



Review Article

Review of Impact of Anthropogenic Activities in Surface Water Resources in the Niger Delta Region of Nigeria: A Case of Bayelsa State

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Abstract: Water is an essential resource required for the sustenance of life. Water is utilized in all sector of any nation economy. Surface water is one of the major sources of water utilized by several communities in coastal region of Bayelsa state. Fishing - a source of livelihood for indigenous people of Bayelsa state is carried out in surface water. Surface water is also a route of transportation using engine boat and canoe. Some of the surface water are used for domestic purposes (such as washing, bathing, cooking) and even drinking. Several anthropogenic activities are carried out in the surface water including dredging, makeshift refinery and dumpsite for various classes of wastes (mainly from domestic and sewage). This paper reviews the impacts of anthropogenic activities in surface water resources in Bayelsa state, Nigeria. The study found that pH, temperature, conductivity, total suspended solid, total dissolved solid, total hardness, total alkalinity, turbidity, nitrite, nitrate, phosphate, sulphate, chloride, sodium, potassium, magnesium, calcium, zinc, copper, iron, lead, cadmium, chromium, lead, mercury and total hydrocarbon content are altered due to various anthropogenic activities. Off these, turbidity is significantly affected by all the activities and to lesser extent pH, total alkalinity, dissolved oxygen, nitrite, magnesium, total hydrocarbon content, iron and lead are also affected above permissible level recommended Standard Organization of Nigeria and the World Health Organization. The alteration of water quality parameters could alter the composition and abundance of biodiversity including fisheries and planktons, downstream application of the water and its potability. This study concludes by suggesting that factors leading to alteration in water quality should be checkmated by appropriate regulatory agencies.

Keywords: Anthropogenic Activities, Bayelsa State, Impacts, Surface Water, Water Quality

1. Introduction

Water resource plays a major role is the sustenance of life in the various environment [1 – 11]. Akpan and Ajayi [12] described water as a life-supporting liquid that is required by living things for metabolism. Water is also used for the nourishment of the body, food production and development of the economy through its downstream applications. Water exist in three major forms including vapour (gaseous form), ice (as solid), and liquid. Majority of water forms that are widely utilized are its liquid state. These typically exist as ground, rain and surface water [1, 4].

Surface water is the most widely water resources apart from

drinking which this typically met by freshwater from the shallow aquifer (groundwater/borehole). Other water resource includes brackish (salt and fresh water interphase) and sea/ocean water. In developing countries like Nigeria, surface water resources are used for several purposes including transportation, source of livelihood through fishing, drinking water sources, domestic water sources (such as washing, cooking, bathing) especially in coastal rural area. Freshwater resource is mostly utilized for drinking and most domestic purposes. According to Izah et al. [1], surface water is majorly consumed in area that groundwater resources i.e. borehole is scarce/ and or far from the residential areas.

Surface water is a major recipient of wastes/materials resulting from activities of human in the environment and to

lesser extent natural effects [2, 13, 14]. In the Niger Delta, especially Bayelsa state, surface water resources receives human wastes including sewage via pier toilet system [5, 6, 13 – 15], abattoir wastes [7], food processing wastes such as oil palm [16], solid wastes from house hold items [5] including remains of used pesticides cans [17 – 25], detergents [2], marketing wastes among others. One major wastes stream that is not discarded into the water directly is scrap metals, and it's a major business in the Niger Delta. This involves gathering and sorting of the scrap metals and selling for future valorization by the iron ore and steel industry. Several others wastes stream could finding their way through runoff after rainfall.

Others human activities that are carried out in water ways including the activities of oil and gas [26 – 29], dredging using both motorized and artisanal approach [30, 31], bridges in the cause of road construction [32]. Movement of goods in the water ways are frequently carried out in the Nigeria coastal region especially in Bayelsa state. Improper application of sustainable approach could lead to contamination of the water ways. Others important source of contamination of the water ways is through water flooding. Flooding that occurs in banks of rivers typically carries all debris in the area into the water and moves it to the water course. In the process, some debris end up as suspended or deposited sediment [9 – 11, 33] depending on the properties of the debris carried out by agent of water flooding.

Water quality research has been several carried out in the Nigeria including surface, ground and rain water. The effects of several anthropogenic activities peculiar to an area to water quality abound in literatures as well. Owing to the fact that water quality monitoring data on both fresh and marine water sources especially the once arising from industrial outfit is uncoordinated in Nigeria [34]. Therefore, the present study reviews the impacts of anthropogenic activities in surface water quality in Niger Delta region of Nigeria, a case of Bayelsa state.

2. Methodology

In this study secondary data from Internet sources was employed. Published journal articles on water quality in different surface water resources in Bayelsa state, Nigeria between 2001 to 2017 was assessed and reviewed. The mean and/or range data was extracted and presented according to seasons i.e. wet (April to October) and dry (November to March of the following year). The data were compared to reference values by Standard Organization of Nigeria and World Health Organization. The data are presented in Table 1. The paper is organized into 7 sections. Section 1 which introduces water resources and source of surface water contaminants in coastal regions of Nigeria. Section 2 is the methodology/approach used in obtaining the data. Section 3 discussed the geology, meteorology and ecology of Bayelsa state in brief. Section 4 discussed the various source of surface water contaminants. Section 5 discussed the various water quality parameters frequently studied in Bayelsa state. Section

6 discussed the impacts of surface water with regard to domestic utilization including drinking. The paper concludes by suggesting means to minimize the impacts of the anthropogenic activities on surface water (Section 7).

