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Assessment of Water Quality of Bayelsa Rivers Using Pollution Index

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Abstract: Water quality of Bayelsa Rivers was evaluated using pollution index (PI). Water collected from four stations along Brass River was studied. Water quality status was analysed with reference to World Health Organization (WHO) standard for domestic water supply for water quality and department of petroleum resources permissible levels for produced water discharge. The results obtained where then used for pollution index (PI) computation. A pollution index above one (PI>1) indicates that the water source is unacceptable for the particular use. The river water quality parameters comply to a large extent with most of the set standard. However, it was very notable very poor at station A and D in terms of chloride (Cl^-), implying that the river Brass and Oloibiri at the points investigated could be chemically unsafe for human consumption as high chloride indicates high chemical activity and possibly anthropogenic pollutant. The pollution index along the rivers Brass, Ewoama, Okoroma, and Oloibiri were 3.53, 2.19, 2.74, 2.88 in terms of numeric value and 2.85, 2.17, 2.41 and 2.55 in terms of relative damage due to pollution respectively. The result revealed that the pollution at Brass was higher than that upstream at oloibiri possibly due to waste inputs from the oil servicing companies. The index declined downstream from Ewoama as the river recovers. This does not imply that no further pollutants were introduced into the rivers as it flows downstream through these locations but rather the level of pollution was within the assimilative capacity of the river.

Keywords: Pollution Index, Water Quality, Contaminants, Bayelsa Rivers, Water Quality Standards

1. Introduction

The birth of the modern oil industry is credited to the discovery oil at Spindletop in 1901 atop a salt dome near Beaumont Texas [1]. In 1956, Shell British Petroleum (now Royal Dutch Shell) discovered crude oil at a village Oloibiri in Bayelsa state located within the Niger Delta of Nigeria [2-3] and commercial production began in 1958. Oil exploration and exploitation has been on-going for several decades in the Niger Delta. Petroleum exploration and production in the Nigeria's Niger Delta region and export of oil and gas resources by the petroleum sector has substantially improved the nation's economy over the past five decades. However, activities associated with petroleum exploration, development and production operations have local detrimental and significant impacts on the atmosphere, soils and sediments, surface and groundwater, marine environment, biologically diversity and sustainability of terrestrial ecosystems in the Niger Delta.

The poor environmental management practices by the petroleum industries and the failure of Nigeria's environmental regulations contribute towards environmental contamination with direct consequences on the surrounding populations' socio-economic wellbeing, human health and the environment. Environmental contamination, human health risks, safety and the environment, and negative socio-economic consequences of most petroleum pollution in the world depend on the intersection of the event, the geographic setting, the characteristics of the regional population, corporate governance systems and political economy. Activities associated with petroleum exploration, development and production have had detrimental impacts on the soils and sediments, surface and groundwater, marine environment, terrestrial and aquatic ecosystems in the Niger Delta. Discharges of petroleum hydrocarbons and petroleum-derived waste streams have caused environmental pollution, adverse human health effects, socio-economic problems and widespread environmental degradation [4]. Almost all offshore oil produces large quantities of contaminated water

that can have significant environmental effects if not handled appropriately [5]. Offshore oil drilling activities are major sources of oil pollution, mainly because of leaking pipes, accidents, ballast water discharges, and production-water discharges. Drilling also involves the use of heavy metals such as vanadium and nickel, and contamination of seawater with these metals is known to affect plants and animals. Oil and gas reservoirs have natural water layer (called formation water). Because, it is denser is found under the hydrocarbons. Oil reservoirs frequently contain large volume of water. To achieve maximum oil recovery, additional water is usually injected into surface. The formation and injected water are eventually produced along with hydrocarbons. The product of the formation and injected water is referred to as produced water.

