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TOXIC IMPACT OF PLASTIC WASTES ON MARINE LIFE OF WOJI AND NEW CALABAR RIVERS

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Abstract

Plastics are one of the most, widely, used materials in the world that, are broadly integrated into the daily lifestyle of people since they are used in almost all product areas. This study examined the resistivity and impact assessment of plastic wastes in Woji and New Calabar River. The objectives were to determine the physico-chemical properties of plastics; physico-chemical properties of water; toxic impact of plastic wastes on the aquatic life and assess the resistivity of different plastic wastes along the Woji and New Calabar Rivers. Standard Analytical Methods were used. Findings showed that the major type of plastic found in the study area (New Calabar and Woji Rivers) were Plastic bags; there is significant difference in the physical properties of plastics at the New Calabar and Woji River; most plastics collected from the Woji axis were combustible; No fish was found in the Woji River which was linked to the high level of industrial wastes in the River; Water quality parameters of the New Calabar River such as turbidity, conductivity, salinity, TDS, DO, BOD_5, Nitrate and Phosphate varied significantly ($p<0.05$) when compared to the water quality parameters of Woji River; major impact of plastic wastes in this study were death, perforated gut, biochemical/cellular death and increased population size; measures of stopping plastic waste disposal with respect to Sustainable Development Goal (SDG) 14 includes prevention of plastic littering, improving waste collection, handling transfer stations and proper transportation, improve final disposal site, introduce plastic waste separation at source and increase plastic waste recovery and recycling. The study concludes that plastic wastes obtained from the study area are characterized by high resistivity values which is as a result of the nature of plastics found. It is therefore recommended amongst others that enforcement of actions should be in place to reduce illegal dumping and open burning of plastic waste at disposal sites.

Keywords: *Waste, Plastic, River, Woji, New Calabar, Chemical*

Introduction

Plastic is a synthetic material made from hydrocarbons that can be molded in solid objects of almost all shapes and sizes. By cracking crude oil, a variety of petrochemicals are obtained that serve as a basis for plastics. Plastics including polyethylene and polypropylene (PP) are synthesized from olefins, while other plastics are synthesized from aromatic hydrocarbons, such as polystyrene (PS) and polyamide (PA) (nylon). Plastics are synthesized as spherical pellets or nurdles typically about

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0.5–5 mm in size. These preproduction materials are transported to factories where they are heated, extruded, or blow molded in the shape of its purpose. Additionally, additives are added depending on the purpose, such as flame retardants for electronic plastics or flexibility enhancers for packaging. Nowadays, the sectors using plastics are roughly divided in; packaging, building, transportation, electronics, textiles, and safety and leisure. In 2017, an estimated 348 million tons of plastic was produced worldwide (Plastics Europe, 2018). Due to its qualities, plastics have replaced heavier and more expensive materials such as glass, steel, and aluminum. In packaging, the use of plastic resulted in a high level of food preservation, decreasing food waste, and increasing the expiration date and transport possibilities. In the transport sector, the use of plastic packaging for transported goods resulted in a high decrease of CO_2 emissions per km (Palencia, Furubayashi, & Nakata, 2012).

Plastics come in a variety of configurations, depending on the used chemical building blocks. Main polymers produced nowadays are polypropylene (PP), high- and low-density polyethylene (HDPE and LDPE), polyethylene terephthalate (PET), polystyrene (PS), polyamide (PA), and polyvinyl chloride (PVC) (PlasticsEurope, 2018). The olefins, PP and PE, are used in all applications but mainly in packaging. PVC is mostly used in the building sector. Polyesters and PAs (nylon) are the main polymers found in textiles (PlasticsEurope, 2018). See Table 1 for an overview of the most commonly produced polymer types and their typical applications.

At the moment, only 9% of all plastics ever made are recycled (Geyer et al., 2017). This is mostly done through mechanical recycling. Mechanical recycling is an open loop recycling, meaning that the recycled plastics are used for different purposes than where they were recovered from (Ragaert et al., 2017). The mechanical recycling methods produces a lower quality end product compared to virgin plastics, due to degradation processes which results in a decrease of quality of the material (la Mantia, 2004). New recycling techniques are being developed that might improve recyclability which can result in potential closed loop recycling. These methods include chemical recycling (by dissolving the plastic in a solvent) and thermochemical recycling (pyrolysis) (Ragaert et al., 2017). Twelve percent of plastics in waste are incinerated (Geyer et al., 2017). In a few countries, energy is obtained from this burning process to heat houses and produce electricity (Scarlat, Fahl, & Dallemand, 2018). Most of the globally produced plastic is disposed in landfills. There are various levels of quality of landfills (Hoornweg & Bhada-Tata, 2012). In developed countries, these are often sanitary landfills, which can be considered “managed” (Jambeck et al., 2015). However, in developing countries, waste is being disposed in semicontrolled dumps. From these dumps, contaminants (which can include plastics) can be introduced in the environment (Hoornweg & Bhada-Tata, 2012).

Additionally, there is a fraction of plastic lost to the environment directly through littering, often estimated at about 2% of the total plastic production (Jambeck et al., 2015). Once in the environment, the fate of plastics varies by a plastic's properties. Travel distances, likelihood of accumulation, and degradation rate may vary considerable between plastic polymer and item types. Polymer identification is critical to develop expectations of a plastic's fate and effect due to its properties. For example, density affects the extend of transportation in aquatic environments (Schwarz et al., 2019). Additionally, also shape of plastics strongly affects exposed surface area, which can be important for transportation processes and chemical leakage (Schwarz et al., 2019). Shape groups observed in previous studies are the hard plastics (solid pieces), pellets (preproduction), films (thin layered), and fibers (elongated lines) (Eriksen et al., 2013; Free et al., 2014). Interestingly enough, the larger modeling studies focusing on river transport of plastics do not distinguish neither shape nor polymer type (Lebreton et al., 2017; Schmidt et al., 2017).

For plastic sizes, consistent terming and dimensions lack throughout plastic pollution studies. Most used terms are nanoplastics, microplastics, mesoplastics, macroplastics, and megaplastics (Blettler et al., 2017; Frias & Nash, 2019; Lebreton et al., 2018). Dividing plastics by size is still useful in terms of determining the source and to assess the final environmental impact.