3. Bayelsa State: Geology, Meteorology and Ecology

Bayelsa state is one of the states in the Niger Delta region. The region is characterized by sedimentary basin. According to Amangabara and Ejenma [35], sedimentary formations of the region are about 8000 metres thickness which comprises of bottom to top of Akata Formation, Agbada Formation and Benin Formation. Other authors have reported lower thickness of the various formations depending on the units. For instance Akpokodje [36], Rim-Rukeh and Agboz [34] reported that Akata formation is Eocene 600-6000m thick at lower unit, Agbada formation is Eocene 300-4500m thick at middle parallic unit and Benin formation is Miocene 200-2000m thick at upper an upper continental sequence. Amangabara and Ejenma [35] further reported that the Benin Formation is Oligocene to Pleistocene in age consisting of freshwater continental friable sands and gravel that are of excellent aquifer characteristics, with irregular intercalation of shales. This formation is one of the major productive and utilized aquifer in the Niger Delta region of Nigeria especially in the central states. Ohimain et al. [37] reported that fishing is the major occupation of the indigenous people of Bayelsa state.

The Niger Delta has several major rivers including River Nun, Forcados, Orashi River among others. Specifically river nun passes through Bayelsa state and it emptied into the ocean through the Nun estuary. Nun River has several tributaries which are often called stream, creek, creekets/ rivulets. Several communities aligning most of the surface water in Bayelsa state. Most often, the communities use pier toilets system and as such sewage are deposited in the surface water bodies [5, 6, 13 – 15]. For instance, Epie Creek which is a non-tidal and fresh water is a major surface water resources in Yenagoa metropolis, the Bayelsa state capital with several communities aligning the creeks including Igbogene, Yenegwe, Akenfa, Agudama Epie, Akenpai, Edepie, Okutukutu, Opolo, Biogbolo, Yenizue Gene, Kpansia, Yenizue Epie, Okaka, Ekeki, Azikoro and Amarata, Onopa, Ovom, Yenagoa, Bebelibiri, Yenaka, Ikolo, Famgbe, Obogoro, Akaba, Ogu, Swali, and Agbura [34]. Most of the surface water is also used for transportation purposes. Typically, canoe and engine boats are used as mean of transportation in some major rivers in the region. Fishing is a major source of livelihood to indigenous people in the state especially in communities aligning surface water [13, 15].

The water table is very close to the ground surface and varies from 0 to 4 metres depending on location [35]. Agedah et al. [5] reported ground water table of 4 – 60 feet and 5 – 100 feet during the rainy and dry season respectively in different part of Bayelsa state depending on the location and relative topography. Amangabara and Ejenma [35] further reported

that a limited groundwater level fluctuation is determined by the amount of rainfall in significant part of the year.

Two predominant seasons are frequently observed in the area viz: raining/wet (which run from April to October) and dry season (which occurs from November to March of the subsequent year). The season is typically identified by the rainfall pattern. The wet season bring about by the Southwest trade wind blowing across the Atlantic Ocean, while the dry, which is often dusty brings about the Northeast trade wind blowing across the Sahara desert [34]. The dry season bring about the harmattan which is usually more intense between December and January.

Like other regions in the Niger Delta, the atmospheric temperature of Bayelsa state shows slight variation from one location to another depending of the time and relative humidity. Typically, the spatial distribution of temperature over the earth is affected by the level of insulation, type of surface, distance from water bodies, relief, type of the prevailing winds and ocean current. Atmospheric temperature also differs based on the time of the day. For instance Izah et al. [38] reported temperature of 24.0 -26.3°C (8:00 hours), 25.0 – 28.0°C (11:00 hours), 27.0 – 35.2°C (14:00 hours) and 25.0 – 29.8°C (17:00 hours) during month of August 2014 in Yenagoa metropolis. Furthermore, based on survey study by Izah et al. [38] a significant number of inhabitants of Yenagoa metropolis are with the notion that atmospheric temperature has been on increase in Yenagoa metropolis.

Bayelsa state has similar relative humidity with other Niger Delta states. Typically, relative humidity is influenced by the laden tropical maritime air mass and to large lower extent the cloud cover. Low relative humidity indicates no rainfall and vice versa. In Yenagoa metropolis, the capital of Bayelsa, Izah et al. [38] reported the relative humidity of 73.1 – 85.1% (8:00 hours), 76.3 – 86.1% (11:00 hours), 69.2 – 86.9% (14:00 hours) and 76.5 – 83.1% (17:00 hours) during the month of August, 2014. Furthermore, Rim-Rukeh and Agboz [34] reported relative humidity level of 55.5% and 96% for dry and wet seasons respectively, and annual rainfall of 2500mm.

The wind pattern in Bayelsa state is within light air and light breeze on the Beaufort scale and as such appears to be calm [38]. Though, wind speed is determined by the prevailing weather condition. Izah et al. [38] have reported wind speed of 0.3 – 0.7m/s (8:00 hours), 0.4 – 0.7m/s (11:00 hours), 0.4 – 1.2m/s (14:00 hours) and 0.3 – 1.3m/s (17:00 hours) during the month of August 2014. Occasionally high wind that could adversely affect vegetation such as plantain and some infrastructures poorly erected especially during the raining season.

Due to the high amount of rainfall which is usually optimum in June, July and September. Flooding event in Bayelsa state is usually high. By September, several communities get flooded especially the ones aligning surface water bodies. In recent times it appears that rainfall pattern appears to be shifting from the known period. In a survey study by Izah et al. [38] about 66.3% of the respondents in Yenagoa metropolis, indicates that the amount of rain fall has increased tremendously. As such three major class of flooding

occurs in the region including urban, river and coastal flood. Urban flood is typically caused as a result of blockage of water canal by wastes and/or lack of drainage system. Otomofa et al. [39] reported that urban flooding takes places over a short period of time and over flow in the area covering several meters. The authors further reported that this type of flooding is common in area undergoing urbanization probably due to anthropogenic activities resulting from deforestation, building without plan among others. While river flooding are common in the lower ridges of River Niger especially the communities aligning River Forcados, Nun River and River Orashi and their tributaries. As such the effect of river flood depends on the topography, which is very common in low-lying belt of both freshwater and brackish water Bayelsa state. Furthermore Otomofa et al. [39] reported that river flood usually take place in an area where a river bursts or overtops its banks and over follow in the surrounding areas. The duration of river flood is very short, and its impacts could be severe especially in farmland aligning water bodies. The effects of water flood are majorly attributed to the relative topography, land use pattern, population density and other factors [40]. Ohimain et al. [40] also stated that these factors could influence the severity, nature, duration and even potential hazard caused by the flooding events. Coastal flood also occur due to heavy storms or extreme weather conditions accompanied by high tides cause by sea rise.

