



RESEARCH ARTICLE

COMPARATIVE INVESTIGATION OF THE IMPACT OF EFFLUENT FOOTPRINT ON THE BONNY ESTUARY

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Abstract

The study, comparative investigation of the impact of effluent footprint on the Bonny estuary was to assess the impact of wastewater on the Bonny estuary and its environment by analyzing the physicochemical and microbial parameters of surface water in four different locations and a control point. The study found that almost all locations exhibited some level of contamination, particularly hydrocarbons and heavy metals. The findings underscore the importance of regular monitoring of the Bonny Estuary and its environment to detect changes in water quality that could be detrimental to aquatic life and human health. Therefore, regular monitoring of these locations is necessary to discover changes in water quality that could harm marine life consumed by the human community in these areas.

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Introduction:-

The release of raw and ill-treated wastewater onto water surfaces has both short- and long- term effect on the environment and human health. Freshwater sources have been negatively impacted by wastewater discharges. Such impacts are dependent on the composition and concentration of the wastewater contaminants as well as the volume and frequency of wastewater effluents entering surface water sources (Akpob OB *et al*, 2011). Eutrophication of water sources may also create environmental conditions that favour the growth of toxin producing cyanobacteria, and exposure to such toxins is hazardous to human beings.

Literature Review of the study area:-

The warmest month in Bonny is January, with an average high-temperature of 31.8 °C (89.2 °F) and an average low-temperature of 24.9 °C (76.8 °F). The months with the smallest moisture in Bonny are January and December, with an average relative moisture of 73. Research has it that throughout the time, there are 300.7 downfall days, and 1894 mm (74.57") of rush is accumulated in this area according to rainfall (Atlas, 2022) (www.weather-atlas.com). Bonny islet occupies an area of 343.9 km² as related by Wikivoyage, 2022 (en.wikivoyage.org).

The nearshore axis of the Bonny River, which is the study area, is the focal point of this quantitative exploration because there have been significant increases in the artificial expansion over the times with affiliated population

progress. presumably, these conditioning have redounded in the direct discharge of organic and inorganic substances including crude oil painting and refined products through normal operation (as backwaters), functional botches, and sabotage to installations into the touching water bodies. In this tone, the study design dives into probing the physicochemical parcels and the position of some trace essence in nearshore Bonny River, Niger Delta, Nigeria.

The study area

The study area lies within rectangular coordinates 291,851.30mE, 302,126.77mE and 485,904.84mN, 495,470.75mN of the Universal Transverse Mercator (UTM) Zone 32 projection.

