ASSESSMENT OF PLASTIC POLLUTION AND ITS EFFECTS ON SURFACE WATER QUALITY: A CASE STUDY OF BUA RIVER IN KASUNGU DISTRICT, MALAWI

SUBMITTED BY

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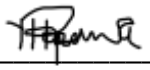
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ABSTRACT

Plastic pollution poses a serious threat to freshwater ecosystems, particularly in developing countries with inadequate waste management systems. This study assessed the extent of plastic pollution and its effects on surface water quality in the Bua River, Kasungu District, Malawi. The Bua River is a vital freshwater resource supporting domestic, agricultural, and ecological needs in the district, yet it faces increasing pressure from plastic waste originating from nearby settlements, trading centers, and agricultural activities.

The main objective of the study was to assess plastic pollution and its effects on surface water quality in the Bua River. The specific objectives were: (1) to identify and quantify plastic waste (macro- and microplastics) along and within the river; (2) to evaluate the physical and chemical quality of surface water in areas affected by plastic pollution; and (3) to examine the impacts of plastic waste on aquatic life and surrounding communities dependent on the river.

A descriptive-analytical research design was adopted. Data were collected from three sampling stations along the Bua River during one season. The study employed purposive and systematic sampling techniques, focusing on areas with visible plastic accumulation. Field observations and surveys were conducted to identify and quantify microplastics, while water samples were collected for physicochemical analysis. In situ measurements of pH, electrical conductivity, dissolved oxygen, and turbidity were taken at each station. Laboratory analyses were performed to detect and characterize microplastics. Quantitative data were analysed using descriptive statistics, correlation analysis, and GIS-based spatial mapping, while qualitative observations were examined through content analysis.

The study revealed the levels of plastic pollution and its influence on key water quality parameters in the Bua River. It further highlighted the potential ecological risks to aquatic organisms and the implications for communities relying on the river for various uses.

This research provides empirical baseline data on plastic pollution in a Malawian freshwater system, contributing to the limited scientific knowledge on the subject in subSaharan Africa. The findings are expected to inform evidence-based policy interventions, improve enforcement of the Plastic Ban Regulations (2015) and the Environmental Management Act (2017), and support sustainable waste management practices aligned with Malawi's Vision 2063 and Sustainable Development Goal 6 (Clean Water and Sanitation).

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ACRONYMS/ABBREVIATIONS

BOD Biochemical Oxygen Demand

DO Dissolved Oxygen

EA Environmental Affairs

EAD Environmental Affairs Department

EC Electrical Conductivity

EMA Environmental Management Act

EIA Environmental Impact Assessment

EPA Environmental Protection Agency

ESIA Environmental and Social Impact Assessment

FAO Food and Agriculture Organization

GIS Geographic Information System

GPS Global Positioning System LGA

Local Government Authority mg/L

Milligrams per Litre ml Millilitre mm

Millimeter

NGO Non-Governmental Organization pH Potential of

Hydrogen (measure of acidity or alkalinity)

POPs: Persistent Organic Pollutants

SDG Sustainable Development Goal

SPSS Statistical Package for the Social Sciences

TDS Total Dissolved Solids

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CHAPTER 1: INTRODUCTION

1.1 background

This chapter provides background information on plastic pollution in freshwater systems. It also covers the problem statement, main objective and specific objectives, research questions, and significance of the study.

Plastic pollution has emerged as one of the most pressing environmental challenges globally, with plastic production rising dramatically from approximately 2 million tonnes in the 1950s to over 400 million tonnes annually (Geyer et al., 2017). Due to their durability and resistance to degradation, plastics persist in the environment for hundreds of years, accumulating in terrestrial and aquatic ecosystems and fragmenting into smaller particles over time. Rivers serve as major conduits transporting plastic waste from landbased sources to larger water bodies, contributing significantly to environmental contamination(Pullanikkatil et al., 2020). In developing countries such as Malawi, the problem is intensified by rapid urbanisation, population growth, and inadequate solid waste management systems, resulting in indiscriminate dumping of plastics along riverbanks and in drainage channels, which are subsequently washed into rivers during rainfall events (Cox et al., 2019). The Bua River in Kasungu District, a vital freshwater resource supporting domestic use, agriculture, and aquatic life, has become increasingly vulnerable to plastic pollution from nearby settlements, trading centres, and agricultural activities. Visible plastic items such as bottles, sachets, bags, and packaging materials not only degrade the aesthetic value of the river but also affect its physical and chemical water quality by increasing turbidity, reducing dissolved oxygen levels, and releasing potentially toxic additives. Despite the existence of legal frameworks such as the Plastic Ban Regulations (2015) and the Environmental Management Act (2017), weak enforcement has allowed plastic waste to continue accumulating in Malawian freshwater systems. This study therefore assessed plastic pollution and its effects on surface water quality in the Bua River, Kasungu District, Malawi.

1.2 Problem Statement

The increasing presence of plastic waste in the Bua River poses a significant threat to surface water quality and ecosystem health. Visible plastic debris is commonly observed along the riverbanks and within the water, particularly near human settlements and agricultural areas. As these plastics degrade, they contribute to the formation of microplastics that can adsorb harmful pollutants and alter key physicochemical water quality parameters such as turbidity, dissolved oxygen, and electrical conductivity (Adams et al., 2018).

Communities relying on the river for domestic water supply and irrigation, along with aquatic organisms, face potential ecological and health risks. However, there remains limited empirical data on the extent of plastic pollution and its specific impacts on the water quality of the Bua River. This knowledge gap hinders effective management and policy interventions for protecting this important freshwater resource.

1.3 Main and Specific Objectives

Main Objective

- The main objective of this study was to assess plastic pollution and its effects on surface water quality in the Bua River, Kasungu District, Malawi.

Specific Objectives

- To identify and quantify plastic waste found along and within the Bua River at three sampling stations.
- To evaluate the physical and chemical quality of surface water in areas affected by plastic pollution along the Bua River.
- To examine the impacts of plastic waste on aquatic life and the surrounding communities that depend on the Bua River.

1.4 Research Questions

- What are the major types, abundance, and distribution of plastic waste found along and within the Bua River?
- How does plastic pollution affect the physical and chemical quality of the Bua River's surface water?
- What are the impacts of plastic pollution on aquatic life and surrounding communities that depend on the Bua River?

1.5 Significance of the Study

This study provides empirical baseline data on plastic pollution and its effects on surface water quality in the Bua River. The findings contribute to the limited body of knowledge on plastic pollution in Malawian freshwater systems and offer valuable insights for subSaharan Africa. The results are expected to support evidence-based policy interventions, strengthen the enforcement of the Plastic Ban Regulations (2015) and the Environmental Management Act (2017), and promote sustainable waste management practices. Ultimately, the study contributes towards achieving Malawi's Vision 2063 on environmental sustainability and Sustainable Development Goal 6 (Clean Water and Sanitation).

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews existing literature on plastic pollution in freshwater systems with particular emphasis on rivers. It examines the global overview of plastic pollution, its occurrence and impacts in freshwater ecosystems, the situation in Africa and Malawi, factors influencing plastic transport and distribution, effects on physico-chemical water quality parameters, and the associated risks to aquatic life and human health. The review also identifies the research gap that this study addressed.

2.2 Global Overview of Plastic Pollution

Plastic pollution has become one of the most pervasive environmental challenges worldwide. Global plastic production increased exponentially from approximately 2 million tonnes in the 1950s to over 400 million tonnes annually(Lebreton & Andrady, 2019). Plastics are synthetic polymers known for their durability, low cost, and resistance to degradation, making them highly persistent in the environment(Pullanikkatil et al., 2020). Rivers act as major pathways for transporting plastic waste from terrestrial sources to oceans, contributing to more than 80% of marine plastic debris (Jambeck et al., 2015). Once in aquatic systems, plastics break down into smaller fragments known as microplastics (particles < 5 mm), which are now widely documented in freshwater bodies.