There is more in produced water than water and oil. Neff and Anderson [6] described produced water for ocean discharge as containing up to 48ppm of petroleum. This is because it had usually been in contact with oil in the reservoir rock. There were also elevated concentration of barium, beryllium, cadmium, chromium, copper, Iron, lead, nickel, silver and zinc and "small amount of the neutral radionuclides radium 226 and radium 228 and non- volatile dissolved organic material of unknown composition". Due to rapid mixing with seawater, most physical-chemical features of produced water (low dissolved oxygen and pH, elevated salinity and metals) do not pose any hazard to water, elevated concentration of hydrocarbon may be detected in surface sediments up to about 1,000 from the discharge, that contains aromatic hydrocarbons and metals. These aromatic hydrocarbons and metals in produced water were reported by [6] to be toxic to organisms. The water environment experiences many dynamic changes induced by various natural events such as the spillage of toxic chemicals that may have significant impact on aquatic life [7].

The Bayelsa Rivers provide the environment for fish, plants, and animals while the banks and nearby lands support creatures such as otters, kingfishers, dragonflies and a variety of water- loving plants. The Niger delta region also consist of diverse ecosystems of mangrove swamps, fresh water swamps, rain forest and is the largest wetland in Africa but due to oil pollution the area is now characterized by contaminated streams and rivers, forest destruction and biodiversity loss in general the area is an ecological wasteland. This affects the livelihood of the indigenous people who depend on the ecosystem services for survival. Oil pollution damages coastal resources and habitats, as well as fisheries, reducing catches and incomes [8]. This increases poverty among indigenous populations and may leave them no choice but to take up livelihoods which are environmentally unsustainable.

The widespread contamination of surface waters by contaminants from oil exploration activities is of increasing concern to scientist. This paper aims at determining the concentration of contaminants in some Bayelsa state rivers (Oloibiri, Brass, Ewoama and Okoroma). This will go a long way to determine the impact of oil and gas exploration and other anthropogenic sources on the water quality of these rivers and potential impact of these metals to the surrounding ecosystem. It will further highlight some of the issues of environmental pollution resulting from unsustainable practices associated with petroleum exploration, exploitation and production in the region. Finally it will serve as a useful reference material and catalyst that will stimulate future researchers.

2. Materials and Methods

2.1. Collection of Sample/Analysis

Oloibiri river was examined for water quality along the river downstream from Brass, Ewoama, Okoroma and Oloibiri (referred to as station A, B, C and D respectively) (Figure 1). The sample stations were chosen based on ecological setting and human activities in these areas. Sampling was done monthly from January to the end of April. The samples were taken approximately 10cm below the water surface and transferred through filtration in the filed by passing through pre-rinsed cellulose acetate 0.45µ membranes to 250ml polyethylene bottles. After collection, the samples were placed in cooler boxes with ice bags whilst being transported to the laboratory and was kept at about 4°C before analysis. The contaminant concentrations were analysed using pollution index techniques.

2.2. Background of the Study Area

Nigeria has a coastal line of approximately 85km towards the Atlantic Ocean lying between latitude 4°15' to 4°50' and longitude 5°25' to 7°37' with a land mass of about 28000sq/km area within the coastal region. The surface area of the continental shelf is 46300sq/km. The coastal areas consist of freshwater swamp, mangrove swamp, beach ridges, sand bars, lagoons marshes and tidal channels. Nigeria has a total land mass of 923,768sq/km; 918,768sq/km being terrestrial land and 13000 sq. /km being aquatic (CIA World Fact Book). The coastal area is humid with a mean average temperature of 24-32°C and coastal area has an average annual rainfall ranging between 1,500-4,000m [9]. Nigeria has two large rivers; the Niger-Benue and the Chad River. There are several rivers that channel into the Atlantic Ocean directly, all other flowing waters flow into the Chad basin or into the lower Niger to the sea eventually [9]. The Niger Delta is located in the Atlantic coast of Southern Nigeria and is the world's second largest delta with a coastline of about 450km which ends at Imo river entrance [10]. The region is about 20,000sq/km as it is the largest wetland in Africa and among the third largest in the world [11-14] 2,370sq/km of the Niger Delta area consists of rivers, creeks, estuaries and stagnant swamps cover approximately 8600sq/km, the Delta mangrove swamp spans about 1900sq/km as the largest mangrove swamp in Africa [14]. Bayelsa state is classified as a tropical rainforest with ecosystems comprising of diverse species of flora and fauna both aquatic and terrestrial species (figure 1). The region can

be classified into four ecological zones; coastal inland zone, freshwater zone, lowland rainforest zone, mangrove swamp zone and this region is considered one of the ten most important wetlands and marine ecosystems in the world [15-16]. As of 1991, the National Census estimated about 25% of the entire Nigerian population lives within the Niger Delta region [17-18].