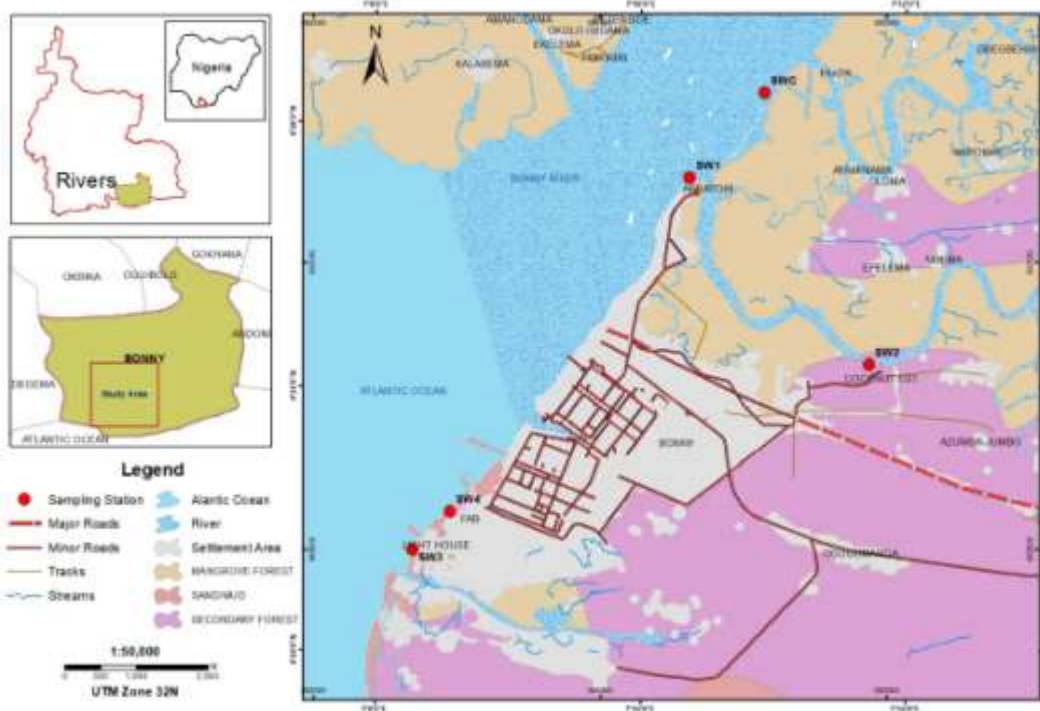


Fig 2.0:- Geographical extent of the study area:

Materials And Methodology: -

Materials: -

Apparatus and equipment

Oven, Incubator (Biobase), Autoclave, Desiccator, Forceps, Glassware, Filter papers, Steam bath, Centrifuge, Thermometer, Ultraviolet visible spectrophotometer (721D) and Dissolved Oxygen meter. Hot plate or gas burner, Biochemical Oxygen Demand bottles, Filtration apparatus, Analytical balance, AAS (PerkinElmer Analyst 400), multiparameter-meter (HANNA HI9829) and Gas Chromatography (Agilent6890GC).

Reagents and procurement

All reagents used were of analytical grade and were prepared in line with standard methods as described in the Manual for Standard Analytical Procedures (1999), except otherwise Stated. Other procedures used are duly acknowledged.

Methodology:-

The criteria for selecting sampling points were based on the population density, proximity to area of anthropogenic activities and direction of flow of the surface water. Bonny Island is famous for its oil and gas activities; thus, it was significant to see the water quality in such an area where there is runoff. Therefore, four (4) different points of surface water locations and one (1) control at Bonny River were chosen based on designed criteria. These locations were Bonny Jetty Abattoir as SW1, coconut estate as SW2, Light House area (Mobil discharge point) as SW3, FAB area as SW4 and FAKPA (control point) as SWC. The five water samples were carefully collected to prevent the use of improper methodology or sampling techniques, insufficient sample preservation, inadequate identification, and

transportation and to ensure it proves the validity of the data from field measurements. In-situ sample analysis for Temperature, pH, Dissolved Oxygen, Total Dissolved Solids, Salinity, Electrical conductivity, and Turbidity was recorded at each sampling point. Thereafter, a waterproof ink label containing all required information such as name, location, date, time, and preservative was affixed to each of the samples collected before they were transported to GIMLAS Integrated Services Limited Laboratory, Port Harcourt, Nigeria for ex-situ analysis. Laboratory analysis was conducted following standard protocols and methods of analysis by the American Public Health Association (APHA) standard procedure for the analysis of water and wastewater, 23rd Edition.