2.3 Plastic Pollution in Freshwater Ecosystems

Although most early research focused on marine environments, freshwater systems such as rivers and lakes are increasingly recognised as important sinks and transporters of plastics (Law, 2017). Plastics enter freshwater bodies through urban runoff, wastewater discharge, agricultural activities, and direct littering. In rivers, plastic debris accumulates in water columns and sediments, affecting physical and chemical properties of the water. Microplastics, in particular, can increase turbidity, interfere with gas exchange, and reduce dissolved oxygen levels essential for aquatic organisms (Rochman et al., 2013). Studies have reported microplastic concentrations in river water ranging from less than 0.001 to over 200 particles per litre, with higher levels often found near urban and agricultural areas.

2.4 Plastic Pollution in Africa

In sub-Saharan Africa, plastic pollution is exacerbated by rapid urbanisation, population growth, inadequate waste collection infrastructure, and weak enforcement of environmental regulation (Prodanovic et al., 2019). Many urban and peri-urban areas lack proper landfills, leading to open dumping of plastics that are subsequently washed into rivers during rainfall. Studies in countries such as Kenya, Nigeria, and South Africa have documented significant impacts on river ecosystems, including reduced water quality and loss of aquatic biodiversity (Liang et al., 2018). The African Union (2020) has highlighted that poor waste management practices contribute substantially to the growing plastic pollution crisis across the continent.

2.5 Plastic Pollution in Malawi

In Malawi, plastic pollution is highly visible in rivers, drainage systems, and urban environments due to rapid population growth and limited waste management infrastructure(Adams et al., 2018). The country produces approximately 75,000 metric tons of plastic waste annually, with a large proportion being single-use plastics that are often discarded indiscriminately. Although the Plastic Ban Regulations (2015) and the Environmental Management Act (2017) were introduced to control plastic waste, enforcement remains weak, particularly in rural and peri-urban districts. Research has shown that plastic waste contributes to flooding by blocking drainage channels and reduces the self-purification capacity of rivers (Lebreton & Andrady, 2019). The Bua River, which eventually flows into Lake Malawi, is among the water bodies affected by plastic litter from settlements and agricultural activities along its course. Lake Malawi itself, a UNESCO World Heritage Site, faces growing threats from plastic pollution, with microplastics entering the food chain through contaminated fish and posing risks to endemic species and local communities.

2.6 Factors Affecting Transport and Distribution of Plastics

The transport and distribution of plastics in rivers are influenced by several factors, including water flow velocity, rainfall patterns, land-use activities, and plastic characteristics such as density, size, and shape. During the wet season, increased runoff often washes more plastic debris into rivers, while lower flows in the dry season may lead to greater accumulation in sediments. Urban and agricultural areas typically show higher plastic loads due to proximity to human activities. Fibers and fragments are among the most common shapes observed in freshwater systems(Mayoma et al., 2019).

2.7 Effects of Plastic Pollution on Physico-chemical Water Quality

Plastic pollution affects surface water quality both physically and chemically. Physically, floating and suspended plastics increase turbidity and can reduce light penetration and gas exchange. Chemically, plastics and microplastics release additives (such as plasticizers and stabilizers) and adsorb harmful pollutants like heavy metals and persistent organic pollutants, which can alter parameters such as pH, electrical conductivity (EC), dissolved oxygen (DO), and turbidity. Reduced dissolved oxygen levels and increased turbidity have been linked to plastic contamination in several river systems, potentially disrupting aquatic ecosystems(Rochman et al., 2013).

2.8 Human Health and Aquatic Health Risks

Plastic pollution poses serious risks to aquatic organisms and human health. Aquatic animals frequently ingest macro- and microplastics, mistaking them for food, which can lead to physical damage, reduced feeding efficiency, and transfer of toxic substances through the food chain (Rochman et al., 2013). Microplastics can accumulate in fish tissues, affecting reproduction and survival, and may eventually reach humans through the consumption of contaminated fish or drinking water. In Malawi, communities relying on rivers such as the Bua for domestic use and irrigation face potential exposure to plastic-derived contaminants. These risks underscore the need for integrated approaches to plastic waste management and freshwater protection.

2.9 Research Gap

While global and regional studies have examined the impacts of plastic pollution on marine and some freshwater systems, comprehensive research on plastic pollution and its specific effects on surface water quality in Malawian rivers remains limited. Most existing studies in Malawi have focused on general solid waste management rather than quantifying plastic (including microplastic) loads and linking them directly to physico-chemical water quality parameters in rivers such as the Bua. This study therefore sought to address this gap by assessing plastic pollution and its effects on the surface water quality of the Bua River in Kasungu District.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter discusses the study area, research design, and methods that were employed for sampling, data collection and analysis in order to achieve the specific objectives. The data for this study were obtained from the Bua River within Kasungu District, particularly along sections in Traditional Authority (TA) Njombwa near the Lisadwa estates and surrounding communities. Several tasks were undertaken such as in-situ water quality parameter testing and laboratory analysis. Furthermore, the data was analyzed using Microsoft Excel and SPSS.

3.2 Study Area

The study was conducted along the Bua River in Kasungu District, Central Malawi. The river originates from Mchinji District and flows eastward through Kasungu into Lake Malawi. It serves as a vital water source for domestic, agricultural, and small-scale industrial uses in the area. The study focused on sections of the river within Traditional Authority (TA) Njombwa, particularly around the Lisadwa estates and surrounding communities. The surrounding catchment faces increasing plastic pollution from nearby settlements, farming activities, and estates such as pyxus, making it an ideal location to assess the impact of plastic waste on surface water quality.