Figure 1. *Map of Bayelsa State showing the sampling sites.*

The Niger Delta region has a steady growing population of approximately 30 million people as of 2005, accounting for more than 23% of Nigeria's total population [17-18].

The Bayelsa Rivers has been and continues to be of vital economic, environmental and social importance to the areas encompassing Brass, Ewoama and Okoroma which constitute

the study area. The middle and lower portions of the river support a variety of industrial, residential and recreational activities. In addition, these areas provide essential habitat for aquatic organisms and aquatic dependent wildlife species. The lower estuary culminates in large onshore and offshore oil exploration including gas production which is one of the most heavily used portions in the River.

Bayelsa Rivers is prone to pollution by metals and biodegradable contaminants. Effluent from the various treatment plants are discharged into the ocean and the inherent pollution are distributed and carried to the coastal land by tidal waves of the sea. These Rivers which flows over seventy percent of Bayelsa state is located in a typical climatic zone characterized by distinct wet and dry season. It is a major source of water supply for commercial, industrial, agricultural, Recreational and fishing activities as it empty itself into the Atlantic Ocean via bight of Bonny. It also serves as a waste disposal site for Agip Oil Company and Shell Production and Development Company and its inhabitants.

3. Result and Discussion

The results of the water quality parameter carried out on fresh water at selected points (point A, B, C, D) to represent Brass, Ewoama, Okoroma, Oloibiri are listed in Table 2. In evaluating the suitability of the river at the various location pollution index was employed as a yardstick for consideration as raw water source.

Table 1. *Contaminants items recommended for index computation (source: TG Leton and JO Nkwueke 2005).*

1	Temperature	8	Total nitrogen
2	Colour	9	Alkalinity
3	Turbidity	10	Hardness
4	pH	11	Chlorine
5	Faecal coliforms bacteria	12	Iron
6	Total dissolved soils	13	Sulphide
7	Suspended solids	14	Dissolved oxygen

According to [19], This high value of Total Dissolved Solids can be attributed to the result of anthropogenic sources such as discharge of produced water into the rivers, land clearing, land utilization, streams and river dredging, transportation, drilling of all types, oil exploration, oil transportation and utilization activities carried out by man in order in these areas aimed at solving economic and social problems. Although total solids analysis was not performed but high total dissolved solids levels indicates the presence of carbonates in water which predominantly causes hardness of water. The concentration of the 4 major cation Ca++, Mg++, a++ and K+ and 4 major anions, HCO_3-, CO_3-, SO_4^{2-} and Cl- usually constitute the total ionic salinity of water for all practical purposes [20]. Concentrations of ionized components of other elements such as N, P and Fe and numerous minor elements are of immerse biological importance but are usually minor contributors to total salinity [19]. The sum of all ionic concentrations is the basis for salinity measurement [21]. Total dissolved solids and ionic conductivity of water, are generally used measurement [21].

The values of ions increased in concentration 117.24-193.21 in the study stations. This is in agreement with the report of [22] that when contaminants are introduced into surface waters more salts are released into river. Thus, the amount of salts contained in aquatic ecosystem increased. These increases could be due to leakage of the cells brought about by salt (ionic) stress and associated oxidative damage [23]. Salt stress refers to an excess of ions and is not limited to Na+ and Cl- ion [24]. According to [25] oxidative stress is influenced by environmental factors, metal ion deficiency and toxicity.

The pollution index along river Brass, Ewoama, Okoroma and Oloibiri were 2.19, 3.53, 2.88, 2.74 respectively in terms of numeric value and 2.17, 2.85, 2.41, 2.55 in terms of relative damage due to pollution (Table 3). All the result obtained indicates that pollution was 58% higher in Oloibiri and Brass than in Ewoama and okoroma upstream possibly due to anthropogenic sources. The results of this study are higher than those of [26-27] in a similar study. The index decline downstream from brass as the river recovers (Figure 2).