Plastic is made up of a wide range of synthetic or semi-synthetic organic substances that are soft and can be molded into solid objects of diverse shapes. Plastics are typically organic polymers of high molecular mass and they often contain other substances. They are usually synthetic, most commonly derived from petrochemicals and many are partially natural (LCPP, 2011).

Plastic make up an estimated 10% of household waste, most of which is disposed in landfill (Barnes, 2009; Hopewell *et al.*, 2009) However, 60—80 % of the waste found on beaches, floating on ocean or sealed is plastic (Derraik, 2002; Barnes, 2005). Annual municipal solid waste generation for Port Harcourt was estimated as 265,129 MT and 352,853 MT for the years 1990 and 2000 respectively, with a generation rate of 0.33 kg/day/capita (Egunjobi, 1983; Ojile, 1998 and CASSAD, 1997). Per capita data shows that Port Harcourt generates waste at 1.0kg per capita per day as against 2.1kg for Nigeria as a whole (Amadi, 1993). Pollutech (1998) reported that solid waste generation was 504 tons per capita per year in 1996 while the quantity of municipal solid waste generated in 1994 in Port Harcourt and Obio-Akpo were given as 932,286.5 and 140,291 metric tons respectively (Rivers state government, 1994). About 70 % of the waste generated in Port Harcourt and Obio-Akpo is biodegradable and organic in nature with valuable plant nutrients (Pollutech, 1998).

Objectives of the study

i. Examine the toxic impact of plastic wastes on the marine life at Woji and New Calabar Rivers.
ii. Assess the resistivity of different plastic wastes along the Woji and New Calabar Rivers.

Literature Review

As stated in previous paragraph, plastics are synthetic or semi-synthetic materials which could molded into any object and still retain its plastic characteristic. Given their numerous good qualities such as low specific gravity, resistance to rust, ease of fabrication, low thermal and electrical conductivities, plastics have attracted wide interest in executing industrial and structural projects. In addition, most plastics possess variety of colours which is making them become a major resource for decorative functions (Pavani and Rajeswari, 2014). In Nigeria today, there are more than a hundred plastic producing factories generating a-tons of plastic products which are commonly used by people due to the fact that they are easy to use, relatively cheap and very convenient (Moharan and Maqtari, 2014). Plastic are also used in making polytene bags which are used in carrying groceries or packaging food items. Plastic bottles are also products of plastic wastes. They are mainly used in packaging liquids and very a common waste in the streets of Nigeria; however, these forms of plastic are known as Polyethylene terephthalate commonly abbreviated PET or PETE. An estimate of over a billion plastic (poly) bags and PET bottles are used yearly in Nigeria, the local markets, food sellers, grocery stores, traffic food hawkers etc. However, without the suns ability to melt this plastic materials and a proper disposal system, these plastic lay wastes on the soil, carried by wind to drainage or simple just fill up land space thus making them a hazard to the environment.

The rapidly developing economy of Nigeria boasts as the highest crude oil exporting country in Africa. This was followed the country's strategy to maximize the production and export of petroleum to drive its growth. However, given the country's unstable economic growth rate and the constant fluctuating world crude oil prices, Nigeria has not been able to maximize the huge opportunity to break out of the underdevelopment status despite the availability of large amount of human and natural resources at its disposal. For the years it has relied solely on its huge crude oil resources as the major source of revenue, while practicing a mono-lithic economy despite facing numerous developmental challenges. The most unfortunately part of this is the fact that the country have not even been able to manage the major resource (Suberu et al., 2015). Howbeit, with the world tending towards sustainability and the county's plastic wastes increase, it is essential Nigeria finds an alternative to improving its economy thus, a need to see plastic wastes as a solution to wealth.

Certainly, there is no gainsaying that plastics are becoming a major available resource in our environment. Although, problems are inevitable when they are poorly used or handled. In the process of plastic production and use major disposal problems arise which leads to poor aesthetics, fire hazards, health hazards, and energy shortages. Plastic waste recycling is definitely the most efficient approach to managing municipal waste, plus this can be perceived as a recent illustration for actualizing the model of industrial conservationism (Dhawan et al., 2019). However, there are no wastes within a natural environment there are only products. Moreover, plastic waste recycling is an approach where its negative effects on nature and the prevention of asset exhaustion can be decreased and harnessed as a means to wealth creation.

TABLE 1 Data on common plastic polymer types and their density. Densities higher than 1 are likely to sink in water. The percentages and most common products are assessed and calculated based on data from Schwarz et al. (2019), Texileworld (2019), and PlasticsEurope (2018)

		Density (g/cm^3)		
Polymer	**Abbreviation**	**Min**	**Max**	**Main application**
Polyethylene	PE	0.91	0.97	Packaging
Polypropylene	PP	0.9	0.91	Many applications, but mainly packaging
Polyester	PES	1.24	2.3	Textiles
Polyethylene terephthalate	PET	1.37	1.45	Packaging
Polystyrene	PS	1.01	1.04	Packaging
Expanded polystyrene	EPS	0.016	0.640	Food packaging, construction material
Ethylene vinyl acetate	EVA	0.92	0.94	Others
Alkyd	AI	1.67	2.1	Paints, fibers
Polyvinyl chloride	PVC	1.16	1.58	Building and construction
Polymethyl methacrylate	PMMA	1.17	1.2	Electronics (touch screens)

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Polyamide (nylon)	PA	1.02	1.05	Automotive, textiles
Polyacrylonitrile	PAN	1.09	1.2	Textiles
Polyvinyl alcohol	PVOH	1.19	1.31	Textiles
Acrylonitrile butadiene styrene	ABS	1.06	1.08	Electronics
Polyurethane	PUR	0.03	0.1	Building and construction