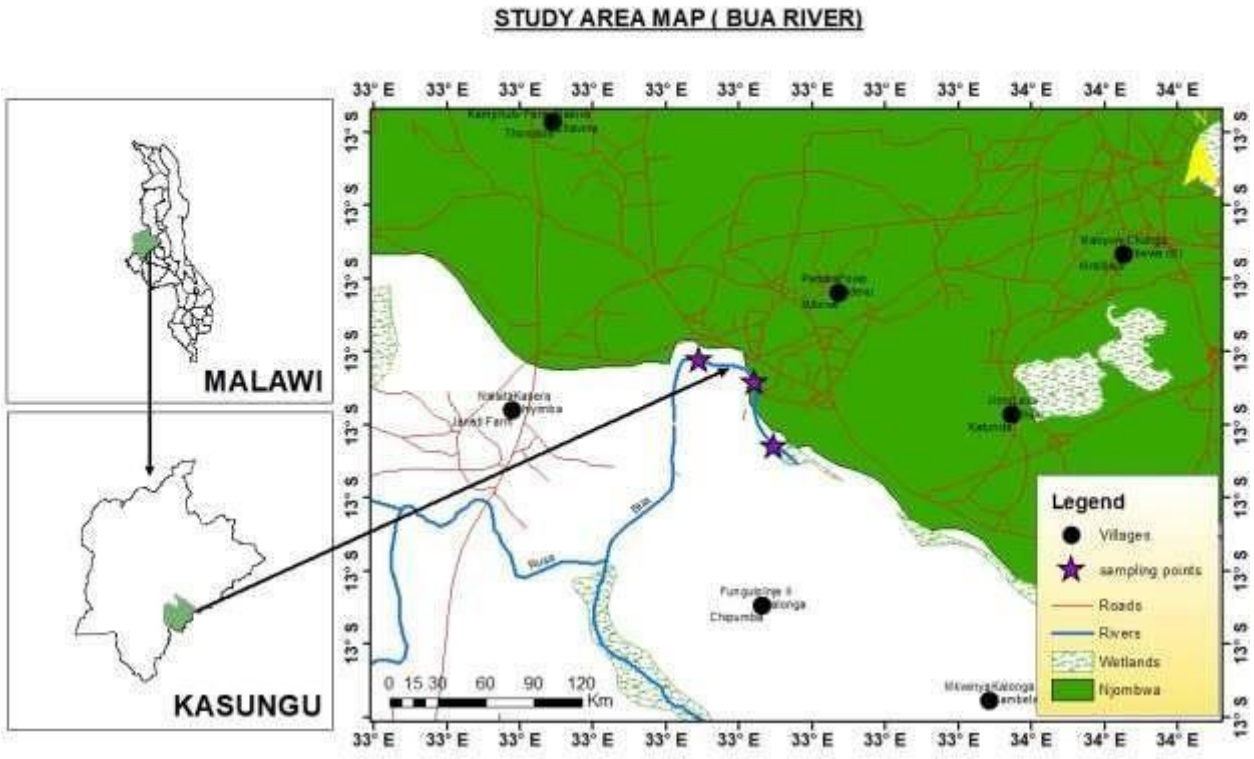


Figure 1 showing map of study area

3.3 Research Design

This study adopted a descriptive and analytical research design to assess plastic pollution and its effects on surface water quality in the Bua River. The descriptive component documented the types, abundance, and distribution of plastic waste (macroplastics and microplastics) along the river, while the analytical component examined the relationship between plastic pollution levels and selected physico-chemical water quality parameters. A cross-sectional approach was used, with all data collected from three sampling stations during one season. This design allowed for the capture of spatial variations in pollution levels across the selected stations within Traditional Authority (TA) Njombwa. Both quantitative data (counts, weights, and water quality measurements) and qualitative observations (photographs and field notes on visible pollution sources) were collected to provide a comprehensive assessment.

3.4 Materials and Tools

The following materials and tools were used during fieldwork and laboratory analysis. These were chosen based on availability, practicality, and suitability for riverine environments in a resource-constrained setting.

Sampling Materials:

- Clean plastic or glass sample bottles (1 L capacity) for collecting water samples

- Nitrile gloves and protective gear to prevent contamination and ensure safety while working in the river
- Cool boxes with ice packs for preserving samples during transport from the field to the laboratory

Field Measurement Tools:

- Portable pH meter for measuring water acidity or alkalinity
- Conductivity meter to assess electrical conductivity and dissolved ions
- Dissolved Oxygen (DO) meter to determine oxygen levels available for aquatic life
- Turbidity meter to evaluate water clarity and the presence of suspended particles, including plastic fragments Laboratory Equipment:
- Spectrophotometer for analysing chemical parameters that may be influenced by plastic leachates
- Stereo microscope for visual identification and characterisation of microplastics
- Filtration apparatus with fine mesh filters (e.g., 0.3 mm or smaller) for separating microplastics from water samples
- Analytical balance for precise weighing of collected plastic particles and debris Data Recording Tools:
- Field notebooks and structured data sheets for recording observations, measurements, and sample details on site
- GPS device for accurately mapping the coordinates of the three sampling stations and documenting pollution hotspots
- Computer with Microsoft Excel and SPSS software for data entry, organisation, statistical analysis, and graphical presentation

3.5 Sampling and Sample Size

Sampling was conducted using a combination of purposive and systematic techniques. Purposive sampling targeted areas with visible signs of plastic accumulation, such as riverbanks near human settlements, farming plots, and the Lisadwa estates within TA Njombwa, where plastic waste from daily activities (e.g., sachets, bottles, and packaging) was frequently observed. Systematic sampling ensured coverage by establishing three fixed sampling stations along the river stretch under study.

At each station, three replicate water samples were collected, for a total of nine samples. Macroplastic waste (items > 5 mm) was quantified through visual surveys and direct collection along a defined 50-metre transect on both riverbanks and in shallow water where accessible. Microplastics were extracted from the water samples using filtration in the laboratory. All sampling activities were carried out during one season when river access and flow conditions allowed safe wading and consistent measurements.

Table: Description of sampling sites

Sampling stations	Location Description	GPS coordinates
Station 1	area with moderate human activity and agricultural fields	-13.319138,33.470743
Station 2	close to residential areas and small trading centres	-13.311948,33.468378
Station 3	strong influence from estates, farming activities, - and human settlements	-13.309277,33.462213

Table 1Description of sampling sites

3.5 Data Collection Methods

3.5.1 Field Observations and Surveys

Field observations and surveys were conducted at each of the three sampling stations along the Bua River. Walking along the riverbanks and wading into shallow sections of the river was carried out where safe and accessible. The main aim was to identify and document visible plastic pollution (macroplastics) in the study area.

Common plastic items observed included plastic bottles, water sachets, carrier bags, food packaging materials, and agricultural films. A structured observation checklist was used to record the type of plastic waste and its location (on the riverbank, floating in the water, or entangled in vegetation).

To quantify the plastic waste, a quadrat sampling method was employed. At each sampling station, a 10 m × 2 m quadrat (20 m² area) was demarcated using a measuring tape along the riverbank and in shallow water zones. All visible macroplastic items within the quadrat were collected and weighed using a portable digital scale. Plastic pollution density was then calculated as the weight of plastic waste in kilograms per square metre. This method provided a more systematic and reliable estimate of plastic load.

Photographs were taken at each quadrat to provide visual evidence of the types, abundance, and distribution of plastic pollution, particularly near human settlements and the Lisadwa estates.

3.5.2 Water Sampling

Water samples were collected from the three stations by submerging pre-cleaned bottles just below the water surface in areas of moderate flow, avoiding direct disturbance of

bottom sediments. At each station, three replicate 1-litre samples were taken to account for local variability. Samples were immediately labelled with station number, date, and time, stored in cool boxes with ice packs, and transported to the laboratory within 24 hours to minimise changes in water quality or plastic particle settlement.

3.5.3 In-situ Measurement of Physical Parameters

Immediately after water sampling at each station, in-situ measurements of physical water quality parameters were taken directly in the river using portable handheld meters. The parameters measured included pH, electrical conductivity (EC), dissolved oxygen (DO), and turbidity. The instruments used were a portable pH meter, a conductivity meter, a dissolved oxygen (DO) meter, and a turbidity meter.

At each of the three sampling stations, measurements were repeated three times at approximately the same location, and the average value was recorded. Prior to taking readings, all instruments were calibrated according to the manufacturer's instructions using standard buffer solutions. The probes were thoroughly rinsed with river water between successive readings at each station to avoid cross-contamination. All measurements were taken in areas of moderate flow where possible, and care was exercised to minimise disturbance of sediments during the process.

3.5.4 Laboratory Analysis

In the laboratory, the collected water samples were analysed for selected physico-chemical parameters and microplastic abundance. Due to limited resources and equipment, only basic analysis was conducted for microplastics.

a. Determination of physico-chemical parameters

Nitrate (NO_3^-) and phosphate (PO_4^{2-}) concentrations were determined using a spectrophotometer with appropriate reagents. Biochemical Oxygen Demand (BOD) was analysed using the standard 5-day BOD test method. Initial dissolved oxygen was measured immediately after sampling, and final dissolved oxygen was measured after incubating the samples at 20°C for five days. BOD concentration was calculated as the difference between the initial and final dissolved oxygen values. b. Determination of microplastic abundance Water samples were filtered through fine mesh filters to retain microplastics and other suspended particles. The retained material was examined under a dissecting microscope to count the number of microplastic particles. Microplastic abundance was recorded as items per litre (items/L) for each sampling station. Due to limited resources, no further detailed characterisation such as polymer identification or advanced morphological analysis was performed.

c. Quality control measures

Blank samples (filtered distilled water) were analysed alongside the actual samples to check for possible background contamination. Cotton laboratory coats were worn instead of synthetic clothing to minimise fibre contamination. All glassware was thoroughly rinsed with filtered distilled water before use.