Quality Assurance, Sample Collection Procedure and Preservation

Surface water samples were collected in one day with duly labelled applicable sample holders{(Sterile vial for microbiological analysis, clear glass bottles for oil and grease, polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbon (TPH), one liter plastic containers for all Physico-chemical parameter analysis, 120 ml blue plastic can for heavy metals, 250 ml amber bottles to hold samples for Biological Oxygen Demand (BOD₅), all enclosed in a Ziploc and kept in well- organized Ice casket (coolers) laced with ice- packs}. Surface water samples from the sample locations were collected using a stainless-steel water sampler. Each sample was got by irrigating the sample vessel with the sample from that position before putting it into the applicable containers. Samples collected for heavy metal analysis were saved with a few drops of nitric acid. At each sample station, in situ measurement of rapid-changing parameters such as temperature, pH, salinity, Electrical conductivity, Total Dissolved Solids (TDS), Dissolved Oxygen, Turbidity and others were determined with the Hanna water quality multiparameter meter (HI9829) with each sample position geo-substantiated with a hand- held geographical position system (GPS). Other parameters to be tested by laboratory analysis are Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chloride, Nitrate, phosphate, sulphate, hydrocarbon components and Trace/Heavy metals.

Laboratory contracted for Analysis

The samples were taken to GIMLAS Integrated Services Laboratory, at Elekahia Housing Estate, Port Harcourt, Rivers State, a Federal Ministry of Environment and Nigeria Upstream Regulatory Commission accredited laboratory where analysis took place following ISO quality operation system and standard logical procedures.

Results And Discussion:-

Result:-

The physico-chemical, heavy metal, hydrocarbon, and microbiological properties of the samples of surface water from five (5) locations inclusive of a control station in Bonny, representing impact on water quality from residential, industrial and commercial areas of Bonny NLNG work site areas are shown in Table 4.1 – 4.6.

Table 4.1:- Insitu/Physical properties of surface water characteristics from the study area.

S/N	PARAMETER	SAMPLE ID				
		SW 1	SW 2	SW 3	SW 4	SW C
1	Temperature(°C)	28.72	28.50	30.39	30.14	27.75
2	pH	6.34	7.25	7.48	7.80	7.77
3	Electrical Conductivity(μS/cm)	41920	22700	29500	44820	36820
4	Total Dissolved Solids (mg/l)	20960	11350	14750	22410	18410
5	Salinity (PSU)	26.79	13.20	18.12	28.82	23.21
6	Turbidity (NTU)	41.9	31.7	8.5	20.8	12.40
7	Dissolved Oxygen (mg/l)	11.70	6.31	8.19	8.17	5.41

Table 4.2:- Chemical properties of surface water characteristics from the study area.

S/N	PARAMETER	SAMPLE ID				
		SW 1	SW 2	SW 3	SW 4	SW C
1	Biological Oxygen Demand (mg/l)	43.33	17.50	32.12	25.50	15.50
2	Chemical Oxygen Demand (mg/l)	200.00	45.00	193.00	120.00	45.00
3	Total Suspended Solids (mg/l)	53.8	30.95	20.25	43.85	30.15
4	Total phosphorus (mg/l)	1.60	1.63	1.65	1.47	1.70

Table 4.3:- Anions properties of surface water characteristics from the study area.

S/N	PARAMETER	SAMPLE ID				
		SW 1	SW 2	SW 3	SW 4	SW C
1	Phosphate (PO ₄ ²⁻) (mg/l)	4.80	4.90	4.95	4.4	5.10
2	Sulphate (SO ₃ ²⁻) (mg/l)	165.00	194.00	204.00	185.00	130.00
3	Total nitrogen (mg/l)	0.08	0.16	0.12	0.09	0.14
4	Nitrate (NO ₃ ⁻) (mg/l)	0.36	0.72	0.54	0.38	0.60
5	Ammonia (NH ₃) (mg/l)	1.57	1.90	1.29	2.52	2.18

Table 4.4:- Trace/Heavy metal properties of surface water characteristics from the study area.

S/N	PARAMETER	SAMPLE ID				
		SW 1	SW 2	SW 3	SW 4	SW C
1	Arsenic (As) (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
2	Cadmium (Cd) (mg/l)	0.03	0.03	0.03	0.04	0.03
3	Chromium (Cr) (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
4	Copper (Cu) (mg/l)	0.04	0.06	0.03	0.05	0.05
5	Mercury (Hg) (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
6	Nickel (Ni) (mg/l)	0.03	0.03	0.02	0.04	0.04
7	Lead (Pb) (mg/l)	0.01	0.01	0.01	0.01	0.01
8	Zinc (Zn) (mg/l)	0.02	0.11	<0.01	<0.01	<0.01
9	Iron (Fe) (mg/l)	0.21	0.89	0.08	0.10	0.06
10	Aluminum (Al) (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01

Table 4.5:- Organic/Hydrocarbon properties of surface water characteristics from the study area.

