persists, there is a foreseeable future where the seas will harbor more plastics than fishes, with an estimated 97% of fish species having ingested microplastics. The presence of microplastics in aquatic ecosystems poses a substantial hazard to marine life, making it a pressing local and global concern. Currently, seas, oceans, and rivers are grappling with the environmental disaster of microplastics and heavy metals. To address this challenge, there is an urgent need for comprehensive assessments of microplastics in both local and global rivers.

Given the widespread occurrence of microplastics and heavy metals as environmental contaminants, there is a notable scarcity of data in existing literature regarding the risk assessment of these pollutants along the prominent rivers (River Ibi). These rivers hold crucial significance for the local population, serving various essential purposes. Consequently, this study aims to provide valuable insights into the risks associated with the contamination microplastics in River Ibi.

MATERIALS AND METHODS

Description of the Study Area

Ibi is a local government in Taraba state, east-central Nigeria, on the south bank of the Benue River, opposite the mouth of the Shemankar River. Ibi lies on both bank of River Ibi; within latitudes 5°65`N and longitudes 9°36`E, 8°36`E. Most of the inhabitants of river Ibi are normally engaged in fishing. Ibi is a collecting point for sesame seeds and soybeans [9]. Ibi town is uniquely situated on both sides of the River Benue, serving as the headquarters of the LGA. Historically, Ibi was an integral part of the Kwararafa Kingdom, with the Sarki Ibi serving as the principal traditional monarch.

Sample Collection

A systematic strategy was adopted in the collecting of water and sediment samples from five unique places along River Ibi, with measurement intervals set at 100 meters. Ten (10) L sample (0-20 cm below the surface) was collected two times into glass sample bottles. Surface sediments were sampled in all cases to approximately 5-cm depth using a Van Veen grab (25 cm^2). Three replicates 10m apart, were randomly collected and pooled as one sample for each site on the same day. Approximately 1.5 kg of the pooled wet sediment was placed in an aluminum foil bag, marked and transferred to the laboratory [9].

Sample Pre-Treatment

Water samples were treated with 30% hydrogen peroxide to aid in organic material digestion before being incubated in darkness for 24 hours. They were then filtered through 0.45 μm membranes to isolate microplastic particles, with careful contamination prevention measures. A blank test using ultra-pure water showed minimal microplastic contamination (0.8 ± 0.4 items per filter membrane). Sediment analysis involved drying 1 kg samples at 60°C for 48 to 72 hours, followed by preparation of three 30g replicates from each location. These samples were immersed in $ZnCl_2$ solution, stirred, settled for 24 hours, treated with 30% hydrogen peroxide, incubated in darkness for another 24 hours, and filtered through 0.45 μm membranes to extract microplastic particles, following methods by [10].

Microplastics Extraction from Water and Sediment Samples

Water samples were filtered using glass fiber filter paper (Whatman™ 1823-047 Grade GF/D, diameter: 4.7 cm, pore size: 2.7 μm, Cytiva, Uppsala, Sweden). Sediment analysis involved oven-drying the samples, recording both wet and dry weights, and rinsing glass fiber filter sheets with distilled water to collect particles. Hydrogen peroxide (35 to 145 mL) was used to digest samples for 5–6 days, following the method by Habiba *et al.* [9] for thorough and uniform analysis. Microplastic (MP) particles were separated from remaining inorganic material using a saturated aqueous potassium formate solution (density: 1.6 g mL−1) in a separating funnel. After 3–4 days, the lower water phase containing inorganic particles was separated. The water, now containing microplastics, underwent further purification using pressure filtering with 0.2 μm nanopore inorganic membrane filters (Whatman Anodisc, 47 mm diameter). Filters were carefully covered, air-dried at 50°C, and stored in aluminum bowls to maintain particle integrity and prevent contamination, ensuring reliable analysis and interpretation of isolated microplastic particles.

Flourier Transform Infrared Spectroscopy Analysis

To comprehensively investigate microplastics (MPs), particles sized 2mm underwent detailed measurements using a Vertex 70 FTIR analyzer by Bruker in Ettlingen, Germany. Subsamples from both water and sediment were further analyzed using a Hyperion 2000 FTIR instrument, also from Bruker, to isolate and examine these particles in depth. The primary objective was to identify the polymer composition of the microplastics, providing crucial insights into their origin and potential environmental impacts. The research methodology followed rigorous specifications outlined for systematic and thorough assessment of microplastic samples, as detailed by [11].