Bayelsa state is one of the core states in the Niger Delta whose wetland is the largest mangrove forest in Africa [41 – 43]. Bayelsa state has several water bodies and they contain several species of fish and macrophytes. In some water system in the area, macrophytes such as water hyacinth constitute nuisance in several water ways including river Nun [6, 44, 45], Ikoli creek [7], Kolo creek [8, 46]. The region being a wetland, it has the tendency to disintegrate and assimilate pollutants from the environment especially in the aquatic ecosystem. But in the recent times, the wetland is being threatened to several human activities. According to Nwankwoala [43], Uluocha and Okeke [47], population growth, urbanization, pollution from industrialization, mining, oil and gas activities, unrestrained tilling of soil for agricultural purposes, over-grazing, logging/lumbering, unmatched land reclamation, dam construction, physical infrastructure, erosion, sea rising, alien invasion, sand storm, desertification, droughts etc are some of the activities having an adverse effect on the wetland system of the Niger Delta in general.

Bayelsa state has several protected area including Taylor creek, Egbedi creek, Apoi creek, Nun River, Edumanom and Ikebiri. But due to industrialization and urbanization the size of majority of the area are shrinking. This could be majorly attribute to poor management practices, quest for bush meat, bush burning, lumbering and unsustainable hunting practices. Bayelsa state has several plant species with antimicrobial, insecticidal properties. The region is a home of several plant species [40] and wildlife including reptiles, mammals, avian fauna among others [40, 48]. Bayelsa state has several species of fish fauna including shelled and fin fish and some of them have been documented by Ogamba et al. [49 – 55], Abowei

and Hart [56], Abowei and Ogamba [57], Abowei et al. [58], Seiyaboh et al. [59 – 61]. Other aquatic resources found in the region include planktons [62], aquatic mammals, sea birds among others [4]. Previously, mammals such as *Trichechus senegalensis*, *Hippopotamus amphibious* and *Lutra maculicollis* have been reported in water bodies in Bayelsa state. But they are rare in the region presently, this could be due to industrialization, urbanization, excessive exploitation among other facts. Some biodiversity found in the region is of both local and international importance. The habitat is also good breeding ground for fisheries and migratory birds.

Bayelsa state is also blessed with several ecological zone and water resources. All the various ecological zones found in the Niger Delta are also present in the region including barrier islands, estuarine, mangroves, freshwater swamp, lowland rainforest, creeks, creeks and lakes. Some of the lakes are a source of revenue to host communities. For instance, Lake Adigbe which is found in Osi-ama community in Sagbama local Government Area of Bayelsa state do fishing festival biannually and during the period non-indigenous are allowed to witness and buy fish species. It also believed by resident of the lake that several species of crocodile are found in the lake as well. Another important lake in the region is Efi Lake which is found in Kalama in Kolukuma/Opokuma local government area. The lake undergoes self-purification process [63].

4. Activities Leading to Water Pollution in Bayelsa State

Bayelsa state is one of the industrializing and urbanizing states in Nigeria. Human activities in the area could alter the environmental components leading to pollution. Several economic activities are carried out in the region but the effective of environmental law/policies are not strongly effective. Oribhabor [64] reported that contamination of Nigerian aquatic resources is mainly due to indiscriminate use of fertilizers, urbanization, pressure in infrastructure due to population growth, mal-utilization and mismanagement of natural aquatic resources, construction works (including dams, road, bridges drainage system), exploration and utilization of petroleum resources (especially during exploration, transportation, storage, marketing). Human activities in the water resources including rivers, lakes, creeks, streams, pond, creeklets render the water resources unhealthy for human utilization for domestic purposes [12]. These sections briefly describe the human activities leading to surface water pollution.

Oil and gas

Nigeria is major oil and producing nations. Bayelsa state is one of the oil producing state that accounts for Nigeria major source of foreign earning –oil and gas. The oil and gas are found in both onshore and offshore in Bayelsa state. Instances of crude oil pollution spill into aquatic ecosystem in Bayelsa state have been documented especially by illegal artisan refining [26 – 28]. The Nun river estuary which is a major river in Bayelsa state are interconnected by several creeks,

creeklets, inlets, and canals which serve as navigational routes and drainages in the area. The Nun River estuary is bordered to the east and west by the Brass and Sangana river estuary [26 – 28]. Several makeshift oil refineries (Kpo fire) are found in the area especially between 2011 to 2015, and processes crude oil into diesel and kerosene for sale in the black market using rudimentary/artisanal technology commonly used to distill locally made alcohol (gin or ogogoro or kaikai) [26 – 28].

Wastes

Wastes resulting from activities of man on the environment are a major source of environmental pollution especially in developing regions. Wastes are originated from home or household item and industrial materials not longer and in use. Wastes alter the characteristics of the receiving environment. For instance, waste could emit noxious gases and odour which disturbs the inhabitants of the area such wastes is deposited. In water it could alter the water quality parameters such as turbidity [65]. Typically the impacts of the wastes are depended on its constituents/composition. Waste management and surveillance in Nigeria is grossly inadequate, and are poor managed [13]. Izah and Angaye [13] listed food processing, industrial, pharmaceutical, fertilizer production, pesticides use, dredging and oil and gas activities as potential sector that contaminate the surface water resources directly or indirectly.

Flooding

Flooding is a natural effect, but its severity is triggered by anthropogenic activities especially poor wastes management and erections of infrastructure in area that drainage system ought to have been created. As such it's a source of concern to all sector of the nation's economy. For instance, the 2012 flood that besieged over 26 states out of the 36 states in Nigeria impacted on several sector including agriculture, markets, hospital, school, telecommunication, housing, roads, bridges, oil and gas facilities among other. According to Otomofa et al. [39], Nkemjika et al. [66], flooding has a wide range of influence on the interactions between man and his social and economic environment. On this perspective, Nkemjika et al. [66] reported topography of the terrain, infrastructure without proper drainage as major cause of flooding. These are caused by anthropogenic/human activities in the environment.