S/N	PARAMETER	SAMPLE ID				
		SW 1	SW 2	SW 3	SW 4	SW C
1	Oil and Grease (mg/l)	0.10	0.12	0.08	0.16	0.05
2	Total Petroleum Hydrocarbon (mg/l)	3.43	3.60	3.53	3.45	3.61
3	Polycyclic Aromatic Hydrocarbons (mg/l)	1.33	1.59	1.70	1.67	1.55

Table 4.6:- Microbiological properties of surface water characteristics from the study area.

S/N	PARAMETER	SAMPLE ID				
		SW 1	SW 2	SW 3	SW 4	SW C
1	Total Coliform (cfu/ml)	1.165×10^4	1.169×10^4	4.8×10^4	7.65×10^3	2.083×10^4
2	Escherichia coli (cfu/ml)	5.0×10^1	6.3×10^1	1.6×10^1	1.56×10^2	0
3	Hydrocarbon Utilizing Bacteria (cfu/ml)	5.8×10^2	3.51×10^3	1.266×10^3	8.3×10^1	3.93×10^2
4	Hydrocarbon Utilizing Fungi (cfu/ml)	0	1.6×10^2	0	4.0×10^1	2.2×10^2

Discussion:-**Physico-chemical Parameters****Temperature**

The temperature of the samples ranged from 28.50 - 30.39 °C at surface water (SW) points 1- 4 and the control (SWC) point recorded 27.75 °C. This temperature range is in scientific harmony with temperatures recorded by other research works conducted in the area, Ngah *et al.*, 2017

pH

The pH of the study area ranged from 6.34 – 7.80, with the control surface water point having a pH of 7.77. The pH result of the study area showed that the water is weakly acidic to weakly alkaline. This is anticipated, the weakly acidic pH values can be scientifically attributed to advanced temperature hence advanced TDS values. A scientific premise has the correlation that the advanced rush and adsorption processes and advanced ion exchange capacity could be taking place in the water. Since the water samples were weakly acidic, the water body will thus warrant capabilities to corrodes metallic outfit around it including causing a much lower rate of dissolution processes as inferred by Ngabirano *et al.*, 2016.