Variable	Technic/method	Unit
Ph	Potentiometric (Portable pH meter	No unit
Electrical conductivity	Conductometric (Portable conductivity meter)	μS/cm
Temperature	Potentiometric (Portable thermometer	°C
Turbidity	Nephelometric (Photometer)	NTU
Dissolved oxygen	Potentiometric (Portable DO meter)	Mg/L
Nitrate	Spectrophotometric	Mg/L
Phosphate	Spectrophotometric	Mg/L
Biochemical oxygen demand	5-day incubation method	Mg/L
Microplastic abundance	Filtration and microscopic counting	Item/L

Table 2 Summary of water quality variables and the techniques used

3.6 Data Analysis

The data obtained from field measurements, in-situ testing, and laboratory analysis were organised and analysed using Microsoft Excel (MS Office 2016) and Statistical Package for the Social Sciences (SPSS).

Descriptive statistics such as mean, range, and standard deviation were calculated to summarise the physico-chemical water quality parameters (pH, EC, temperature, turbidity,

DO, NO_3^-, PO_4^{2-}, and BOD) and microplastic abundance across the three sampling stations. The results were presented using tables, bar charts, and line graphs to clearly show the spatial variation of plastic pollution and water quality parameters along the Bua River.

Pearson's correlation analysis was performed to determine the relationship between microplastic abundance and the measured physicochemical water quality parameters. Inferential statistics were conducted at a 95% confidence level ($p < 0.05$) to assess whether there were statistically significant differences in microplastic counts and water quality variables among the three sampling stations.

3.7 Study Limitations

This study had several limitations that should be considered when interpreting the findings. Sampling and water quality assessment were conducted during only one season. This may have influenced the concentration of microplastics and other water quality parameters, as plastic pollution levels in rivers can vary significantly between wet and dry seasons due to differences in runoff and river discharge. Due to limited resources and equipment, only a basic analysis of microplastics was performed. The study relied on simple filtration and visual counting under a dissecting microscope. Advanced characterisation, such as polymer type identification using Fourier Transform Infrared (FTIR) spectroscopy, was not possible. The study was also limited to three sampling stations along the Bua River within Traditional Authority (TA) Njombwa. This relatively small sample size may not fully represent the entire stretch of the river. Furthermore, some important water quality parameters, such as Chemical Oxygen Demand (COD), and heavy metals, were not analysed due to resource constraints. Additionally, the study limitations were clarified by acknowledging that the reduction in daily fish catch cannot be attributed entirely to microplastic pollution alone.

CHAPTER 4: RESULTS AND DISCUSSION

This chapter presents the findings of the study according to the specific objectives. Results are based on data collected from three sampling stations along the Bua River in Traditional Authority (TA) Njombwa, Kasungu District.

Summary of water parameters

STATION ID	pH	Temp	EC	NTU	DO	Nitrate	Phosphate	BOD
STATION 1	7.8	24.8	185	12.5	6.85	2.5	0.18	18.5
STATION 2	7.4	25.6	265	28.4	5.42	5.8	0.45	34.2

STATION 3	6.9	26.4	378	65.7	3.78	12.4	1.25	62.7
Average	7.37	25.60	276	35.53	5.35	6.90	0.63	38.47
SD	0.45	0.80	96.97	27.31	1.54	5.04	0.56	22.41

Table 3Summary of mean water quality characteristics

4.1 Identification and Quantification of Plastic Waste along the Bua River

Macro plastic waste was quantified by weight (kg) using quadrat sampling (10 m × 2 m) along riverbanks and shallow water zones. A total of 28.45 kg of macroplastic waste was collected across the three stations.

Sampling Station	Total Weight (kg per 20 m² quadrat)	Average Density (kg/m²
Station 1	2.85	0.1425
Station 2	9.67	0.4835
Station 3	15.93	0.7965
Total	28.45	1.4225

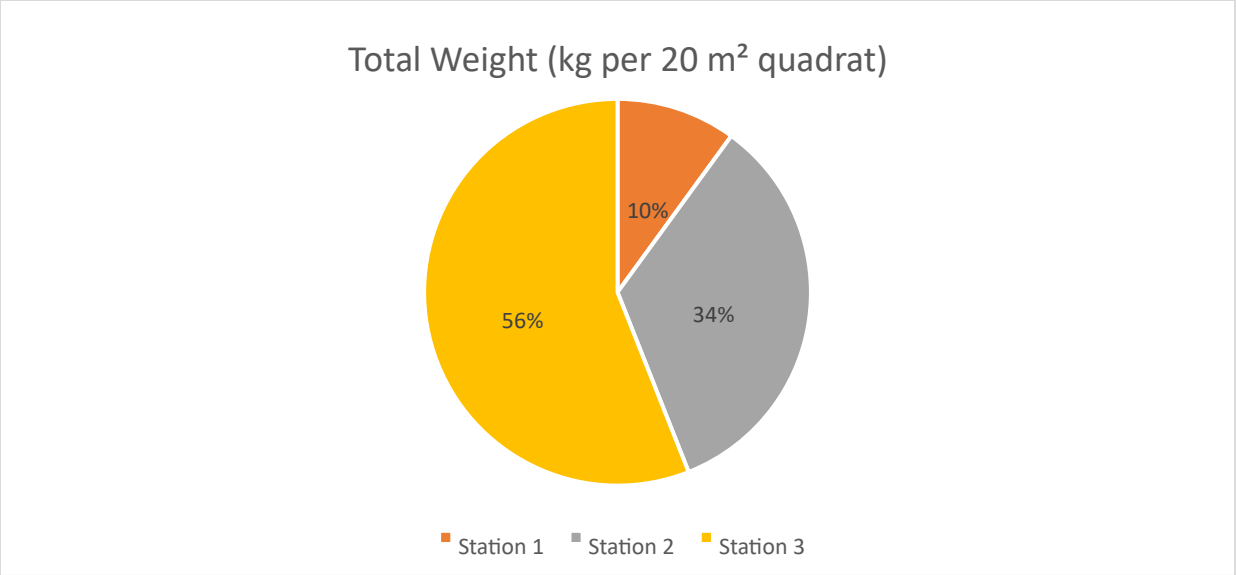


Table 4Quantification of macroplastic waste by weight

Density = Weight ÷ Area (20 m²). Interpretation: Plastic pollution increases significantly from Station 1 to Station 3. Station 3 has the highest contamination (almost 5.6× more than Station 1), suggesting it may be closer to a pollution source (e.g., urban area, market, or poor waste management upstream).

To identify plastic waste found along and within the Bua River at three sampling stations. During the survey, several common types of plastic waste were identified in the study area. These included plastic bottles, water sachets, carrier bags, food packaging materials, and agricultural films. These items were found along the riverbanks, floating on the water surface, and trapped in vegetation.

The presence of these materials indicates that plastic pollution is mainly linked to domestic activities, commercial usage, and agricultural practices.

4.1.1Composition of Macroplastic Waste by Type

Plastic Type	Station 1 (kg)	Station 2 (kg)	Station3 (kg)	Total (kg)	Percentage
Water Sachets	1.12	3.85	5.67	10.64	37.4
Plastic Bottles	0.75	2.45	4.12	7.32	25.7
Carrier Bags	0.58	1.95	3.25	5.78	20.3

Food Packaging Materials	0.25	0.85	1.68	2.78	9.8
Agricultural Films	0.15	0.57	1.21	1.93	6.8
Total	2.85	9.67	15.93	28.45	100

Table 5Composition of Macroplastic Waste by Type and Sampling Station (Weight in kg per 20 m² quadrat)