Microplastics Risk Assessment Analysis

Microplastics risk analysis, utilizes the Pollution Load Index (PLI) to quantify microplastic (MP) pollution levels, particularly in estuarine environments. The formulae involved include Fi = Ci/Coi to determine the pollution factor at each sampling point, where Ci is the microplastic concentration and Coi is the background concentration indicating no pollution. PLI is then calculated as the square root of Fi (√Fi), providing a numerical measure of pollution intensity. PLI zone further aggregates these values across sampling points to assess overall microplastic pollution across the study area. These methods offer insights into the extent and distribution of microplastic contamination in the environment.

Environmental Risk Analysis

To assess how much risk microplastics (MPs) pose to the environment, we used the Risk Quotient (RQ). This is a common measure for understanding environmental risk. The RQ is calculated by dividing the measured concentration of the microplastics (MEC) by the predicted concentration where no harmful effects are expected (PNEC). This helps us gauge the potential environmental impact of microplastics:

RQ = MEC/PNEC……………………………………………………1

Risk level was judged as follows: $RQ < 0.01$, very low risk; $0.01<RQ < 0.1$, low risk; $0.1<RQ < 1$, intermediate risk; $RQ > 1$, high risk.

Due to the absence of toxicological data for microplastics (MPs) in sediment, the Predicted No-Effect Concentration (PNEC) for sediment was computed using the equilibrium distribution method. This approach aligns with the technical guidance document of the European Union for the risk assessment of chemical substances (TGD).

RESULTS AND DISCUSSION

In this study, the identification of eight different samples of water and sediment was investigated using FTIR spectroscopy by monitoring different functional groups. The spectra were shown in the figures while the interpretations were given in the Tables.

FTIR spectrum of water sample from Ibi (B3):

The FTIR spectrum showed the water sample from Ibi has bands and wave numbers of 3268 cm^{-1} to 2117 cm^{-1} as the prominent peaks. The peaks at the frequencies of 3268 cm^{-1} to 668 cm^{-1} were strong, broad and medium. The result confirmed the presence of alkanes, alkenes, amines, alkyl halide, esthers and amides in the sample shown in Table 1.

FTIR spectrum of sediment sample from Ibi (I 2):

The FTIR spectrum in sediment sample from Ibi has bands and wave numbers of between 3651 cm^{-1} to 3622 cm^{-1} as the prominent peaks. The peaks between the frequencies of 3622 cm^{-1} to 1004 cm^{-1} were strong, broad and medium. The present FTIR results confirmed the presence of, alkenes, aliphatic amines, carboxylic acids and alcohols in the Soil sample as shown in Table 2.

FTIR spectrum of sediment sample from Ibi (I 3):

In the FTIR spectrum showed in sediment sample from Ibi has bands and wave numbers of 3622 cm^{-1} to 1987 cm as the prominent peaks. The peaks at the frequencies of 3622 cm^{-1} to 1033 cm^{-1} were strong, broad and medium. The results confirmed the presence of alkenes, Nitriles, alkyl halide and alcohols in soil sample as shown in Table 3.