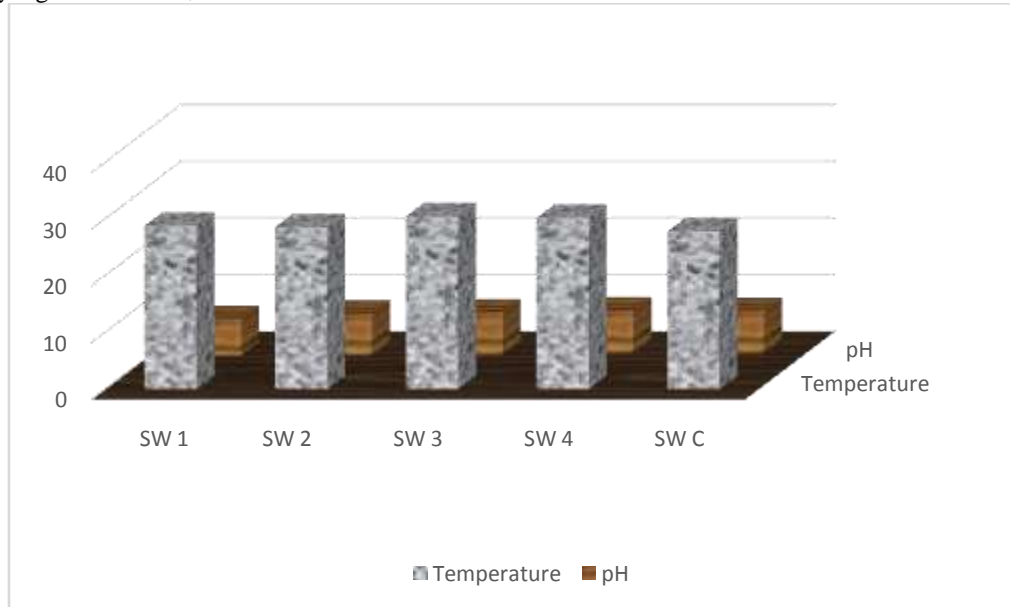


Fig 4.1:- Variations in Temperature and pH across the study area.

Electrical Conductivity

The electrical conductivity of the study area ranged from 22700 $\mu\text{S}/\text{cm}$ – 44820 $\mu\text{S}/\text{cm}$ with the control zone having electrical conductivity value of 36820 $\mu\text{S}/\text{cm}$. These high values of electrical conductivity are anticipated since the water body has high salt content (brackish water type), Onojakeet *et al.*, 2017. Differences in the abiotic factors of the terrain from anthropogenic conditioning were minimum around the control zone of the study area. There are several factors that affect the conductivity of a water body. These include amount or number of ions, mobility of ions, oxidation state (valence) and temperature of the water. Conductivity also increases as result of heavy metal ions released from pollutants such as derivatives of acids in effluents being discharged.

Total Dissolved Solids

Total Dissolved Solids (TDS) is made up of inorganic salts, as well as a small quantum of organic matter. Common inorganic salts that can be found in water include calcium, magnesium, potassium, and sodium, which are all cations; and carbonates, nitrates, bicarbonates, chlorides, and sulfates, which are all anions. These solids can also come from human activities. Agricultural and civic runoff can carry redundant minerals into water sources, as can wastewater discharges (Water Exploration Center, 2016).

TDS values attained from the study ranged from 11350 mg/ l – 22410 mg/ l, with 18410 mg/ l at the control zone.

TDS itself may be only an aesthetic and specialized factor, a high concentration of TDS similar as the values attained in this study is an index that dangerous pollutants, similar as iron, manganese, sulfate, lead, and arsenic, are present in the water. This is especially true when the excessive dissolved solids are added to the water as human pollution, through run-offs and untreated wastewater discharges.