Sewage is deposited in surface water resources through pier toilet system in most coastal communities aligning water bodies in Bayelsa state [5, 6, 13 – 15]. Sewage deposits are also carried out by the inhabitants' aligning surface water by directly connecting the sewage pipes to the available surface water. Predominant ways of depositing human fecal materials are through open toilet system [12]. Oxygen demanding wastes such as sewage are one of the more serious pollutants in natural environment due to their health effect [34]. Wastewater from industries and sewage collected from homes and offices are released directly into streams and rivers [34].

Dredging

Dredging for sand used for construction works is common in Bayelsa state. Dredging is carried out by artisan and motorized approach. Sand mining is carried out in several locations including Epie creek [34], Igbedi creek [30 – 32],

Nun River at different locations, among other. Dredging is one of the potential activities that alter water quality of aquatic systems [30- 32]. Depending on the nature of the dredged material, its disturbance from the sea bed may lead to in the chemical composition of the water. Materials heavy metals and organic contaminants used during the dredging could leach into the aquatic ecosystem and may bioconcentrate in the sediment [30 – 32, 67].

Marketing activities

Several markets are built and transact close to surface water in Bayelsa state. Most of the wastes generated are dumped in the surface water. For instance in Yenagoa meteropolis, wastes generated in busy Tombia Junction and old Akenfa market end up in the Epie creek. Various form of wastes including solid and liquid. Abattoir wastes are also deposited in surface water resources and they have the tendency to alter the water quality

characteristics [7].

5. Water Quality Assessment in Bayelsa State

Water quality parameters are numerous. But in Bayelsa state, the most commonly analyzed water quality parameters include pH, temperature, conductivity, total suspended solid, total dissolved solid, total hardness, total alkalinity, turbidity, nitrite, nitrate, phosphate, sulphate, chloride, cations (sodium, potassium, magnesium and calcium) and heavy metals (iron, lead, cadmium, chromium, lead, mercury) and total hydrocarbon content (Table 1). This section briefly discusses the quality of these key parameters with regard to different surface water resources in Bayelsa state, Nigeria.

Table 1. Water quality parameters from different surface water in Bayelsa state, Nigeria.

	[34]	[15]	[71]	Seiyaboh [31]		[32]	[5]	[63]	[6]		
	Epie creek	River Nun	Epie creek	Igbedi creek		Tombia Bridge Construction across the Nun River	River Igbedi	River Nun	Efi lake	Nun River	
Year of study	June 2009 – May 2010	2005	1999 - 2000	2009 – 2011		-	2007	2007	2015	2014	
Seasons	All season	Wet	Dry	Wet	Dry	Wet	-	Wet	Wet	Dry	Wet
Temp. (°C)	-	-	28.7-30.5	27.3-29.3	27.41 – 28.27	28.17 – 28.33	36	27.25 – 27.33	27.3 – 27.4	28.36 – 30.1	25
pH	5.6 – 6.8	6.78 – 7.16	7.4-7.57	6.9-7.33	6.88 – 6.89	7.44 – 7.65	7.4 – 7.6	6.8 – 7.11	6.53-6.73	6.55 – 7.20	6.910 – 7.350
Conductivity (µS/cm)	34.7 – 5.2	0.28 – 0.33	78.33-89.33	47.73-54	76.91 – 85**	54.02- 64.47**	87 – 95	56.08-58.0	60.05 -64.95	48.13 – 68.93	33.167 – 68.000
Salinity (‰)	-	6.88 – 7.61*	-	-	-	-	-	0.01 – 0.02	0.02 – 0.05	-	0.000 – 0.017*
Turbidity (NTU)	21.5 – 34.7	-	11.67-19.67	16.67-28	36.59 – 50.76	51.99-73.91	5 – 64	114.7 – 117.0	103.75-107.25	7.89 – 17.29	25.700 – 40.533
Total Hardness, mg/l	-	-	3.27-5.27	2.27-3.36	-	-	-	-	-	-	0.903 - 3.333
TDS (mg/l)	57.3 – 187	-	55-62	33-37.83	38.2 – 43.23	27.06 – 29.13	62.1 – 67.9	28.18 – 29.26	30.0 - 32.55	54.25 – 102.92	10.333 – 34.333
TSS (mg/l)	17.7 – 45.8	-	-	-	-	-	-	-	-	-	3.4333 – 5.466
Total Alkalinity (mg/l)	-	5.6 – 6.2	30-37.33	15.33-22	30.28 – 40.34	79.95 – 87.95	-	-	-	-	-
BOD (mg/l)	12.4 – 36.7	8 – 22.4	1.53-6.77	0.31 - 4.29	4.8 – 7.4	1.4 – 3.2	2.6 – 4.3	-	-	-	-
DO (mg/l)	3.73 – 5.2	5.44 – 6.56	1.76-5.68	1.38-9.06	3.6 – 4.2	3.1 – 3.2	5.2 – 7.2	10.2 -14.23	12.08 – 13.28	9.07 – 19.52	-
Nitrite (mg/l)	-	-	-	-	0.084 – 0.089	0.059-0.096	-	-	-	-	-
Ammonia, (mg/l)	-	-	0.003-0.1	0.15-0.21	-	-	-	0.325 – 0.53	0.378 - 0.415	-	-
Nitrate (mg/l)	-	0.185 – 0.319	0.02-0.27	0.14-0.28	0.107 – 0.271	0.142 – 0.159	0.32 – 4.15	0.43 - 0.813	0.33 - 0.35	1.34 – 2.82	0.117 – 0.394
Chloride (mg/l)	-	-	1.65-4.62	3.62-4.28	0.32 – 0.36	0.45 – 0.59	-	-	-	-	0.500 – 3.466
Sulphate (mg/l)	-	0.00	1.98-2.66	2.22-6.27	7.45 – 7.5	6.16 – 9.12	-	-	-	-	0.566 – 0.866
Phosphate (mg/l)	0.73 – 1.73	0.00	0.10-0.23	0.09-0.47	-	-	0.06 – 0.14	-	-	-	-
Sodium (mg/l)	-	-	3.27-5.27	2.27-3.36	-	-	-	-	-	-	0.533 – 1.310
Potassium	-	-	2.55-3.33	2.55-3.35	-	-	-	-	-	-	0.333 –