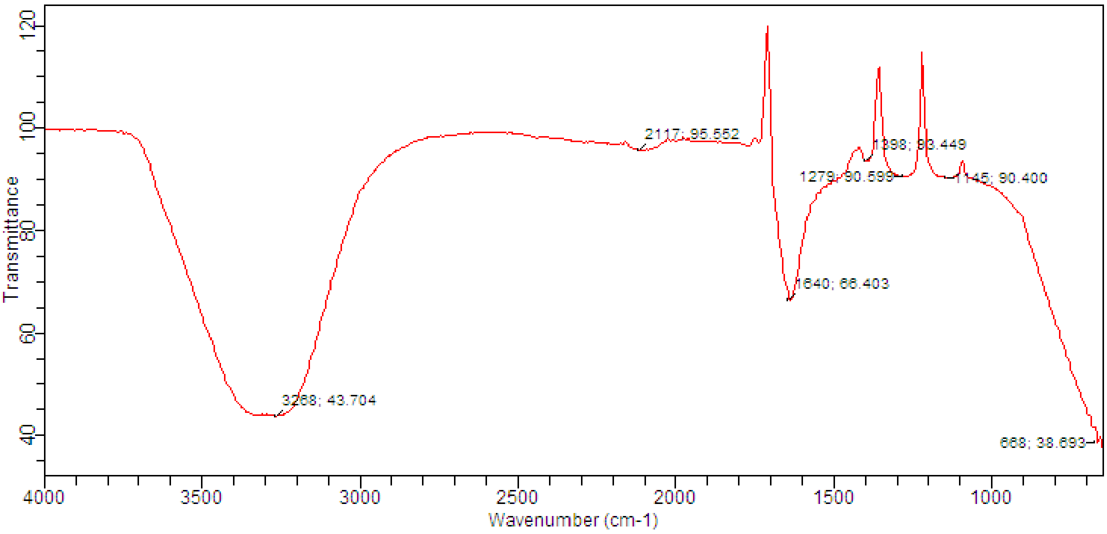

Figure 1: FTIR Spectrum of Water Samples from River Ibi (B3)

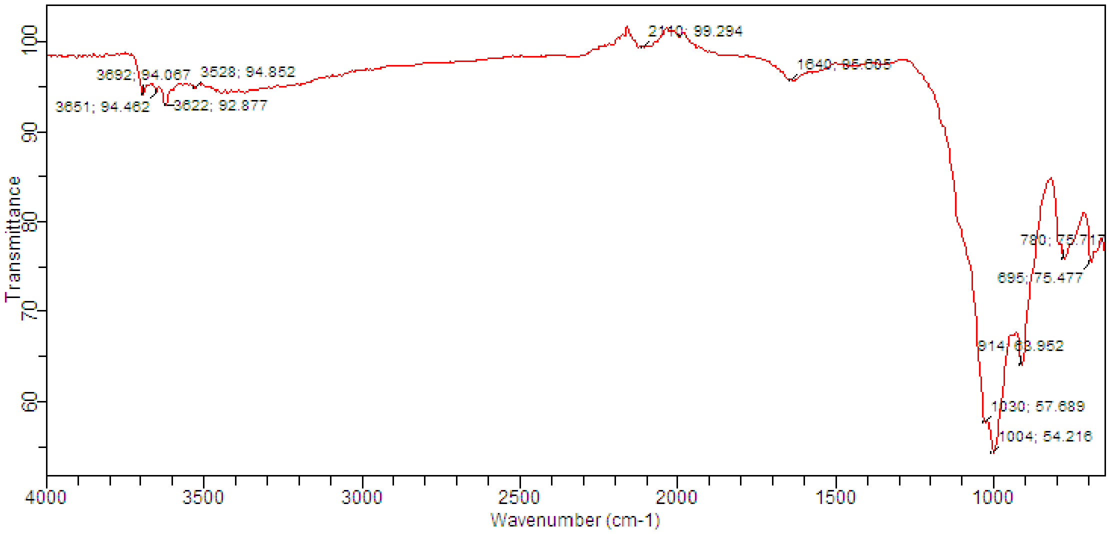

Figure 2: FTIR Spectrum of Sediment Samples from River Ibi (I 2)