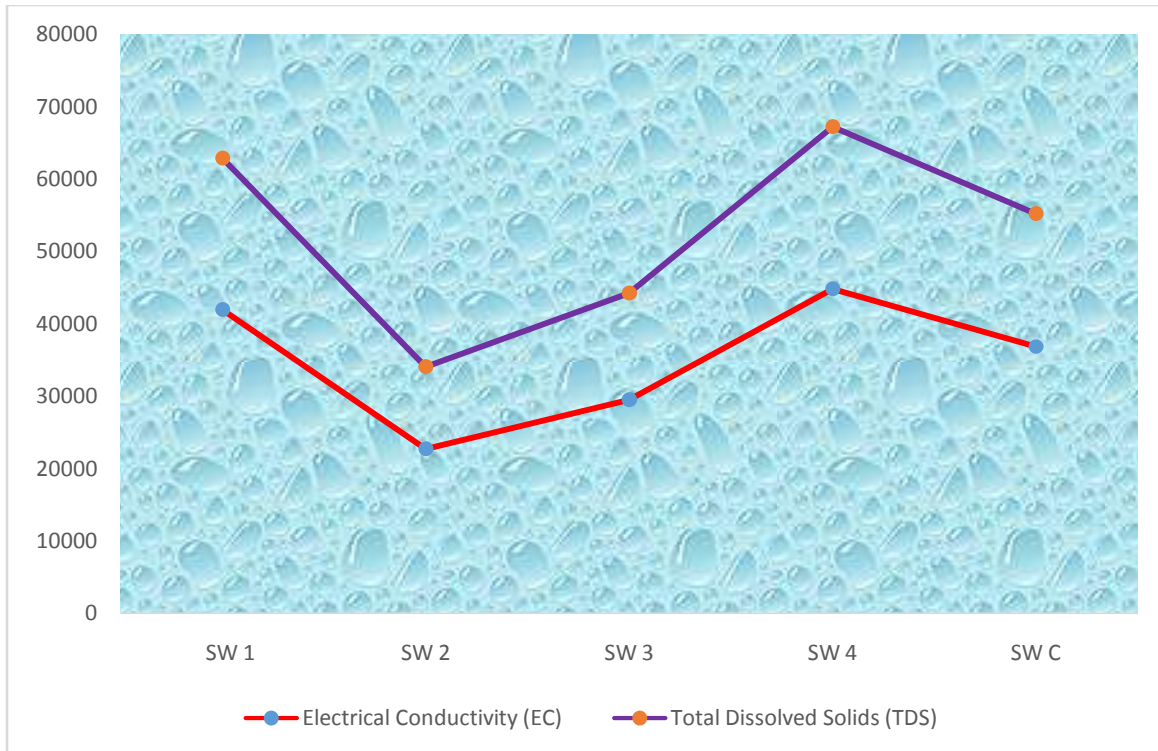


Fig 4.2:- Variations in the EC and TDS across the study area

Salinity

Salinity content ranged from 13.20 – 28.82 PSU in the study area and obviously highest in the SW4 position with the control zone SWC having a saltiness value of 23.21 PSU. The observed values of saltiness can be attributed to the proximity of the Bonny River to the high sea.

Turbidity

Turbidity is a measure of suspended minerals, bacteria, plankton, and dissolved organic and inorganic substances. Turbidity frequently is associated with surface water sources, Onojakeet *et al.*, 2017. Turbidity ranged from 8.5 –41.9 NTU at the study position and 12.4 NTU at the control station.

Dissolved Oxygen

The values recorded for DO at the study area ranged from 6.31 –11.70 mg/ l and 5.41 mg/l at the control point. The values obtained for DO were sufficient to support a luxuriant aquatic life. Although, it was observed from the results that dissolved oxygen at the control point may have been consumed by the bio-oxidation of nitrogenous material in water (Onojakeet *et al.*, 2011). Dissolved oxygen situations at the control zone were smallest in concentration. This is due to the high proliferation of microbes and inorganics depleting the dissolved oxygen situations in the water.

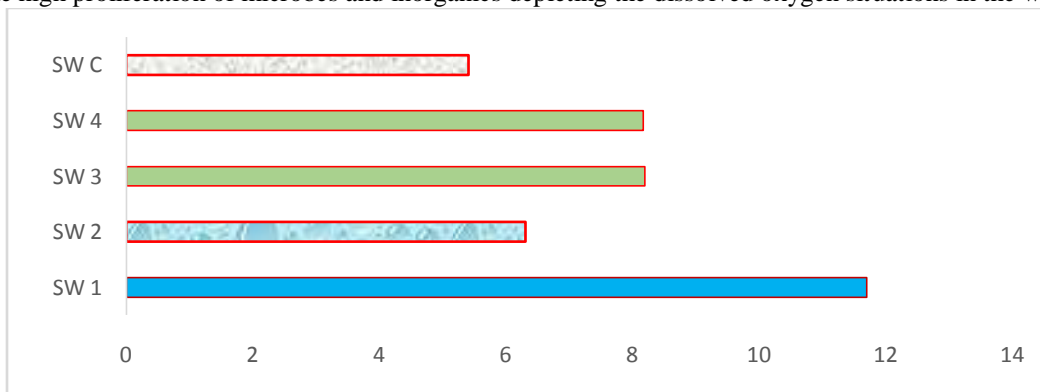


Fig 4.3:- DO levels in the study area.