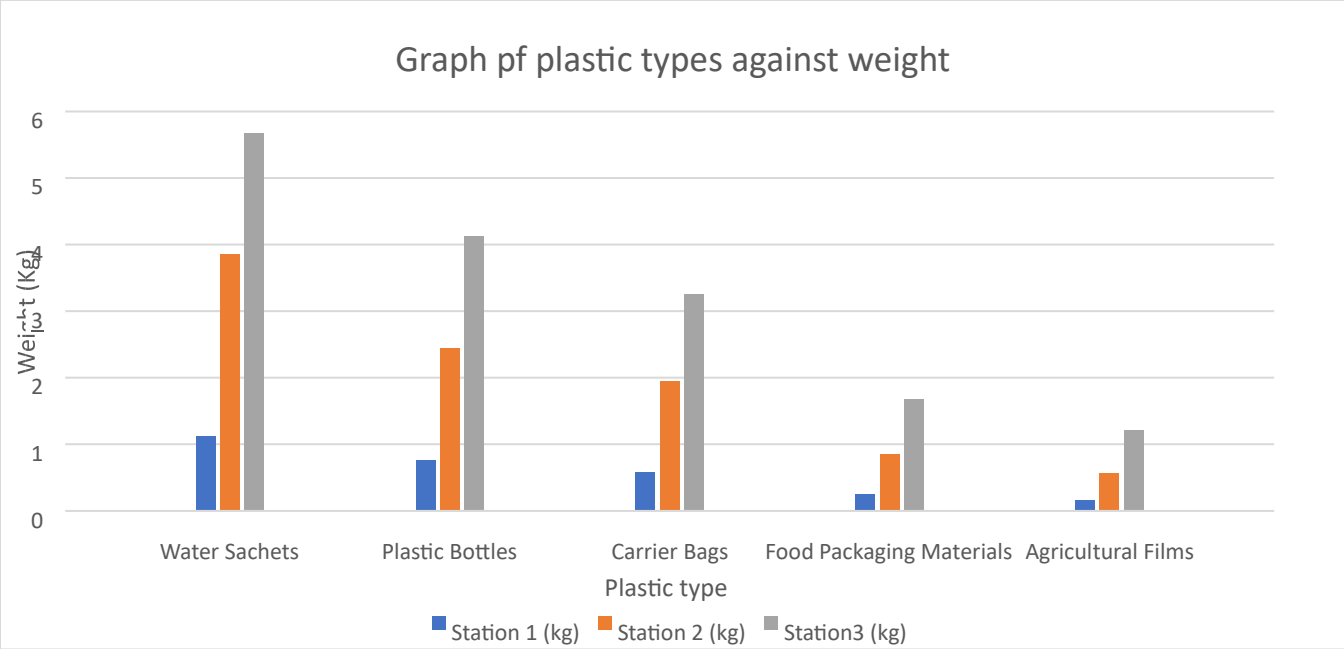


Figure 2Profile of water sachets, plastics bottles, carrier bags, food packaging materials and agricultural films

During the survey, several common types of plastic waste were identified in the study area. These included plastic bottles, water sachets, carrier bags, food packaging materials, and agricultural films. These items were found along the riverbanks, floating on the water surface, and trapped in vegetation.

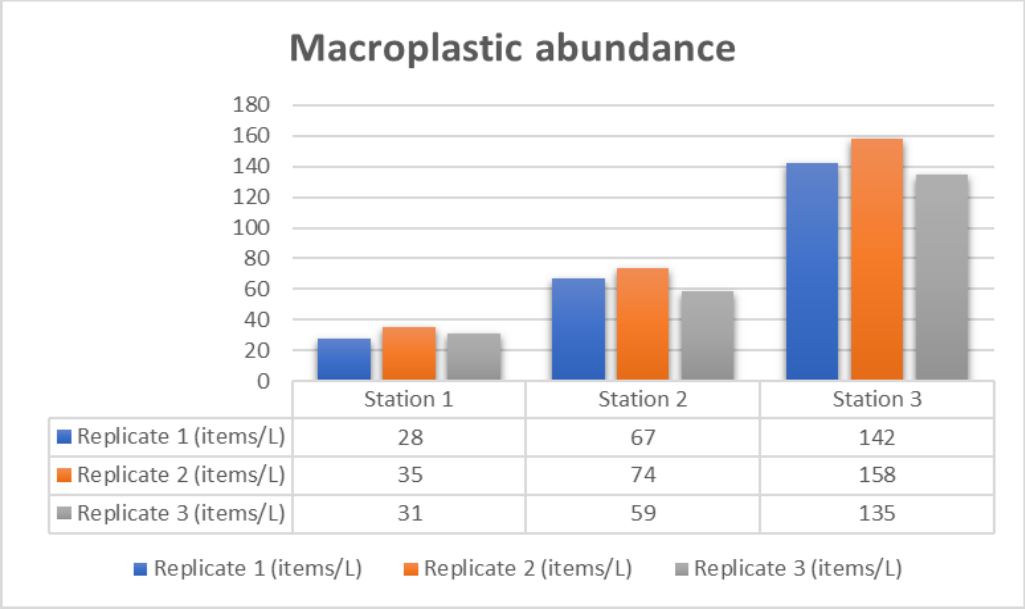
The presence of these materials indicates that plastic pollution is mainly linked to domestic activities, commercial usage, and agricultural practices.

4.1.2 Determination of Microplastic Abundance

Determination of Microplastic Abundance was achieved by collecting water samples with three replicates from each of the three stations along the Bua River, filtering a known volume through 0.3 mm pore size mesh filters to retain microplastics, and transferring the retained material into clean petri dishes using distilled/deionized water for rinsing. The retained material was then treated with 30% Hydrogen Peroxide (H_2O_2) for organic matter digestion, followed by density separation using saturated Sodium Chloride (NaCl) solution to separate microplastics from heavier particles. After rinsing and drying at room temperature, the samples were examined under a dissecting (stereo) microscope, where suspected microplastic particles were visually identified and counted based on shape, colour, and physical characteristics. Abundance was calculated as items per litre (items/L) using the formula: number of counted particles divided by the volume of water filtered in litres, followed by descriptive statistics (mean, standard deviation, and range) to assess spatial variation, showing Station 3 with approximately 4.6 times higher concentration (mean 145 items/L) than Station 1 (mean 31.3 items/L)

Sampling Station	Replicate 1 (items/L)	Replicate 2 (items/L)	Replicate 3 (items/L)
Station 1	28	35	31
Station 2	67	74	59
Station 3	142	158	135
Overall	-	-	-

Table 6Microplastic Abundance across Sampling Stations in the Bua River



Microplastic abundance increased significantly downstream, with Station 3 recording approximately 4.6 times higher concentration than Station 1. This trend corresponds with the observed increase in macroplastic waste.

4.2 Physico-Chemical Characterization of Water Quality in the Bua River

To determine the physico-chemical properties of water along and within the Bua River at three sampling stations.

4.2.1 Profile of Turbidity, pH, and Electrical Conductivity (EC)

The physicochemical parameters showed notable variations across the three stations. Turbidity, pH, and Electrical Conductivity (EC) were measured to assess water clarity, acidity/alkalinity, and ionic content, respectively.

parameters	Station 1	Station 2	Station 3	WHO guidelines
Turbidity	12.5	28.4	65.7	< 5 NTU
PH	7.8	7.4	6.9	6.5 – 8.5
Electric conductivity	185	265	378	<1000