Table 2. *Concentrations of contaminants from the study stations.*

Parameter	A	B	C	D	WHO	DPR
					Limit	**for near shore**
pH	5.12	5.70	5.43	5.32	6.5-9.0	8.5
EC(mg/l)	18100	158	2350	264	1242	Ns
TDS(mg/l)	3212	3316	2852	2788	1500	5000
Chloride(mg/l)	9266	604	319	8485	250	2000
Hardness(mg/l)	500	120	240	450	500	Ns
BOD(mg/l)	132	17	26	113	Ns	25
Alkalinity(mg/l)	4.70	4.40	4.70	4.20	100	Ns
Sulphate(mg/l)	117.24	140.32	137.11	193.21	500	Ns
Manganese(mg/l)	0.4271	0.1540	0.7134	0.3866	0.4	Ns
Iron(mg/l)	0.0266	0.323	0.028	0.0147	3	Ns
Salinity (mg/l)	23534.9	21550.6	811.5	1713.2	Ns	Ns

A – Brass, B – Ewoama, C – Okoroma, D – Oloibiri N

S – No specification, DPR – Department of petroleum resources.

Table 3. *Pollution index for these rivers studied.*

Stations	Numeric Expression	Relative damage due to pollution
A	3.53	2.85
B	2.19	2.17
C	2.74	2.41
D	2.88	2.55

Table 4. *Computation of pollution index for brass river at station a.*

Parameter	Ci	Lij	Ci/Lij	Lo (Ci/Lij)	1.0+5 x log (Ci/Lij)
pH (tempt)	5.70	6.50-9.0.	0.74	----------	0.74
TDS (mg/l)	3316	1500	2.21	0.30	1.80
Hardness (mg/l)	650	500	1.30	0.13	0.78
Sulphate (mg/l)	140	500	0.28	----------	0.26
Nitrate (mg/l)	17.99	50	0.36	----------	0.36
Alkalinity (mg/l) 4.40	100	0.04	----------	0.04	
Total			4.93		3.98
Mean (Ci/Lij)			0.82		0.66
PI (A)			3.53		2.85

Ci = item of water concentration such as pH, TDS, Hardness, Lij = permissible levels of water quality

This does not imply that no further pollutants were introduced into the river as it flows downstream through these locations but rather the level of pollution could be low enough to be accommodated by the assimilative capacity [27].

A plot of pollution index (numeric expression and relative damage due to pollution is presented in (Figure 2). The chart indicates that the pollution index (PI) is 2. The value is above the PI acceptable limit of 1.0. This is an indication that the river is highly impacted with external contaminants possibly due to crude oil exploration from oil and gas companies operating in these areas and other commercial activities from human and as such should be rejected as a possible source of raw water for potable use.

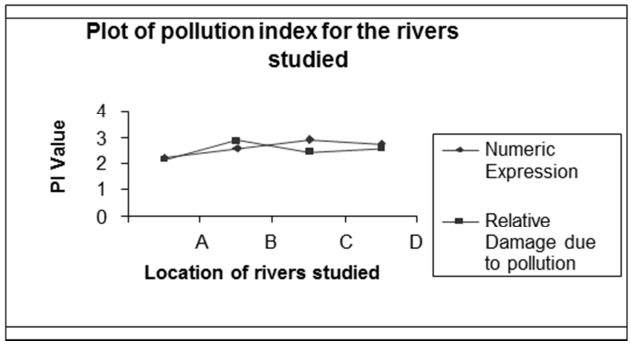

Figure 2. *Pollution index for Brass River.*

4. Conclusion

The environmental problems of the Niger Delta result in generally land resource degradation, renewable resource degradation and environmental pollution, agricultural land degradation, fisheries depletion, deforestation, biodiversity loss, oil pollution, gas flaring and mangrove degradation. Oil exploration and exploitation activities such as this have significantly contributed to the environmental pollution of the Niger Delta region in spite of government measures to regulate the discharge of produced water into these rivers.

Despite the fact that the rivers are above the acceptable levels of pollution index (PI = 1), the rivers could be put to other beneficiary uses such as boating, sports, and swimming. For consideration as a source of raw water for potable use, the rivers is at this point could be treated using washing soda or ion exchange resin or permutit process since the water is observed to be hard before sedimentation → filtration → aeration → chlorination → coagulation → distribution.

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