Characterisation of commodity plastics, plastic waste and its treatment

Plastics

The production and consumption of plastics has been increasing continually since the first half of the twentieth century. Since 1940s their worldwide production increased 100 times and in 2004 it amounted to around 200 Mio. Thermoplastics, mainly polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyamides (PA) and polyethylene terephtalate (PET), constitute 80% of around 50 Mio. Mg of the plastics produced in Western Europe. The remaining 20% covers thermosets, mainly polyurethanes (PUR), amino-, phenolic-, and epoxy resins.
The growth of the production of plastics compared with the production of steel and aluminium is presented in Figure 2.1. This dynamic increase is related not only to very good features of the polymeric materials, but also to the relatively lower energy demand that is needed for its production in comparison with the traditional materials: to produce 1 kg of commonly used plastics 10 MJ of energy is required, while to produce 1 kg of steel, aluminium or bottle glass, 20-50 MJ, 60-270 MJ and 30-50 MJ, respectively

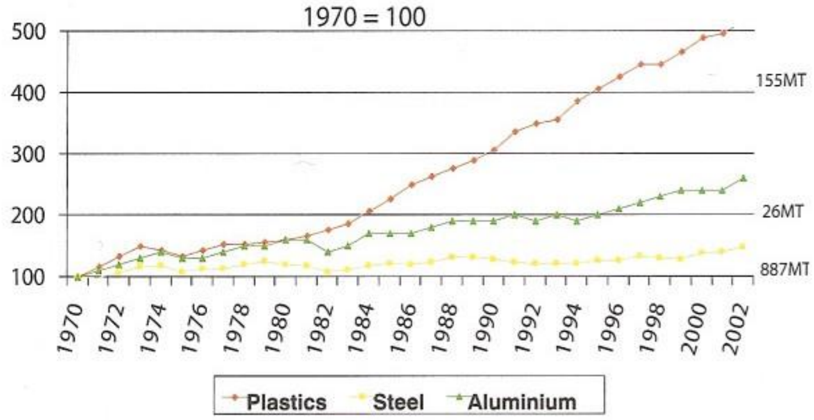

Figure 1 Plastic growth versus other materials

Source: Mayne, (2006)

The consumption of plastics per capita differs significantly from country to country: in

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Belgium it amounts to 144 kg, in Germany and in the USA to above 100 kg, while in India only around 1 kg. Due to the broad variety of polymer types and very useful features of the polymeric materials, e.g. durability, resistance, availability and relatively low production costs, the plastics cover a wide range of different applications. The use of main polymer types in different product groups is shown in the Table 2.1.

Table 2. Use of various polymers types in reference to application field

	Polymer type*
Packaging	LDPE, HDPE, PP, PET, PVC, PS, EPS
Building (except of pipes)	PVC, EPS, PUR
Pipes	HDPE, PP, PVC, PE, ABS/SAN
Electric/electronic	PP, PVC, HIPS, ABS/SAN, PUR
Automotive	HDPE, PP, PMMA, PA, ABS/SAN, PUR, PVC
Domestic wares	HDPE, PP
Furniture	PP, PUR, PVC

*names explained in abbreviations   Source: Pilz,et al (2005)

Apart from being used in typical plastic application fields like packaging and construction materials or household and electronic products, the polymers are also applied to the production of coatings, textile fibres, adhesives and other goods. According to the estimations of the PlasticsEurope organisation around 39% of thermosets and 13% of thermoplastics are used for the manufacture of so called non-plastic application products (APME, 2004). The structure of plastics use in different application fields, with packaging and construction sectors being in the lead, is presented

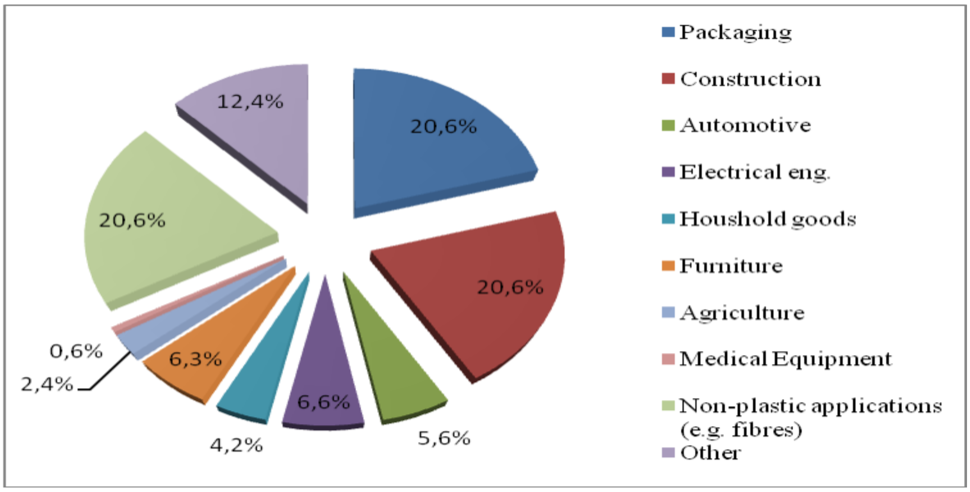

Fig. 2 Consumption of plastics in reference to application sector in Europe

Source: Simon (2004) & Harald et al, (2000)

Table 3 Consumption of plastics in reference to polymer type in Europe

	Consultic, 2004	PlasticsEurope, 2004
	[%]	
Low density polyethylene (LDPE)	14,7	16,5
High density polyethylene (HDPE)	11,1	11,1
Polypropylene (PP)	16,2	16,1
Polystyrene (PS) Expanded polystyrene (EPS)	5,9	6,4
Polyvinyl chloride (PVC)	15	12
Polyethylene terephtalate (PET)	3,9	7,8
Polyamide (PA)	3	2,7
Polymethyl methacrylate (PMMA)	0,9	0,7
Polyurethane (PUR)	6,2	5,5
Other	23,1	21,2

Source: Simon (2004) & Harald et al, (2000)

The life span of plastic products differs significantly among various applications. According to Huckestein et al. (2006), only 25% of plastic goods become waste within one year, while 60% have life span of eight years or even more. The construction industry products have especially long life spans, exceeding 30 years. The Association of Austrian

Chemical Industry (FCIO) estimates that around a half of all the plastic articles belongs to the so called long-living products group and is used mainly in construction and automotive sectors, as well as for electric & electronic appliances; while around one third of all plastic goods, mainly packagings, medicine articles and some office equipment, reach the end of their life cycle within one year. The rest of the plastic products is assigned to the medium- long use group – with a life span below ten years (FCIO, 2005). The approximate life spans of the plastic products from different applications fields are presented

Table 4 Approximated life spans of plastic products

	Lifespan [years]
Packaging	~ 1
Construction, building	20-50
Automotive	~ 15
Electrical engineering	5-50
Household goods	~ 5
Furniture	~ 15
Agriculture	~ 3
Medical equipment	~ 1
Non-plastic applications	5-15
Other	~ 5

Source: Bogucka & Brunner (2007)

Methodology

Study Area

The study was carried out at two (2) different locations, Woji River and the New Calabar River both in Port Harcourt (*see Fig. 1*).