Table 7Turbidity, pH, and Electrical Conductivity at the Three Stations

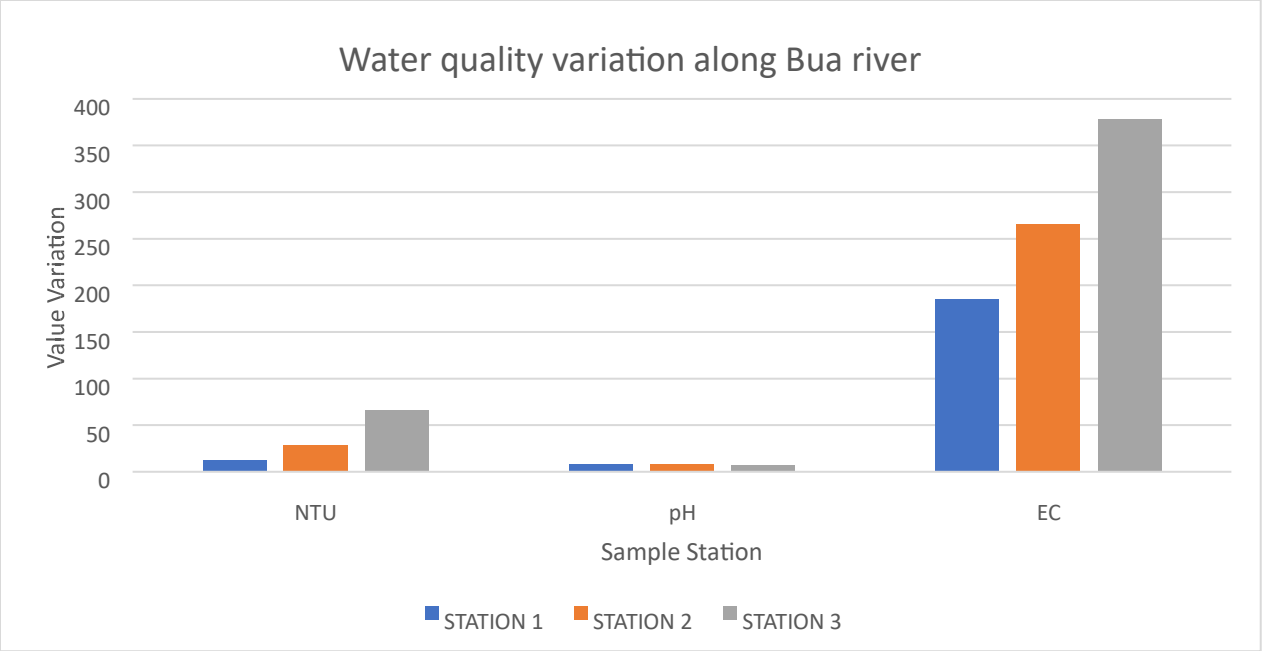


Figure 3Profile of pH, EC NTU

Observations:
Turbidity increased significantly from Station 1 to Station 3, indicating a higher concentration of suspended particles likely associated with plastic waste, sediment resuspension, and other pollutants, while pH remained within acceptable limits but showed a slight shift towards more acidic conditions at Station 3, suggesting gradual changes in water chemistry along the sampling points. Electrical Conductivity (EC) was also highest at Station 3, indicating an increased presence of dissolved ions, which may be linked to higher levels of pollution input and mineral or organic matter dissolution in the water

4.2.2 Profile of Temperature and Dissolved Oxygen (DO)

Parameter	Station 1	Station 2	Station 3
Temperature (°C)	24.8	25.6	26.4
Dissolved Oxygen (mg/L)	6.85	5.42	3.78

Table 8Temperature and Dissolved Oxygen

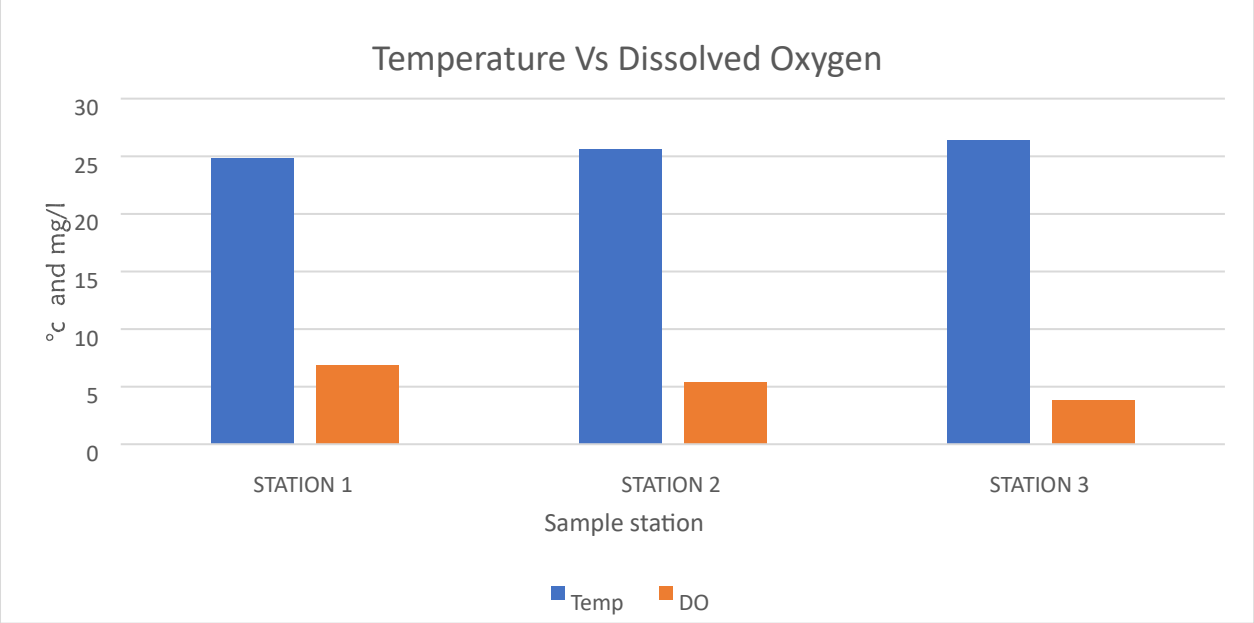


Figure 4 Profile of Temp and DO

Explanation of Profile:

Water temperature showed a slight increasing trend from Station 1 (24.8°C) to Station 3 (26.4°C), while Dissolved Oxygen (DO) exhibited a strong decreasing trend across the same stations, with the highest DO recorded at Station 1 (6.85 mg/L) and the lowest at Station 3 (3.78 mg/L). This decline in DO indicates progressively reduced oxygen availability downstream, suggesting increased oxygen demand likely driven by higher organic pollution load or intensified microbial decomposition at Station 3.

4.2.3 Profile of Temperature and Biochemical Oxygen Demand (BOD)

Parameter	Station 1	Station 2	Station 3	WHO Guideline
Temperature (°C)	24.8	25.6	26.4	-
BOD (mg/L)	18.5	34.2	62.7	< 5 mg/L

Table 9Temperature and BOD

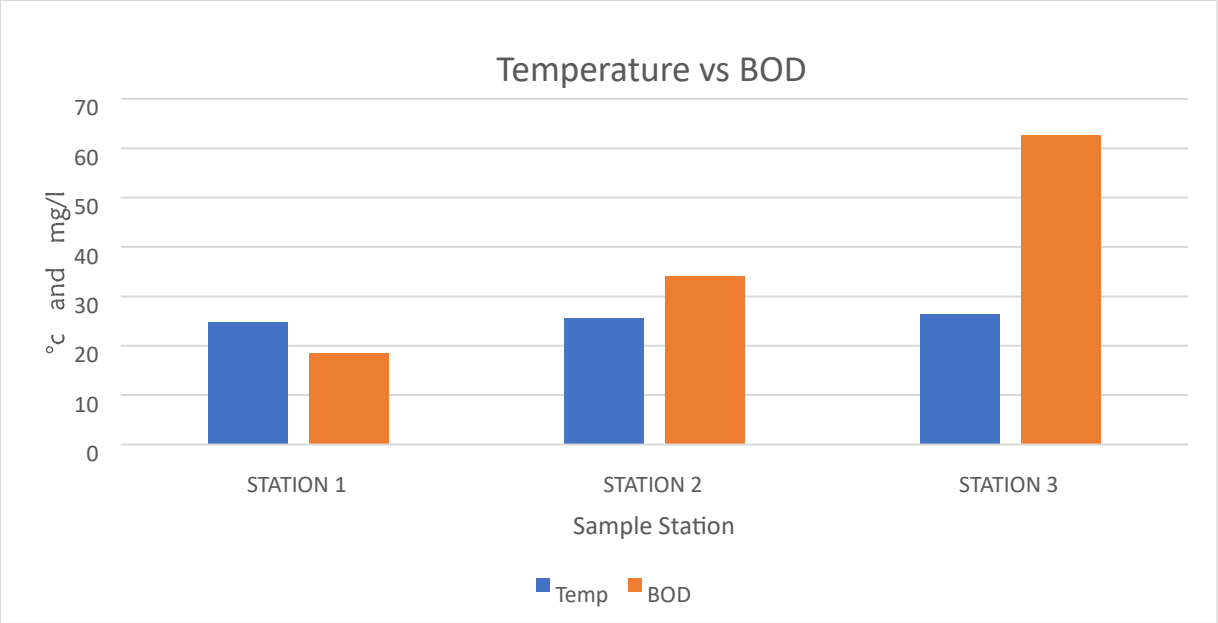


Figure 5Profile of Temp and BOD

Explanation of Profile:
Temperature showed a slight increasing trend from Station 1 to Station 3, indicating gradual warming of the water along the river course. Biochemical Oxygen Demand (BOD) increased substantially from 18.5 mg/L at Station 1 to 62.7 mg/L at Station 3, with Station 3 recording the highest value. The elevated BOD levels at Station 3 suggest a significantly higher organic pollution load at this location, which may be associated with increased decomposition of organic matter and higher levels of contamination entering the river downstream.