Biological Oxygen Demand (BOD)

Biochemical oxygen demand indicates the quantum of oxygen which bacteria and other microorganisms consume in a water sample during the period of 5 days at a temperature of 20 °C to degrade the water contents aerobically. BOD is therefore a circular measure of the sum of all biodegradable organic substances in the water. The BOD indicates how important dissolved oxygen (mg/ l) is demanded in a given time for the natural declination of the organic wastewater ingredients.

The values of BOD attained in the study area ranged from 17.50 – 43.33 mg/ l and 15.50 mg/ l at the control station. The Biochemical oxygen demand here infers that the water body is fairly good.

Chemical Oxygen Demand (COD)

The quantum of oxygen that's needed for the chemical oxidation of the organic and inorganic chemicals present in the wastewater by exercising oxidizing agents like Potassium permanganate, Potassium dichromate etc. is referred to as chemical oxygen demand (COD).

COD in the study area ranged from 45.00 – 200.00 mg/l with 45.00 mg/l in the control area. This value indicates that the quantum of oxygen needed for chemical oxidation in the surface water is relatively fair for both human activities and aquatic lives, hence there is a need for continuous monitoring of the surface water.

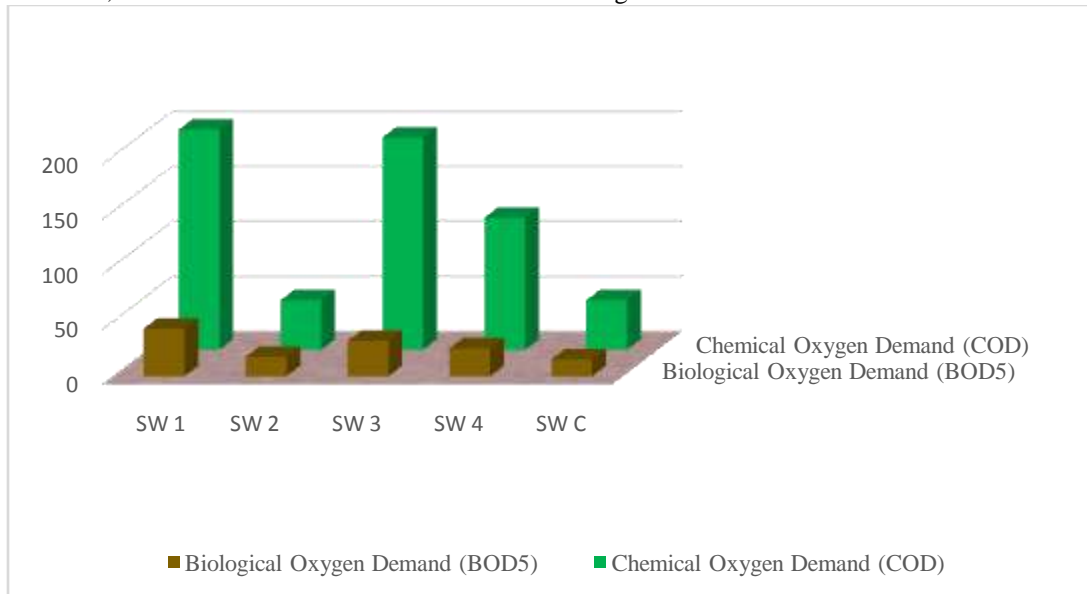


Fig 4.4:- Variations of COD and BOD in the study area.

Total Suspended Solids (TSS)

Total suspended solids (TSS) values are often related to the turbidity (cloudiness) of water. If TSS is high and the water is murky then light from the sun will not travel well through the water, making it difficult for plants and algae to grow. The load of total suspended solids (TSS) is one of the most important parameters for evaluating wet-weather pollution in urban sanitation systems. A high TSS load indicates the potential impact on any receiving water body, Luca *et al.*, 2005.