	[34]	[15]	[71]	Seiyaboh [31]			[32]	[5]		[63]	[6]
	Epie creek	River Nun	Epie creek	Igbedi creek			Tombia Bridge Construction across the Nun River	River Igbedi	River Nun	Efi lake	Nun River
(mg/l)											0.816
Calcium (mg/l)	-	-	5.47-7.53	3.20-4.84	-	-	-	-	-	-	0.800 – 2.333
Magnesium (mg/l)	-	-	2.29-3.6	1.77-2.98	-	-	-	-	-	-	0.390 – 1.466
Iron, mg/l	-	-	-	-	-	-	-	-	-	0.034 – 0.74	0.023 – 0.463
Manganese, mg/l	-	--	-	-	-	-	-	-	-	-	0.003 – 0.023
Mercury (mg/l)	-	-	-	-	-	-	-	-	-	<0.01	-
Lead (mg/l)	-	-	-	-	-	-	-	-	-	<0.01	-
Copper (mg/l)	-	-	-	-	-	-	-	-	-	<0.01	-
Cadmium (mg/l)	-	-	-	-	-	-	-	-	-	0.00 – 0.057	-
Chromium (mg/l)	-	-	-	-	-	-	-	-	-	0.00 – 0.137	-
Zinc (mg/l)	-	-	-	-	-	-	-	-	-	0.00 – 0.231	-
THC, mg/l	-	-	-	-	-	-	-	-	-	-	-

Table 1. Continue.

	[7]	[72]	[11]	[26]	[8]	[55]	[29]	[68]	[69]
	Ikoli creek	Ikoli creek	Sagbama creek	Nun River Estuary	Kolo creek	Kolo creek	Kolo creek	SON limits	WHO limits
Year of study	2013	2014	2014	2014 - 2015	2014	2015	2016	-	-
Seasons	Wet	Dry	Wet	Dry	Wet	Wet	Dry	-	-
Temp. (°C)	25.5 – 30.1	27.30 – 27.80	26.89 – 27.53	26.67 – 27.25	30.24 – 31.5	25.1 – 31.23	-	Ambient	-
pH	5.53-6.85	6.72 – 6.86	6.72-7.27	6.13 -6.95	5.73 – 5.9	5.82 – 6.03	6.61 – 6.797	6.28 – 6.60, 6.5 – 8.5	6.5 – 8.5
Conductivity (µS/cm)	57.3-105	25.87-28.57	27.93 - 49.90	60.57 - 67.33	-	-	31.6 – 39.167	72.67 – 112.97	1000
Salinity (‰)	0.01 - 0.03*	-	-	-	5.52 – 12.83	0.36 – 12.36	0.003-0.007	0.04 – 0.44*	-
Turbidity (NTU)	28.8 – 48.5	37.73-50.42	26.67 - 37.73	21.80 – 23.03	-	-	27.367 – 31.8	5.36 – 10.73	<1
Total Hardness, mg/l	2.1 – 6.1	-	-	3.10 – 3.82	-	-	1.033 -1.367	39.33 – 50.00	150
TDS (mg/l)	28.7 – 53	6.83 - 7.40	23.10-25.67	30.23 -33.52	-	-	16.1-19.0	26.57 – 58.00	500
TSS (mg/l)	-	-	-	-	-	-	1.753 – 3.427	2.12 – 2.56	500
Total Alkalinity (mg/l)	-	-	-	-	-	-	-	36.67 – 48.00	20
BOD (mg/l)	-	21.53 - 26.37	6.80-25.01	5.03 - 7.05	8.67 – 9.12	9.24 – 10.37	-	-	50
DO (mg/l)	-	5.31- 6.63	5.45 - 9.60	6.13 – 8.01	0.93 – 1.3	1.18 – 1.44	-	-	6
Nitrite (mg/l)	-	0.01 - 0.09	0.02 - 0.10	0.07 – 0.1	0.85 – 1.01	0.63 – 0.84	-	-	0.2
Ammonia, (mg/l)	0.01 – 0.09	-	-	-	-	-	-	-	-
Nitrate (mg/l)	0.12 – 0.26	0.09- 0.13	0.09 - 0.14	0.12 - 0.13	-	-	0.130-0.146	0.12 – 0.32	<50
Chloride (mg/l)	1.6-3.4	2.60 - 4.10	2.60 - 3.56	2.27 – 3.33	-	-	1.257-1.467	11.00 – 15.83	<250
Sulphate (mg/l)	1.4 – 3.5	2.65 – 5.43	3.04 - 5.59	0.52 - 2.62	470.43 – 677.8	268.11 – 494.38	0.417 - 0.567	1.28 – 4.87	<250
Phosphate	-	-	-	-	0.16 –	0.11 –	-	-	250