Woji River is an estuarine tidal water, a tributary of upper Bonny River located between longitudes 7°00 E and 7°15 N and latitudes 4°28 E and 4°40 N. It rises from the bifurcation to the left of the Okpoka River, which drains into Bonny River. The area has a mean water depth of 4.8 m, which is tidal and gradually transits from fresh to salt water at the head. Woji River receives industrial effluent discharges from the Nigerian Bottling Company, Schlumberger, Halliburton and Rivers State Vegetable Oil Company and transverses through several communities among which are: Azuabie, Woji, Okuru-ama, Abuloma, Kalio-ama and Oba-ama. The Trans-Amadi slaughter house and market generate wastes and faeces entering the River.

The New Calabar River lies between longitude 06º53 53086’E and latitude 04º53’ 19.020’N in Choba, Rivers State, Nigeria. The entire river course is situated between longitude 7º60’E and latitude 5º45’N in the coastal area of the Niger Delta and empties into the Atlantic Ocean.The river is used as a domestic and industrial waste

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disposal point for companies and people living close to it. The land around the river houses an abattoir, poultry, a fabrication company and a weekly market. A small cluster of houses were seen close to the river bank where toilets and bathrooms are also constructed close to the river bank. Dredging and fishing activities are still ongoing alongside numerous other human activities (such as waste disposal, bathing, washing and so on). All aforementioned activities pollute the water body in varying degrees.

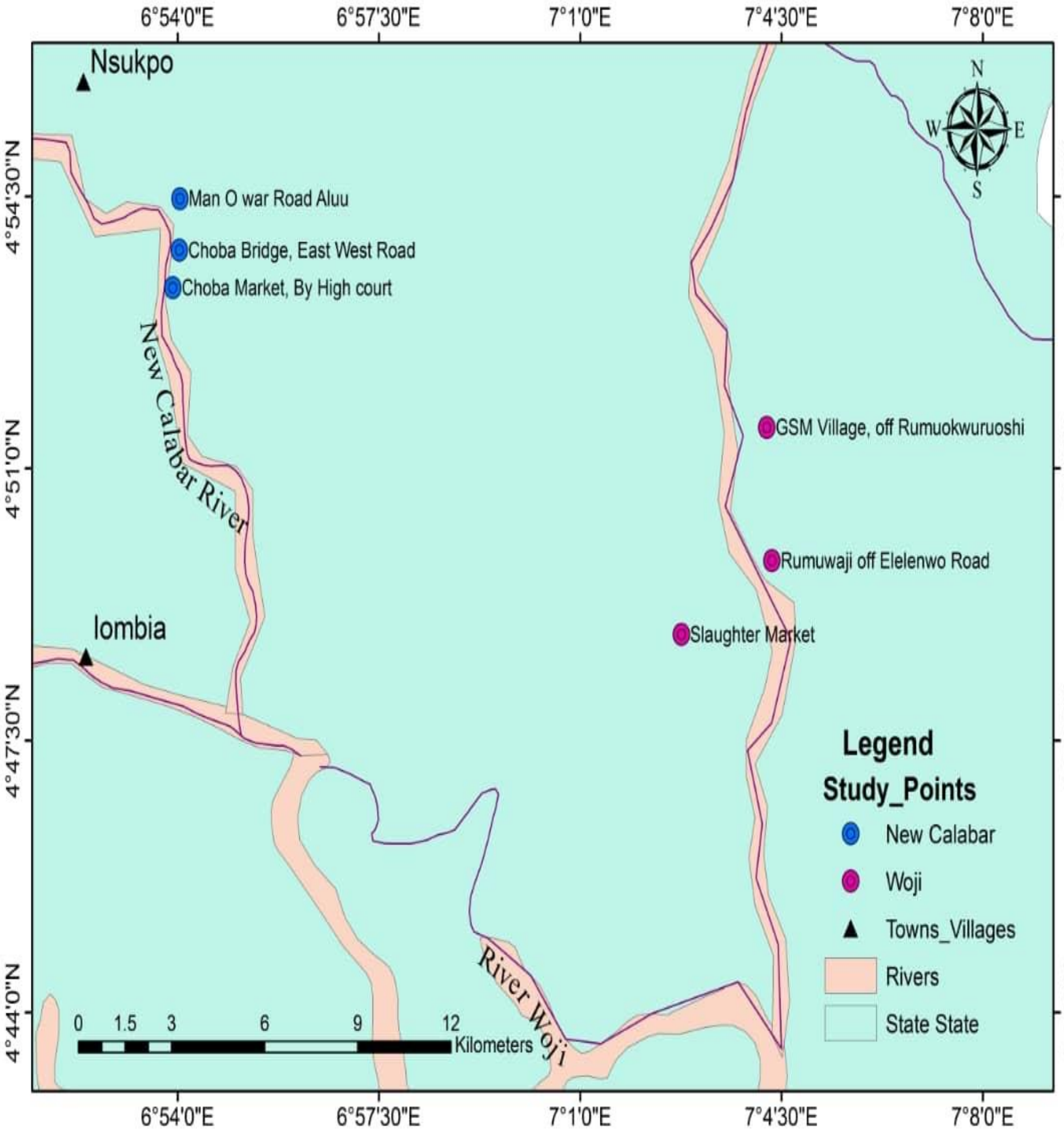

Fig 3: Map of Study Area showing study points

Sample and Sampling Technique

In a bid to obtain information onmeasures of stopping plastic waste disposal into the rivers with focus on Sustainable Development Goal (SDG) 14 (Blue economy). The researcher sampled the opinions of respondents (Staff of Rivers State Waste Management Agency) experienced in waste management in Rivers State using the questionnaire. The purposive sampling technique was used in selecting 192 respondents used in this study. The reason for this approach was to focus on the particular population that can provide answers to the research question.