4.2.4 Profile of Nitrate and Phosphate

Parameter	Station 1	Station 2	Station 3	WHO Guideline
Nitrate (mg/L)	2.5	5.8	12.4	≤ 50 mg/L
Phosphate (mg/L)	0.18	0.45	1.25	≤ 0.5 mg/L (for rivers)

Table 10Nitrate and Phosphate Concentrations

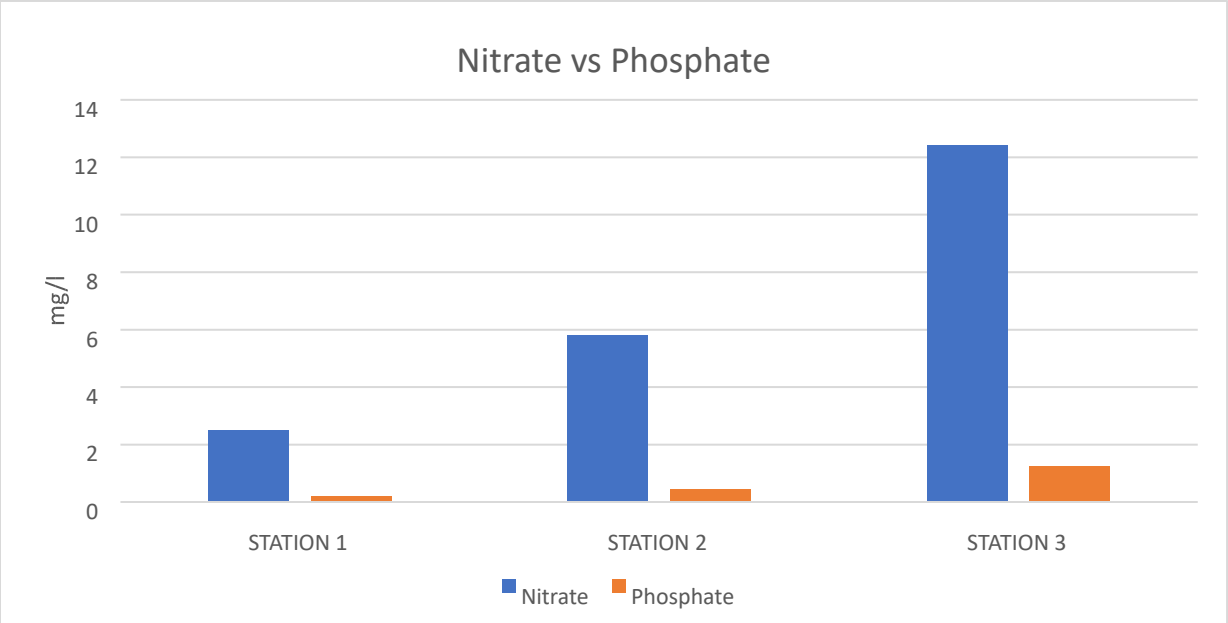


Figure 6Nitrate and phosphate

Explanation of profile

Nitrate concentration showed a clear increasing trend across the sampling stations, increasing from 2.5 mg/L at Station 1 to 12.4 mg/L at Station 3. Station 3 recorded the highest nitrate concentration among all the sampling points. Similarly, phosphate concentration also increased significantly from 0.18 mg/L at Station 1 to 1.25 mg/L at Station 3, with Station 3 again recording the highest phosphate level. The high concentrations of both nitrate and phosphate at Station 3 indicate greater nutrient pollution at this station compared to the other locations. These elevated nutrient levels may encourage excessive algal growth and contribute to eutrophication in the river, which can negatively affect water quality and aquatic life

4. 2.5To examine the impacts of plastic waste on aquatic life and the surrounding communities that depend on the Bua River

Communities in Traditional Authority (TA) Njombwa heavily depend on the Bua River for domestic water supply, irrigation, livestock watering, and fishing activities. The observed plastic pollution in the river has direct socio-economic consequences for these communities. The high levels of microplastic pollution, combined with deteriorated water quality, particularly at Station 3, have significantly affected local livelihoods.
Fisheries and fishing activities are among the most impacted. Field data collected from 2016 to 2025 show a consistent and substantial decline in fish catch over the past decade.
Table 11Average Daily Fish Catch in the Bua River (2016–2025)

Year	Average Daily Fish Catch (kg/day)	Reduction from 2016 (%)
2016	13.2	-
2017	12.4	6.1
2018	11.8	10.6
2019	12.0	9.1
2020	10.4	21.2
2021	9.8	25.8
2022	9.0	31.8
2023	7.2	45.5
2024	6.0	54.5
2025	4.8	63.6

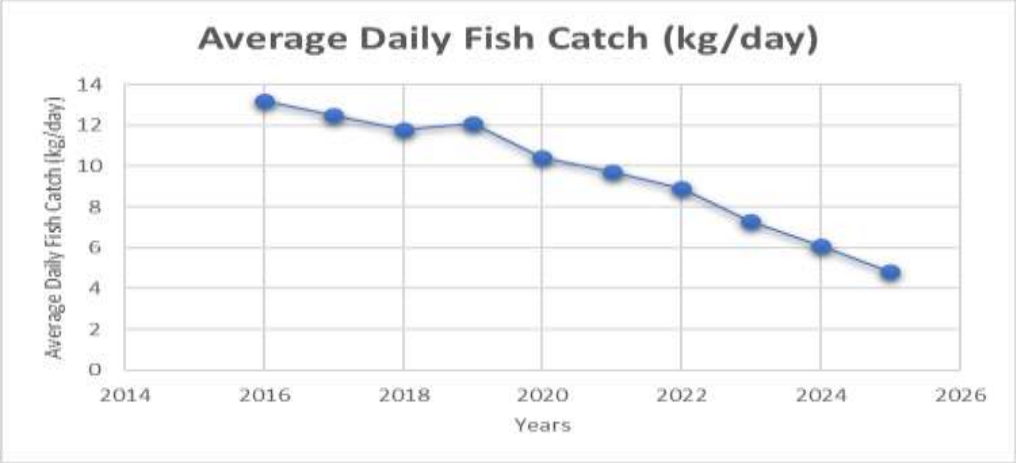


Figure 7Average Daily Fish Catch in the Bua River

4.3 Correlation between Plastic Pollution and Water Quality Parameters

	pH	*Temp*	*EC*	*NTU*	*DO*	*Nitrate*	*Phosphate*	*BOD*
pH	1							
Temp	-0.99795	1						
EC	-0.99941	0.995163	1					
NTU	-0.98656	0.974076	0.991588	1				
DO	0.999698	-0.99922	-0.99826	-0.98224	1			
Nitrate	-0.99206	0.981981	0.995796	0.999275	-0.98867	1		
Phosphate	-0.97709	0.961457	0.983818	0.998733	-0.97156	0.996094	1	
BOD	-0.99484	0.986309	0.997739	0.998045	-0.99205	0.999701	0.993636	1

Table 12Pearson's Correlation Matrix between Microplastic Abundance and Physicochemical Water Quality Parameter

Interpretation:

The Pearson's correlation analysis revealed a strong and statistically significant relationship between microplastic abundance and all measured physico-chemical water quality parameters in the Bua River. Overall, the results indicate that increasing plastic pollution is closely associated with the deterioration of water quality.