	[7]	[72]	[11]	[26]	[8]	[55]	[29]	[68]	[69]
	Ikoli creek	Ikoli creek	Sagbama creek	Nun River Estuary	Kolo creek	Kolo creek	Kolo creek	SON limits	WHO limits
(mg/l)				0.18	0.69				
Sodium (mg/l)	-	2.57 - 4.20	3.11 - 4.60	1.40-2.18	-	0.58-0.68	-	3.59 – 6.84	200
Potassium (mg/l)	-	1.68 - 2.22	2.38 - 2.67	0.64 - 1.06	-	0.313-0.363	-	1.18 – 1.53	-
Calcium (mg/l)	-	2.11 - 2.53	2.51 - 2.59	1.90 -2.22	-	1.107 – 1.317	-	7.24 – 12.49	-
Magnesium (mg/l)	-	1.10 - 1.67	1.38 - 2.08	0.63 - 0.85	-	0.37- 0.50	-	2.18 – 3.26	0.2
Iron, mg/l	-	-	-	0.02 – 0.35	-	0.10 – 0.16	0.137 – 0.157	0.04 – 0.10	0.3
Manganese, mg/l	-	-	-	0.01 – 0.02	-	0.013 – 0.033	0.013 – 0.017	0.003 – 0.027	0.2
Mercury (mg/l)	0.000 – 0.001	-	-	-	-	-	0.000 – 0.001	-	0.001
Lead (mg/l)	0.004 – 0.06	-	-	-	-	-	0.001 – 0.002	-	0.01
Copper (mg/l)	-	-	-	-	-	-	0.019 – 0.114	-	1
Cadmium (mg/l)	-	-	-	-	-	-	0.001 – 0.001	-	0.003
Chromium (mg/l)	-	-	-	-	-	-	-	-	0.05
Zinc (mg/l)	-	-	-	-	-	-	-	-	3
THC, mg/l	0.3 – 0.62	-	-	1453.76 – 1629.67	1363.55 – 1766.74	-	-	0.08 - 2.32	-

*mg/l; **=µhmosc⁻¹

Temperature

The spatial spreading of temperature over the water is prejudiced by; amount of insulation received and nature of surface [6] including the dissolved oxygen concentration. The temperature of the various water resource is within the ambient temperature of Bayelsa state and Niger Delta at large. Therefore, anthropogenic activities leading to water pollution may not be having impact on surface water quality in Bayelsa state. Though, slight variation in exist, which authors have attributed to the season of sampling and environmental condition as well as the relative humidity of the days [6].

Total Dissolved solids

Total Dissolved solids are one of the major water quality parameters that are majorly determined in-situ. Typically, total dissolved solid gives information of all mobile charged ions, (including minerals, salts or metals dissolved in water [34]. Total dissolved solid in surface water in Bayelsa state is typically below the limit of 500mg/l specified by SON [68], WHO [69] and permissible and desirable criteria for water quality in Nigeria as specified by Ademoroti [70]. Low total dissolved solid suggest low nutrients especially cations and anions. According to Amangabara and Ejenma [35], high total dissolved solid indicates the level of cations and anions in such water. Low salinity in water may be connected to effective recharge from both precipitation and surface/river drainages [35].

Salinity

Salinity of water is a measure of salt concentration. Freshwater typically have low salinity level compared to marine water. As such salinity of different water sources are in

the order; marine/sea> brackish/estuarine> fresh water. The concentration of salinity in the different fresh water sources studies were typically low apart from the study of Gijo et al. [26] which was conducted from estuarine. Based on the values previously reported, the salinity level appears to be moderate base on the different water sources. Though no low limit have been specified for potable sources. The salinity is also a measure of salt concentration in the water. According to Amangabara and Ejenma [35], high ions in water make it become saline.

Total suspended solids

Total suspended solids provide information about inorganic (silts, clays, etc) and organic composition (algae, zooplankton, bacteria, and detritus) in a water body that are carried along via runoff [34]. Total suspended solid also provide information on the microbial load of a water body [69]. Basically high total suspended solid have adverse effect on aquatic organisms especially fisheries.

Total hardness

The hardness of the water is an indication of the ability of the water to tolerate high soap concentration [6]. The hardness of the water in the various studies is within the permissible limits specified by SON [68] and WHO [69]. The low total hardness could be due to the type of anthropogenic activities carried out in the water resources. The season could also affect hardness, which could be lower during the wet season probably due to dilution effects in the water resources [6].

pH

The pH of water is typically used to assess the acidity and alkalinity of the water. Most pH values previously reported in

surface water resources in Bayelsa state is within the standard limits of 6.5 – 8.5 as specified by WHO [70], SON [68]. Some studies have the pH values slightly out range specified by SON and WHO including the work of Rim-Rukeh and Agboz [34], Ogamba et al. [7], Seiyaboh et al. [11], Seiyaboh and Ayibaefie [29]. Gijo et al. [26] have reported pH values lesser than the recommended limit from Nun River estuary. The variation could be associated to different anthropogenic activities carried out the different water resources. Dilution effects may also accounts for slight variation among the different water bodies [6] and seasons.

Conductivity

Electrical conductivity of water is a measure of electrical current that can pass through the system. Electrical conductivity has a relationship with dissolved solids (mostly inorganic salts) [34] especially total dissolved solid. When the water contain high ions and the salinity increases, the conductivity level is more likely to increase [35]. Conductivity is essential in ecology and environmental management. This is because its provide information about the total dissolved inorganic salts and other solids in the water [34]. The conductivity in various freshwater resources in Bayelsa state (Table 1) is within the various limits specified by SON [68] and WHO [69].

Turbidity

Turbidity of water is measure of cloudiness of such water probably due to the presence of suspended solids which cannot be seen with naked eye [34]. According to Rim-Rukeh and Agboz [34], turbidity accounts provide information about the visibility of river bed from the surface. As such, the constituents i.e. particles of water with high turbidity cannot be easily seen with the naked eye. High turbidity in water is majorly due to human interference in the water. The turbidity level of fresh water resources in Bayelsa state has high turbidity which exceeds the permissible level specified by SON [68] and WHO [69]. The major activities that could account for increase in turbidity level include unsustainable wastes disposal system in the water resources, dredging (both artisan and motorized), transportation and navigation using canoe and engine boat and soil erosion especially during the rainy season.