Collection of plastic samples

In the study, two locations throughout the New Calabar and Woji River were sampled for analysis of plastic debris at Iwofe and Choba. Sampling sites selection was based on a number of criteria including site access and suitability for sampling and most, importantly, the different anthropogenic activities to which they are thought to be exposed.

The methodology of transect determination and selection, quadrant (1 m^2) placement as well as sampling, sample processing and analysis procedures were based on the existing shoreline monitoring protocols established by the National Oceanic and Atmospheric Administration Marine Debris Program (Lippiatt, 2013).

A survey of 100 m long, 5 m deep area along the study area was taken to quantify density and composition of debris. After selecting a site that ideally allows 100 m of continuous riverside collecting (that is, avoiding walls, private property, or an impenetrable landscape), the site was measured and marked a 100 m length of shoreline with survey flags, starting at the river's edge. Then, 5 m depth landward was measured from the shoreline, marking this distance with flags along the 100 m length , which produced a total collection area of 500 m^2.

Thereafter, a systematic pattern of walking back and forth from the shoreline to the edge of the 5 m deep area was repeated until the entire area was covered. Everything visible within the project area that was attributable to humans was collected and use for the study.

The materials collected from the site were returned to the laboratory for analysis. It was systematically counted, weighed, and cataloged the constituents in accordance with laboratory standards, which include data sheets for both site data and for cataloging debris, derived and adapted from Opfer *et al.* (2012).

Determination of the Physico-chemical properties of plastics

Physical Properties of plastics collected

The physical properties like density and weight of the plastics were determined using the methodology adopted by Opfer *et al.*(2012) as seen in Table 3.1.

Density determination

Each size class was then weighed on a digital balance (EJ-13) to 0.01 g precision and their density (mass of debris items/m^3 of the sand) was calculated as follows:

$D = w/(a \times h)$

D = density of debris items (mass of debris items/m^3 of the sand)

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w = mass of debris items

a = area sampled = 500 m^2

h = depth of sampling = 1 m

Table .5: Types ofplastics collected at the Woji and New Calabar River

	Plastic Waste Data	Number	Density	Weight in grams
1	Hard plastics fragments			
2	Foamed plastic fragments			
3	Filmed plastic fragments			
4	Food wrappers			
5	Beverage bottles			
6	Other jugs or containeers			
7	Bottle or containeer caps			
8	Cigar tips			
9	Cigarettes			
10	Disposal cigarette lighters			
11	6-pack rings			
12	Bags			
13	Plastic rope and small net pieces			
14	Buoys and floats fishing lures and lines			
15	Cups			
16	Plastic utensils			
17	Straws			
18	Balloons			
19	Personal care products			
20	Pen			
21	Diapers/pads			

22	Woven plastic bags
23	Plastic wire
24	Nylon foam sponge
25	Children toys
26	Others

Source: *Field survey 2020*

Chemical properties of plastics sampled

The chemical properties of plastics sampled were analyzed, at the Department of Chemical/Petrochemical Engineering Laboratory, Rivers State University (RSU), to determine the type of chemicals present in the study area.

Determination of Physico-chemical properties of water

Water samples for the determination of total dissolved solids, dissolved oxygen, salinity, conductivity, temperature and pH were collected for each sample station. Water samples collected were transported to the Biological Sciences Laboratory of the Institute of Pollution Studies (IPS), Rivers State University for water quality analysis. Physico-chemical parameters such as total dissolved solids (TDS), dissolved oxygen (DO), salinity, conductivity, temperature and pH were used to determine the water quality and pollution effects from plastics. The Azide modification method was used to determine the initial dissolved Oxygen (APHA, 1998), the total dissolved salts was used to measure the salinity of the water by evaporating the known volume of water then weighing the solid residue remaining. Temperature measurements of surface water were undertaken with a mercury-in-glass thermometer (Degrees Centigrade, °C), while the pH was determined using a pH meter (PHS-25).

RESULTS AND DISCUSSION

4.1 Research and Analysis

Distribution of plastics collected at different reaches of Woji and New Calabar Rivers

Table 4.1 revealed the distribution of plastics collected at different reaches of Woji and New Calabar River. At Woji River it showed that out of 421 plastics collected, 165(39.2%) were Nylon plastic bags, followed by plastic wire 41(9.7%), 38(9%) consists of fishing lures and lines, 32(7.6%) consists of bottles or container caps, 28(6.7%) consist of hard plastic fragments, 21(5%) consists of foamed plastic fragments, 18(4.3%) consists of cups, 14(3.3%) consists of plastic ropes and small net pieces, 12(2.9%) consists of food wrappers, 13(3.1%) consists of beverage bottles and disposable cigarette lighters respectively, 8(1.9%) consists of Other jugs or containers and children toys respectively, 6(1.4%) consists of pen and 4(1%) consists of bags.

Similarly, at New Calabar River it also showed that out of 546 plastics collected, 87(15.9%) were Nylon plastic bags, followed by food wrappers 75(13.7%), 59(10.8%) consists of bottles or container caps, 51(9.3%) consists of fishing lures and lines, 45(8.2%) consists of bags, 43(7.9%) consists of other jugs or containers, 33(6%) consist of hard plastic fragments and cigarette lighter respectively, 31(5.7%) consists of cups, 25(4.6%) consists of plastic ropes and small net pieces, 20(3.7%) consists of beverage bottles, 18(3.3%) consists of foamed plastic fragments, 11(2.1%) consists of children toys, 8(1.5%) consists of pen and 7(1.3%) consists of plastic wires.