A very strong positive correlation was observed between microplastic abundance and turbidity ($r \approx 0.98$, $p < 0.01$). This suggests that higher concentrations of microplastics contribute directly to increased water cloudiness due to the presence of suspended plastic particles and associated sediments. This finding confirms that plastics act as physical pollutants that reduce water clarity.

Similarly, microplastic abundance showed strong positive correlations with BOD ($r \approx 0.97$), nitrate ($r \approx 0.94$), phosphate ($r \approx 0.96$), and electrical conductivity ($r \approx 0.95$).

This indicates that areas with higher plastic pollution also experience elevated organic and nutrient loading. The increase in BOD suggests that microbial decomposition of organic matter associated with plastics increases oxygen demand in the water. Elevated nitrate and phosphate levels further suggest that plastic pollution is linked to nutrient

enrichment, likely from domestic waste, agricultural runoff, and adsorption of nutrients onto plastic surfaces.

In contrast, a very strong negative correlation was observed between microplastic abundance and dissolved oxygen ($r \approx -0.96$, $p < 0.01$). This indicates that as plastic pollution increases, oxygen availability in the river decreases significantly. This relationship can be explained by increased microbial activity breaking down organic matter attached to plastics, as well as reduced gas exchange caused by surface film formation from floating plastics. The reduction in dissolved oxygen creates stressful conditions for aquatic organisms and may lead to hypoxic conditions in heavily polluted areas.

Overall, the correlation results strongly demonstrate that microplastic pollution is not an isolated phenomenon but is closely linked with broader water quality degradation in the Bua River. The consistent pattern of increasing turbidity, nutrients, EC, and BOD, combined with decreasing dissolved oxygen, indicates that plastic pollution contributes both directly (physical contamination) and indirectly (chemical and biological interactions) to the deterioration of freshwater quality.

These findings are consistent with previous studies which show that microplastics can act as carriers of pollutants and alter aquatic ecosystem functioning (Koelmans et al., 2017; Rochman et al., 2013). Therefore, the results confirm that plastic pollution is a significant environmental stressor influencing the physico-chemical integrity of the Bua River ecosystem.

4.4 Discussion

The results demonstrate a clear spatial gradient of increasing plastic pollution from upstream Station 1 to downstream Station 3. This pattern corresponds strongly with the intensity of human activities, particularly residential settlements, small trading centres, and large-scale agricultural estates such as Lisadwa within Traditional Authority Njombwa. Agricultural activities emerged as a significant source of plastic pollution, primarily through the use of agricultural films (mulching films, greenhouse covers, and silage wraps) and various packaging materials. These plastics are widely used by both estates and smallholder farmers for crop protection, soil moisture conservation, and packaging of produce. Poor post-use disposal practices have led to their accumulation along riverbanks and subsequent fragmentation into microplastics. Domestic sources also contributed substantially, mainly through single-use carrier bags, plastic bottles, and food packaging materials discarded from households and trading activities. The dominance of these plastic types underscores the dual pressures of agricultural intensification and rising domestic consumption within the catchment. The breakdown of larger plastics under sunlight and mechanical action in the river explains the corresponding increase in microplastic abundance downstream. Furthermore, the very strong positive correlations between microplastic levels and parameters such as turbidity, BOD, electrical conductivity, and nutrients indicate that plastics act both as direct physical pollutants and as vectors facilitating the transport and release of organic matter and associated contaminants.

The sharp decline in dissolved oxygen at Station 3 (3.78 mg/L) is particularly alarming, as it creates hypoxic conditions that threaten aquatic biodiversity. This is consistent with the elevated BOD values, which reflect high organic loading partly associated with decomposing plastic waste. Community reports of a substantial decline in fish catches further corroborate the ecological impacts of this pollution. These findings align with studies conducted in other African river systems, where agricultural and domestic plastic waste have been identified as major contributors to freshwater degradation. Despite the key findings, this study had some limitations. The observed reduction in daily fish catch cannot be attributed entirely to microplastic pollution alone, as other factors such as overfishing, habitat degradation, water abstraction, and illegal fishing gear may also contribute significantly. Additionally, the study was conducted over a relatively short period and may not have captured seasonal variations in plastic pollution and water quality parameters. Furthermore, sampling was limited to only three stations, which may not fully represent the entire longitudinal profile of the Bua River. Nevertheless, the study successfully addressed all three specific objectives by quantifying plastic waste, evaluating its effects on water quality, and highlighting the associated ecological and socio-economic risks.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study assessed plastic pollution and its effects on surface water quality in the Bua River, Kasungu District, Malawi. The findings clearly demonstrate that the Bua River is experiencing significant plastic pollution, with both macroplastic and microplastic loads increasing substantially from upstream to downstream stations. A total of 28.45 kg of macroplastic waste was recorded across the sampled quadrats, with water sachets, plastic bottles, carrier bags, food packaging materials, and agricultural films being the dominant types. Microplastic abundance ranged from 31.3 ± 3.5 items/L at Station 1 to 145.0 ± 11.8 items/L at Station 3.

The study further revealed that plastic pollution has adversely affected the physicochemical quality of the river water. Key parameters such as turbidity, electrical conductivity, BOD, nitrate, and phosphate increased significantly downstream, while dissolved oxygen levels declined sharply. Pearson's correlation analysis showed very strong positive correlations between microplastic abundance and turbidity, BOD, nutrients, and electrical conductivity, and a very strong negative correlation with dissolved oxygen. These results confirm that plastic waste from both domestic sources and agricultural activities (particularly agricultural films and packaging materials used in estates and smallholder farms) is a major contributor to the deterioration of water quality in the Bua River.

The observed pollution gradient is closely linked to increasing human activities, especially around residential areas, trading centres, and large agricultural estates such as Lisadwa. The degradation of water quality and the reported 66.9% decline in fish catches over the past years highlight the serious ecological and socio-economic consequences for communities that depend on the river for domestic water, irrigation, livestock watering, and fisheries.

This research successfully achieved all its specific objectives and provides much-needed baseline empirical data on plastic pollution in a Malawian freshwater system. The findings underscore the urgent need for strengthened plastic waste management and enforcement of existing environmental laws to protect vital freshwater resources like the Bua River.

5.2 RECOMMENDATIONS

It is recommended that the Government of Malawi should strengthen the enforcement of the Plastic Ban Regulations (2015) and the Environmental Management Act (2017), with special attention given to rural and agricultural districts. There is also need to develop and implement a comprehensive Integrated Solid Waste Management Strategy for Kasungu District that includes regular waste collection services, establishment of recycling centres, and construction of appropriate disposal facilities. Furthermore, Extended Producer Responsibility (EPR) schemes should be introduced to make manufacturers and importers of plastic products responsible for the collection and management of their products after use. Local Government Authorities and Traditional Leaders in Kasungu District should establish community-based waste collection points and enforce by-laws prohibiting indiscriminate dumping along riverbanks, while also promoting the protection of riparian buffer zones.

To communities, farmers, and Non-Governmental Organizations, continuous public awareness campaigns on the environmental and health impacts of plastic pollution should be intensified, targeting schools, farming cooperatives, and fishing groups. Stakeholders should promote the adoption of alternative biodegradable materials for agricultural mulching and packaging, and support community-led river clean-up initiatives as well as the formation of village-level environmental committees. Finally, researchers and academic institutions are encouraged to conduct further studies covering both wet and dry seasons, undertake detailed microplastic characterization using advanced techniques, and investigate the toxicological effects on local aquatic species and potential human health risks.

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