Alkalinity

Alkalinity which is often expressed as calcium carbonate is not a pollutant and as such it's a measure of amount of substances in water that have acid neutralizing capability [35]. But when the concentration far exceeds the permissible limit it could be deleterious to the survival of aquatic resources. The concentration of alkalinity found in surface water are within the permissible level of 20mg/l recommend by WHO [69] except for few instance in Igbedi creek [31], Epi creek [71] and Kolo creek [29]. The high concentration is mostly due to anthropogenic activities in such water ways. Thus the occurrence of alkalinity in the water could be attributed to geologic formations which consist of carbonate, bicarbonate and hydroxide compounds [35]. But high concentration is mostly due to anthropogenic activities of humans in the environment.

Oxygen related parameters

Oxygen related parameters include dissolved oxygen, chemical and biological oxygen demand. Oxygen is need by the aquatic resources to thrive at optimum level. As such, they are important water quality parameter. Typically, Biochemical oxygen demand provides oxygen information needed by microorganisms to stabilize decomposable organic matter over a period of time at specific environmental conditions including temperature at a particular time and temperature [34]. According to Rim-Rukeh and Agboz [34], biological oxygen demand provides information about the pollution level in aquatic ecosystem brought about by human activities. While the chemical oxygen demand gives information about the organic matter level susceptible to oxidation by chemical oxidant [35]. Amangabara and Ejenma [35] opined that high chemical oxygen demand level in water indicates forms of oxidative stress. Furthermore, Rim-Rukeh and Agboz [34] reported that chemical oxygen demand is the amount of dissolved oxygen needed to stabilize and oxidize organic and inorganic content of the water. The authors also asserted that chemical oxygen demand in contaminated water/effluents/wastes is also higher than the biological oxygen demand probably due to oxidation processes that takes place over a short period of time. Instance of dissolved oxygen exceeding the recommended value of 6mg/l by WHO [67] in several surface water resources in Bayelsa state including Nun river [5, 15], Epi creek [71], Tombia bridge construction area of River Nun [32], Efi lake [63], Ikoli creek [72], Sagbama creek [11] and extreme low values have been reported in Nun river estuary [26], Igbedi creek [31]. For Biological oxygen demand, the values variously reported in within the permissible limit of 50mg/l specified by WHO [69]. Extreme low dissolved oxygen reported by Gijo et al. [26], suggest that the nun river estuary is highly contaminated and could not encourage the survival of biodiversity especially fisheries. Rim-Rukeh and Agboz (2013) reported that low dissolved oxygen could lead to degradation organic matters.

Ionic composition

Ionic composition of aquatic resources provides information about productivity and sustainability of such water. Ions is classified into cations (positively charged) and anions (negatively charged). The cations include sodium and potassium (mono valent ions) and magnesium and calcium (divalent ions). The concentration of sodium and calcium were far below the permissible limits. Based on the other cations, total dissolved solid, salinity and conductivity in the various water resources, potassium level may be within the limit level that could enhance the survival of aquatic life. The magnesium concentration were far higher than the permissible limit recommended by SON (SON, 2007), but far lower than the level recommended by WHO [69]. Each of these cations is useful to bioresources including humans. For instance, calcium salt and other calcium ions typically occurs in inorganic form in water resources. Excess concentration in the body could be deleterious though its toxicity emanating from water resources is rare. Nutrient availability and nutrient leachability depends on the relative proportions of the

monovalent and divalent cations [6, 8].

Anionic nutrients typically studied during water quality assessment include nitrite, nitrate, ammonia, sulphate, phosphate, and chloride. In fresh water resources, the concentration of these anions are lower than the permissible level previously reported in different water bodies in Bayelsa state (Table 1). Of all the parameters, only ammonium has no set limit for water resources. However, based on the concentration of other anions the level is with acceptable level. In estuary, high concentration of sulphate and lower concentration of nitrite have been recorded by Gijo et al. [26]. This is predominantly due to the characteristics of the water resources. Higher ionic could be due to high salinity in the water resources compared to freshwater. Dissolution of sulphides such as pyrite from the interstratified material by percolating water produces sulphate ions in water [35]. High nutrient level especially the anions such as phosphate and ammonical nitrogen may lead to eutrophication [34]. Most nitrate pollution is often associated with septic systems and agricultural activity [34]. Some of the activities that could change water characteristics include excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, organic pollution and obnoxious fishing practices [8, 73].

Total Hydrocarbon Content

Total Hydrocarbon Content in water typically emanates from oil spill and the activities of makeshift oil refinery in Bayelsa state. Like heavy metals, few studies have been conducted on the level of total hydrocarbon in surface water resources in Bayelsa state. The concentration in fresh water is typically in the range of 0.08 – 2.32 [7, 29]. Instance of high total hydrocarbon have been reported in nun river estuary due to the activities of artisan crude oil refining [26].

Heavy metals

Heavy metals are metallic elements that have specific gravity of $\geq 5 \text{ cm}^3$ [1, 74]. Heavy metals are classified into essential (have important role on body at certain concentration) and non-essential (have no known function). Most heavy metals that have been widely studied and known to have beneficial roles include iron, manganese, copper, zinc. Some other that does not have any role include mercury, lead etc. Heavy metal studies in surface water are scanty in literature. Among the available data, concentration of heavy metals including iron, manganese, copper, zinc, lead, mercury, chromium and cadmium are within the various permissible level specified by WHO [69] and SON [68] apart from few instances (Table 1). Heavy metals are known to have serious health and environmental concerns. Some of the roles and effects of heavy metals have been comprehensively documented by Izah et al. [1, 75], Izah and Angaye [13]. On pollution perspective, heavy metals can enter the surface water resources through several routes including runoff from soil erosion, direct discharge of wastes into the water and other anthropogenic activities in the water resources including dredging.

6. Impacts of Anthropogenic Activities in Surface Water Quality in Bayelsa State

Water typically enters the subsurface through infiltrating precipitation and through percolation from surface water bodies [35]. The composition of the pollutants plays a significant role on the impact level of the receiving water. Akpan and Ajayi [12] reported that water contamination has great impact on human health, domestic and industrial development, survival of lives which serve as a source of food for humans [12]. Some of the notable source of contamination to surface water includes oil and gas, market activities, sewage and wastes, dredging. Thus their impacts could be severe depending on the constituents of such wastes.