Table 6: Plastic waste types at different reaches of Woji and New Calabar Rivers

S/N	Plastic Waste Type	Woji River			New Calabar River		
		Frequency	(%)	Rank	Frequency	(%)	Rank
1	Hard plastics fragments	28	6.7	5th	33	6.0	7th
2	Foamed plastic fragments	21	5.0	6th	18	3.3	11th
3	Food wrappers	12	2.9	10th	75	13.7	2nd
4	Beverage bottles	13	3.1	9th	20	3.7	10th
5	Other jugs or containeers	8	1.9	11th	43	7.9	6th
6	Bottle or containeer caps	32	7.6	4th	59	10.8	3rd
7	Disposal cigarette lighters	13	3.1	9th	33	6.0	7th
8	Bags	4	1.0	13th	45	8.2	5th
9	Plastic rope and small net pieces	14	3.3	8th	25	4.6	9th
10	Fishing lures and lines	38	9.0	3rd	51	9.3	4th
11	Cups	18	4.3	7th	31	5.7	8th
12	Pen	6	1.4	12th	8	1.5	12th
13	Plastic wire	41	9.7	2nd	7	1.3	13th
14	Nylon plastic bag	165	39.2	1st	87	15.9	1st
15	Children toys	8	1.9	11th	11	2.1	
	Total	**421**	**100**		**546**	**100**	

Source: *Field survey, 2019*

4.1.1 Physico-chemical properties of plastics collected at different reaches of Woji and New Calabar River

Table 4.2 and 4.3 revealed the physico-chemical properties of plastics at different reaches of the study area.

The physical properties of plastics were measured based on the plastics thickness and density. Hence, the thickness of plastics found at the New Calabar River (28.57 ± 0.89) was higher than that of Woji River (22.21 ± 4.39) with a p-value of 0.000. Also, the density of plastics

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found at the New Calabar River (0.034±0.02) was higher than that of Woji River (0.010±0.01) with a p-value of 0.010. Similarly, the chemical properties of plastics collected were measured based on combustion and resistivity. Table 4.3 further showed that the plastics in the New Calabar and Woji River were within the slow-burning range of (50-75) while the resistivity of plastics collected in the two rivers were above the threshold of 10^{11}, thus considered electrical insulator.

Table 7: Physical Properties of the plastics at different reaches along the Woji and New Calabar Rivers, Port Harcourt.

	Physical Properties	
	Thickness (µm)	Density (kg/m^3)
Woji River	22.21±4.39	0.010±0.01
New Calabar River	28.57±0.89	0.034±0.02
P-Value	0.000	0.010

Note: *Values represents (Mean± S.E.M)*

Table 4.3: Chemical Properties of the plastics at different reaches along the New Calabar River and Woji River

	Combustion	**Resistivity (Ohms)**
New Calabar River	66.87±5.42	10^{11}
Woji	72.87±3.66	10^{11}
Plastic Technology Handbook	50-75 = Slow- burning 75-200 = Combustible	> 10^9 is considered an electrical insulator

Note : *Values represents (Mean± S.E.M)*

4.1.2 Physico-chemical properties of water collected at different reaches of the Woji and New Calabar River

Table 4.4 and 4.5 revealed the mean and individual values of the physicochemical parameters from the different stations compared with the World Health Organisation standard. It was seen that parameters such as pH, temperature, turbidity, salinity, dissolved oxygen, Nitrate and phosphate had mean values within the permissible limit of W.H.O. On the other hand, conductivity, total dissolved solids, BOD, Faecal Coliform Bacteria (FCB), Total Coliform Bacteria (TCB) and Total Heterotrophic Bacteria (THB) were above the permissible limit of W.H.O.

pH

Results obtained as seen in table 4.4 and 4.5 showed the ph value obtained across the study area ranged between 6.65 and 6.82 with *mean±S.E* ph value of 6.91 ± 0.00 at Woji River and 6.67±0.00 at New Calabar River. A p-value of 0.214 was also obtained which indicates no significant variation in pH across sample stations as values were within the W.H.O permissible limit of (6.5-8.5).

Temperature

Table 4.4 and 4.5 showed that the temperature values obtained across the study area ranged between 26.8°C and 28.0°C with *mean±S.E* temperature value of 27.13±0.29 (New Calabar) and 27.73± 0.25 (Woji River). A p-value 0.449 was obtained which indicates no significant variation in temperature across sample stations as values were within the W.H.O permissible limit of (26.5 – 32).

Turbidity

Similarly, the turbidity values shown in table 4.4 and 4.5 showed turbidity values ranging between 0.2NTU and 1.3NTU across the study area with *mean±S.E* turbidity value of 0.20±0.00 at New Calabar River and 1.17±0.07 at Woji River. A p-value of 0.005 was obtained which indicates a significant variation in turbidity across sample stations although values were within the W.H.O permissible limit of 5NTU.

Conductivity

The conductivity values range between 5879µS/cm and 15580µS/cm across the study area with *mean* ± *S.E* conductivity value of 6183.33±179.01 at New Calabar River and 15303.33±307.16 at Woji River (See table 4.4 and 4.5). A p-value of 0.003 which indicates a significant variation in conductivity across sample stations. Values obtained were above the W.H.O permissible limit of 500 µS/cm.

Salinity (mg/l)

The salinity values range between 3.25mg/l and 9.07mg/l across the study area with *mean* ± *S.E* conductivity value of 3.34±0.05 at New Calabar River and 8.72±0.34 at Woji River. A p-value of 0.000 which indicates a significant variation in salinity across sample stations. Values obtained were below the W.H.O permissible limit of 5000mg/l.

Total dissolved solid, TDS (mg/l)

The total dissolved solid values range between 3960mg/l and 11000mg/l across the study area with *mean* ± *S.E* conductivity value of 4586.67±442.02 at New Calabar River and 10406.67±398.18 at Woji River. A p-value of 0.006 which indicates a significant variation in total dissolved solid across sample stations. Values obtained were above the W.H.O permissible limit of (250-500) mg/l.

Dissolved oxygen, DO (mg/l)

The dissolved oxygen values range between 6.1mg/l and 9.3mg/l across the study area with *mean* ± *S.E* dissolved oxygen value of 6.17±0.07 at New Calabar River and 7.16±0.13 at Woji River. A p-value of 0.038 which indicates a significant variation in dissolved oxygen

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across sample stations. Values obtained were within the W.H.O permissible limit of (5-10) mg/l.

BOD_5 (mg/l)

The BOD_5 (mg/l) ranged between 0.6mgl and 6.8mg/l across the study area with *mean* ± *S.E*BOD_5 value of 0.67±0.03 at New Calabar River and 6.73±0.07 at Woji River. A p-value of 0.000 which indicates a significant variation in BOD_5 across sample stations. Value obtained in the New Calabar River was below the W.H.O permissible limit of 4mg/l while at Woji River it was above.