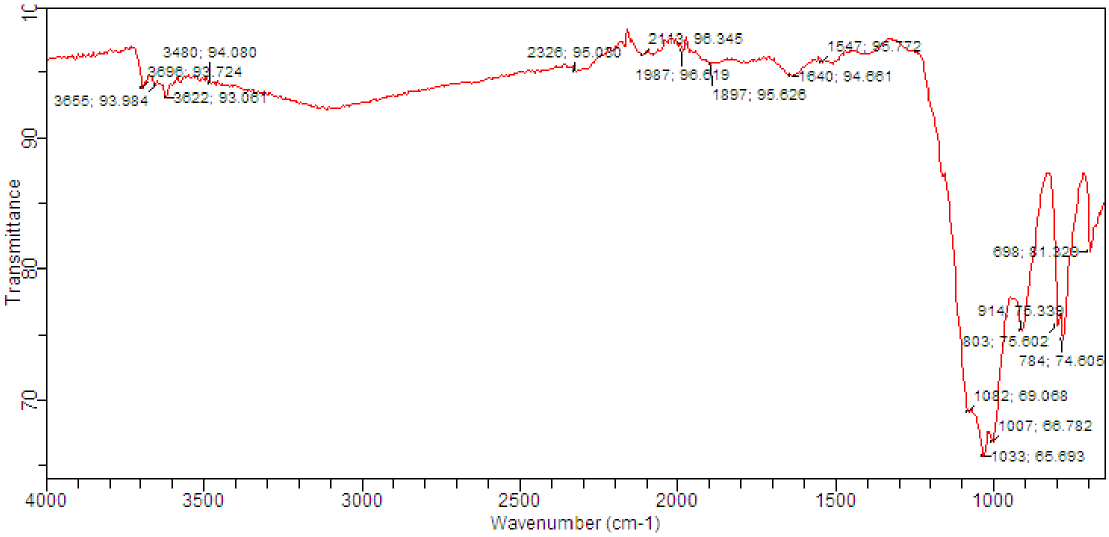

Figure 3: FTIR Spectrum of Sediment Samples from River Ibi (I 3)

Table 1: FTIR Spectroscopy of Water Samples from River Ibi (B3)

Wavelength number (cm^{-1})	Functional group	Inference
3268	N-H stretch	1°, 2° amines, amides
2117	C=C stretch	Alkynes
1640	C=C stretch	Alkenes
1279	C-F stretch	Alkyl halide
1145	C-O-C stretch	Esters
668	C-Cl stretch	Alkyl halide

Table 2: FTIR Spectroscopy of Sediment from River Ibi (1 2)

Wavelength number (cm^{-1})	Functional group	Inference
3651	O-H stretch, free hydroxyl	Alcohols, Phenols
3622	O-H stretch, free	Alcohols, phenols
2110	C-N stretch	Alkenes
1004	C-N stretch	Aliphatic Amines
914	O-H bend	Carboxylic acid

Table 3: FTIR Spectroscopy of Sediment from River Ibi (1 3)

Wavelength number (cm^{-1})	Functional group	Inference
3655	O-H stretch, free hydroxyl	Alcohols, Phenols
2326	C=N stretch	Nitriles
1897	C=O stretch	Anhydrides
1640	C=C stretch	Alkenes (Conjugate)
1033	C-F stretch	Alkyl halides
1007	C-F stretch	Alkyl halide

Microplastic is defined as the particies size ranging from 1 nanometre to 5 millimetre. The size of MPs is very small, it can be ingested by a wide range of organisms by mistake as food for prey [12]. Microplastics (MPs) are not only contaminants by themselves, they are also associated with different chemical additives, which were added during their manufacturing process to optimize their physical attributes. These chemicals, including those incorporated during plastic production (additives), can leach into biological tissues, posing health risk to organisms and bio-accumulating in the food chain [13]. Therefore, MPs have the potential to act as vectors for the transport of hydrophobic organic pollutants [14]. The vector effect of particle mediated transport of pollutants can be divided into three groups [6]: (1) an environmental-vector effect (MPs with adhered pollutants are transported through the environment), (2) an organismal-vector effect (the pollutant is transported into the organisms) and (3) a cellular-vector effect (the pollutant is transported with the particle into cells).

Based on the peak values in the area of IR radiation, the FTIR spectrum was used to identify the all the molecular and functional groups present in plastic polymers [15]. FTIR spectroscopy deals with measurement of infrared (IR) radiation absorbed by the MP sample, allowing the study of molecular composition. An infrared spectrum represents a fingerprint of a sample (MP) with absorption peaks correspond to the frequencies of vibration between the bonds of the atoms making up the material. Because each different polymer material is a unique combination of atoms, no two compounds produce exactly the same infrared spectrum. FTIR technique is also used to study the changes in chemical bond structures (hydroxyl, carbonyl groups and carbon-oxygen).

CONCLUSION

Flourier Transform Infrared Spectroscopy **(**FTIR) is a well-recognized rapid and quite reliable method to identify polymer types of different MPs by comparing the resulting FTIR spectra with known plastic polymers in the spectral library. The human health risk assessment indicated that the water from both the sampling locations may not be suitable for human consumption, domestic activities and prolonged ingestion and other domestic utility. Non-healthy risk was determined in sediment; the risk to human health in the river water can be attributed to the dissolution of minerals, trace metals from direct sewage discharge, agricultural runoff, tailings dams and increasing concentration due to bioaccumulation downstream. Therefore, it can be established that the population living in the riverine landscape and using untreated surface water for drinking could be vulnerable to the health risk from pollution of these microplastics.

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