For instance, the Nun River Estuary which has high aquatic pollution from crude oil spills, which caused severe damages to the flora (especially, mangrove) and the fauna (especially, the benthic organisms) [26 – 28]. Gijo et al. [27] reported that the activities of makeshift oil refining had adversely impacted on the benthos organisms. The authors reported 30 species (from 15 families) of benthic macro invertebrates during the baseline study, and 18 species (from 10 families) after impartation of the environment by the activities of illegal refinery in Nun River estuary. The authors reported the notable benthic species impacted to include *Marphysa*, *Lumbrinereis*, *Lillyalla*, *Mandippi* species, *Marphysa sanguinae*, *Notomastus latericeus*, *Marianida pinniger*, *Littorina anguilifera*, *Neritina owenensis*, *Pachymelania aurita*, *Pachymelania bryonensis*, and *Crassostrea gasar*. Baghebo et al. [76] reported that the activities of oil and gas affects water quality and collapse in fisheries distribution and abundance in addition to other environmental, economic, social and health impacts including emergence of new diseases, reduction in the quality of mangroves, loss of soil fertility and shift in regional climate..

The effect of anthropogenic activities alters the sediment composition of such water. Gijo et al. [28] reported that illegal refineries in Nun River estuary of Bayelsa state have led to pollution of the sediment of the water. The authors reported high concentration of pH, total hydrocarbon content and total organic carbon in the range of 5.11 to 6.32, 17.8mg/kg to 1125.9mg/kg and 0.34mg/kg to 51.4mg/kg, respectively. High concentration of hydrocarbon content and total organic carbon in the sediment suggests that the environment is not suitable for benthic organisms to thrive

Low dissolved oxygen in aquatic ecosystem could determine the type of biodiversity found in such area. Rim-Rukeh and Agboz [34] reported that the level of dissolved oxygen varies according to season and as well as day and it could influence species and abundance of phytoplankton, light penetration, nutrient composition, temperature of the water, salinity and conductivity, water movement, partial pressure of atmospheric oxygen [34].

Rim-Rukeh and Agboz [34] reported that Epie creek in Yenagoa which received effluent from Byanoil and gas company camp site and other wastes from human activities is fairly polluted especially from sewage (fecal contamination).

The major activities carried out in Epie creek include fishing, washing, boating, swimming, bathing and defecating [34]. Therefore depending on the composition of such wastes it could affect humans indirectly. Apart from odour pollution emanating from the water resources, human that consumes fisheries from such contaminated water could be at risk of diseases associated to the contaminant.

Poor hygiene due to the deposition of sewage in water could cause water borne diseases [12] when the water is consumed or used for domestic purpose like washing and cooking food materials. Some of the notable diseases associated to water include *Plesiomonas* infection caused by *Plesiomonas shigelloides*, Typhoid fever caused by Typhus, Salmonellosis caused by *Salmonella*, Cholera caused by vibrio (bacteria), Acute gastroenteritis caused by Norwalk-Type virus and Rotaviruses (viruses) and Toxoplasmosis caused by *Toxoplasma gondii*, Giardiasis caused by *Giardia* (protozoans) among other diseases. The vectors of some other diseases such as malaria complete their life cycles in the water.

Prekeyi et al. [69] reported that water flooding entering the groundwater and river water alters the physicochemical characteristics of the receiving water. Some notable parameters that are majorly affected by flooding water include biological oxygen demand, chemical oxygen demand and dissolved oxygen (oxygen related parameters), iron, copper, chromium, zinc (heavy metals), cations nutrients (calcium, potassium, magnesium and sodium), anionic nutrient (sulphate, nitrate, ammonia, carbonate) among others.

Dredging in surface water alters the water quality parameters [31, 32, 67, 77]. In a specific study Seiyaboh et al. [31] reported that dredging materials alters the water quality. Other impacts of dredging have been several reported by dredging including on fisheries composition and abundance [30], macrobenthic invertebrates [78], algal bloom [79], zooplankton assemblages [80]. Other studies on impacts of dredging have been comprehensively documented by Ohimain [81, 82].

Flooding has adverse effect on the environment. It could lead to loss of biodiversity including vegetation, mammals, aves, reptiles among others [40] and alter the hydrological cycle and water quality parameters (including surface and groundwater) [69]. Nkemjika et al. [66] reported that flooding has several impacts including water pollution due to disposition of sediment, destruction of infrastructure such as pavement, culverts and drainages.

7. Conclusion and the Way Forward

Water resources abound in Bayelsa state. Water resources mostly include fresh, brackish and marine water. Several anthropogenic activities are carried out in the water ways. Indiscriminate discharge of wastes resulting from human activities is a major source of concern. Sometimes wastes could obstruct free flow of vehicles along highways and street. The wastes could end up the aquatic ecosystem via runoff. In some communities' aligning surface water, the water is the major recipient of the wastes. Sewage is also

directly discharged into the water bodies through the use of pier toilet system. Flooding occurs in the region during the wet season which is usually at optimum during July and September. Other anthropogenic activities such as dredging, makeshift oil refinery also alter water quality. The study found that water quality parameters such as turbidity are mostly affected and to lesser extent, pH, total alkalinity, dissolved oxygen, nitrite, magnesium, total hydrocarbon content, iron and lead based on the standard specified by Standard Organization of Nigeria and World Health Organization. Others water quality parameters are also altered by the various anthropogenic activities in the area are with the various levels recommended by appropriate agencies such as Standard Organization of Nigeria and World Health Organization.

Therefore, the impacts of water quality could be reduced when wastes (from several sector including domestic, market, dredging, sewage) produced in the area are adequately managed. Proper drainage system could also ready the severity of flooding thereby minimizing the impacts on water quality. In case of oil spill, appropriate agencies should be contacted to remediate the environment as soon as possible.

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