Nitrate (NO_3^- (mg/l))

The Nitrate values obtained ranged between 0.12mgl and 0.18mg/l across the study area with *mean* ± *S.E* Nitrate value of 0.16±0.01 at New Calabar River and 0.13±0.01 at Woji River. A p-value of 0.035 which indicates a significant variation in NO_3^-across sample stations. Value obtained were below the W.H.O permissible limit of 10mg/l.

Phosphate (PO_4^{-3} (mg/l)

The Phosphate values obtained were below detectable limit across the study area with *mean* ± *S.E* phosphate value of 0.01±0.00 at New Calabar River and 0.03±0.00 at Woji River. A p-value of 0.023 which indicates a significant variation in phosphateacross sample stations. Value obtained were below the W.H.O permissible limit of 0.5mg/l.

Table 8: Mean values of physico-chemical parameters of water collected from the different stations compared with WHO Standard (2006)

S/N	Parameters	Permissible Limits by W.H.O	New Calabar River	Woji River	P-Value
1	pH	6.5 -8.5	6.67±0.00	6.91 ± 0.00	0.214
2	Temperature (°C)	26.5 – 32	27.13± 0.29	27.73± 0.25	0.449
3	Turbidity (NTU)	5	0.20±0.00	1.17±0.07	0.005
4	Conductivity (µS/cm)	500	6183.33±179.01	15303.33±307.16	0.003
5	Salinity (mg/l)	1000-5000	3.34±*0.05*	8.72±0.34	0.000
6	Total dissolved solid, TDS (mg/l)	250-500	4586.67±442.02	10406.67±398.18	0.006
7	Dissolved oxygen, DO (mg/l)	5-10	6.17±0.07	7.16±0.13	0.038
8	BOD_5 (mg/l)	4	0.67±0.03	6.73±0.07	0.000
9	Nitrate as NO_3^- (mg/l)	10	0.16±*0.01*	0.13±0.01	0.035
10	Phosphate as PO_4^{-3} (mg/l)	0.5	0.01±0.00	0.03±0.00	0.023

Note: <0.05 = Less than detection limit

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Table 9: Results of physico-chemical parameters at each sampled stations in the Study area

		New Calabar River			Woji River			
S/N	**Parameters/Sampled Stations**	**Choba Market**	**Choba Bridge**	**Man O War**	**Slaughter**	**Rumuwaji**	**GSM village**	**Permissible Limits by WHO,2006**
1	pH	6.67	6.70	6.65	6.91	6.85	6.82	6.5 -8.5
2	Temperature (°C)	27.3	26.8	27.3	28.0	27.5	27.7	26.5 - 32
3	Turbidity (NTU)	0.2	0.2	0.2	1.1	1.3	1.1	5
4	Conductivity (µS/cm)	6190	6490	5870	15640	14690	15580	500
5	Salinity (mg/l‰)	3.42	3.36	3.25	9.07	9.05	8.05	1000-5000
6	Total dissolved solid, TDS (mg/l)	4360	5440	3960	11000	10570	9650	250-500
7	Dissolved oxygen, DO (mg/l)	6.1	6.3	6.1	7.3	6.9	7.3	5
8	BOD_5 (mg/l)	0.7	0.7	0.6	6.6	6.8	6.8	4
9	Nitrate as NO_3^- (mg/l)	0.14	0.16	0.18	0.12	0.13	0.14	10
10	Phosphate as PO_4^{-3} (mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.5

Note: *<0.05 = Less than detection limit*

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Toxic impact of plastic wastes on the marine life at Woji and New Calabar Rivers.

Table 4.6, Plate 1 and 2revealedthe type of encounter, predominant debris type and impact response of marine life found in the study areas. As previously mentioned in the review that entanglement is very difficult to estimate. Nevertheless, as seen in table 4.6, Plate 1 and Plate 2. Twenty-two fishes (22) were found only in the New Calabar River out of which 10(45.5%) were observed to be entangled with fishing ropes and gears whereas ten 12(54.5%) fishes also in the New Calabar River had their guts perforated with plastic materials such as plastic ropes and pellets. Other marine lives such as lug worms and marine insects were also in abundance and can't be quantified. Nevertheless, the impact of plastic waste as a result of ingestion and interaction were death and increase in population size.

Table 10: Showing evidences of plastic wastes on the marine life at Woji and New Calabar Rivers.

Marine life found	Woji River	New Calabar	Encounter type	Predominant debris type	Impact response
Chrysichthys nigrodigatatus	-	10	Entaglement	Plastic, fishing line	Death
Clarias gariepinus	-	12	Ingestion	Plastic bags, ropes	Perforated gut
Lugworms	Many	Many	Ingestion	Microplastics	Biochemical/cellular ,death
Marine insects	Many	Many	Interaction	Microplastic	Increased population size

Source: *Field survey, 2020/20*

Plate.1*: Dead fish found at the New Calabar River*

Conclusion

Physico-chemical properties of plastics collected at different reaches of Woji and New Calabar River

The plastic debris data from the Woji and New Calabar Rivers are shown in Table 4.1 and Fig 4.1. A total of 421 plastic pieces were collected from the Woji River while 546 plastic pieces were collected from the New Calabar River. In Woji River, the most frequently found type of plastic was Nylon plastic bags (39.2%), followed by plastic wire (9.7%) and fishing lures and lines (9.0%) and the source of these plastic material appears to be from industry, manufacturing, commercial fishing, recreational fishing, aquaculture, or shipping) while in the New Calabar River Nylon plastic bags (15.9%) was found followed by food wrappers, bottles and container caps. The source of these plastics were mainly through market wastes.

Table 4.2 revealed that there is significant difference in the physical properties of plastics at the New Calabar and Woji River as their p-values with regards to the thickness, density and tensile strength of the plastics were lesser than the critical value of $\alpha = 0.05$.

The thickness of the plastic in the study area ranged from 22-29µm *see appendix*. Sampled plastics consisted of micro, meso and macro plastics.

The density of plastic ranged from 0.010 – 0.034g/m *see appendix* as sampled. The density of plastics in Choba was more compared to the ones from Woji. See Fig. 4.3

Table 4.3 further revealed the chemical properties of plastics collected at the New Calabar River and Woji River. Based on the Plastic Technology Handbook Standard, a plastic with a combustible rate of 50-75 is seen as slow-burning although most plastics collected from the Woji axis were combustible (73) see fig 4.4. The table also depicts that the resistivity of all the plastics sampled where electrically insulated judging with the resistivity spectrum as all were >10^9. See fig 4.3. In a similar study by Woke and Wokoma (2007) they discovered that 65% of most Plastics at the New Calabar River are mostly cellulose acetate.

Physical-chemical properties of water collected at different reaches of the Woji and New Calabar River

The pH values were within the recommended pH value for drinking or domestic purposes by W.H.O (2002). The values obtained in the different discharge points were all acidic in nature similar to those observed in another study (Onwughara *et al.,* 2015). The acidic nature of the water samples from the various sample points can be attributed to the type of effluents discharged into the river through domestic and industrial activities hence retarding the growth of the fish and increasing the possibility of infections by decreasing the fish immunity (Ilan and lengy, 1963 and Elamei, 2001).

The temperature value obtained in all three (3) stations of the New Calabar River were within the permissible limit. This could be why fishes were found in this river as it provided the fishes with a habitable environment thus influencing the behaviour of organisms and the proper functioning of the ecosystem (Palamuleni, 2015). This finding tally's with Uche et al., 2014 who in his study on Chobar river had mean temperature values of 26.0-28.2ºC.

The observed turbidity in the New Calabar River was high. Turbidity is a measure of the transparency or opacity of water. Any water which contains high level of suspended and dissolved particles has the tendency to possess very high values of turbidity. Notably, all the stations in New Calabar River had high turbidity values ranging between 7.9-8.9NTU. This high turbidity has a significant impact of parasitic abundance as it interferes with the penetration of light through water hence decreasing photosynthesis and resulting to further drop in oxygen level making it impossible for aquatic life to survive. This study is similar to that of (Edori and Nna, 2018) in their study on the same river. The average values obtained were 12.48 NTU which was 2.5 times the WHO value of 5 NTU. In a similar vein, (Onyando et al., 2005) who in their study on fish parasites and fisheries productivity found out a high turbidity ranging from 400 to 950 NTU in lake Baringo. The lake deterioration is thought to be related to lakes flooding and pollutants from rivers that discharged water into the lake.

The values observed for conductivity were lower or within the recommended value by W.H.O. The conductivity of any water or aquatic body is dependent on concentration of ions or current carrying species present in the water. Low conductivity in this study is not actually toxic to the parasite abundance in fishes at environmental concentrations rather may act as indicators of fish productivity. This finding tally's with those of Abdar et al. (2013) in Morna Lake, Shirala, India and those observed by (Sharma, et al., 2017) in Satluj River, Himachal Pradesh, India.

Salinity values obtained for this study were lower than the permissible limit of W.H.O. The low salinity values could be linked to the influence of rainfall and river runoff in bringing down the salinity at the point of observation. The impact of this finding to the parasitic abundance could be that Nematodes and Apicomplexa occurred in very low numbers in fish from the New Calabar River, a condition that may be attributed to the fact that the supposed intermediate hosts, copepods, is affected by the salinity of the water and therefore occurs in very low numbers (Dias *et al*., 2013). This finding is also supported by that of Aken'ova (2000) who concluded that the presence of nematodes in fish lead to decline in population in their natural environment due to the salinity of the water.

The Total Dissolved Solids which revealed the degree of contamination or pollution of water in this study had values lower than the WHO recommended limit. Hence, will have little or no impact to the parasite abundance of fishes in New Calabar River. This finding concurs with that of Thirupathaiah *et al.,* 2012.

The New Calabar River recorded an average DO value of 6.07mg/l across all stations as against 5-10mg/L recommended by W.H.O. The values were within the WHO standard in all the stations. The low DO in this study could be linked to excessive algae growth caused by phosphorous which results in insufficient amounts of dissolved oxygen available for fish and other aquatic life. This finding is similar to that of (Edori and Nna, 2018) in their study on the same river obtained an average DO value of 3.74 mg/L as against the 10mg/L recommended by WHO and also with that of Welcome, 1979 who found out that low oxygen level is usually as a result of high oxygen demand caused by allochthones input, mainly fallen leaves of the riparian vegetation.

The New Calabar River recorded an average Biochemical Oxygen Demand (BOD) value of 0.50mg/l which is within the WHO recommended standard of 4.0mg/l. The value obtained in the present work is far lower than those observed by Yapo et al. (2012) from waste water in Abijan, which was 14500 mg/L. Although the WHO maximum requirement for BOD in water is 4.0 mg/L, yet 1.0 mg/L is most appropriate for drinking water. Values of BOD up to 5.0 mg/L gives a serious doubt on the portability of water due to the presence of bio-organisms.

The mean value of nitrates in New Calabar River was 0.31 mg/L. The observed values from the different stations were lower than the WHO limit of 10 mg/L. Hence, the low levels of this parameter will not have a direct effect on the fishes. The values obtained in this work though very low, yet are higher than the values obtained by Abdar et al. (2013) in Morna Lake, Shirala, India, where he obtained a concentration range of 0.0157-0.032 mg/L. Proteins, chlorophyll and other organic matter are the sources by which nitrates are transmitted to river. Similar findings in Iwofe jetty Nigeria by (Edori and Nna, 2018) revealed a mean value of nitrates in their research work as 0.415 mg/L which is within the WHO limit.

Recommendations

1. Baling and shredding equipment should be introduced at the transfer stations.
2. Government should place a ban recyclable plastics disposal at dumpsites.
3. Set targets on zero plastic waste to landfills in overall waste management strategies/ policies
4. Enforcement of actions should be in place to reduce illegal dumping and open burning of plastic waste at disposal sites

5. Enforcement of legislation requiring the closing of open dumpsites and establishment and operation of sanitary landfills should also be put in place.

6. Setting incentives to promote waste separation at source (pay-as-you-throw systems, volume-based collection fees).

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