TSS values in the study area ranged from 20.25mg/l – 53.8 mg/l with the control zone having a value of 30.15 mg/l. TSS in the study area were low with a less murky water so light from the sun travels through the water enough thereby allowing for algal bloom.

This phenomenon can increase productivity (sufficient plant and animal life that a river or lake can support) and more oxygen generation. Lots of soil and silt in the water can also clog fish gills and, if it settles to the bottom, bury fish eggs.

Total phosphorus

Total phosphorus (TP) is a measure of all phosphorus found in a sample, whether that phosphorus is dissolved or particulate. This is generally used when sampling in wastewater treatment and is specially used to determine the health of waterways.

High concentration of phosphorus may result from poor agricultural practices, runoff from civic areas and meadows, leaking septic systems or discharges from sewage treatment plants. The total phosphorus in the study area ranged from 1.47 – 1.65 mg/l and 1.70 mg/l at the control station. This is a suggestion that agricultural runoffs, leakages from septic systems, etc into the surface water are relatively fair with phosphorus contents.

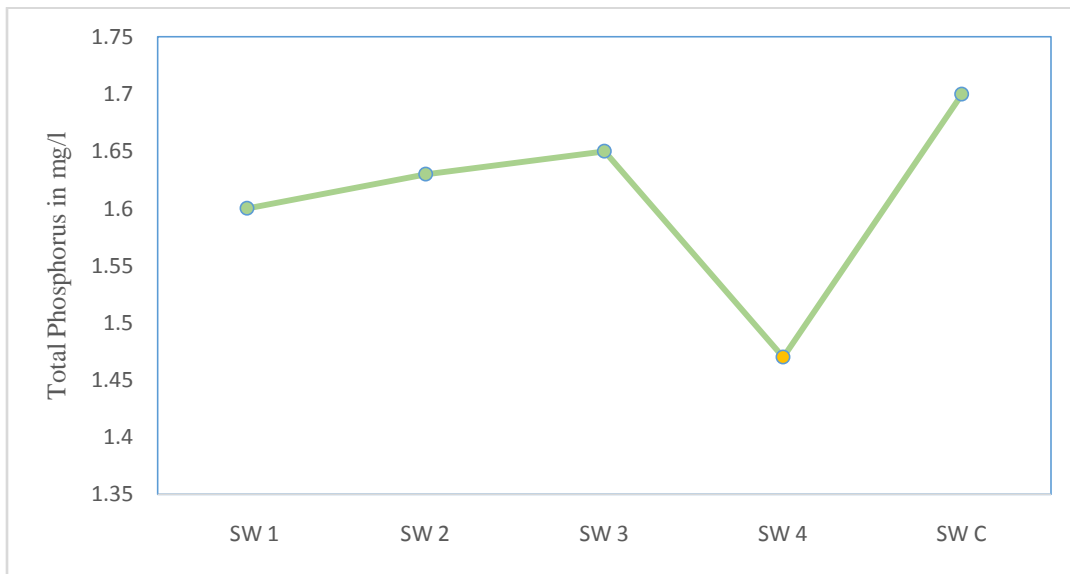


Fig 4.5:- Total Phosphorus showing highest concentration at the control zone.

Surface Water Anions (Nutrients)

Phosphate, (PO₄²⁻) Sulphate (SO₄²⁻) and Nitrate (NO₃⁻)

Phosphate, Sulphate, and Nitrate situations in the study area ranged from 4.4 – 4.95 mg/l, with the control area having 5.10 mg/l, 165.00 – 204.00 mg/l with the control zone having a value of 130.00 mg/l and 0.36 – 0.72 mg/ l with the control position having 0.60 mg/ l. The nutrients values attained in the surface water are a symbol of low agricultural activities in the study which could have impacted the water high nutrients still these values show pitfalls of possible water pollution from other pollutants sources if not controlled.

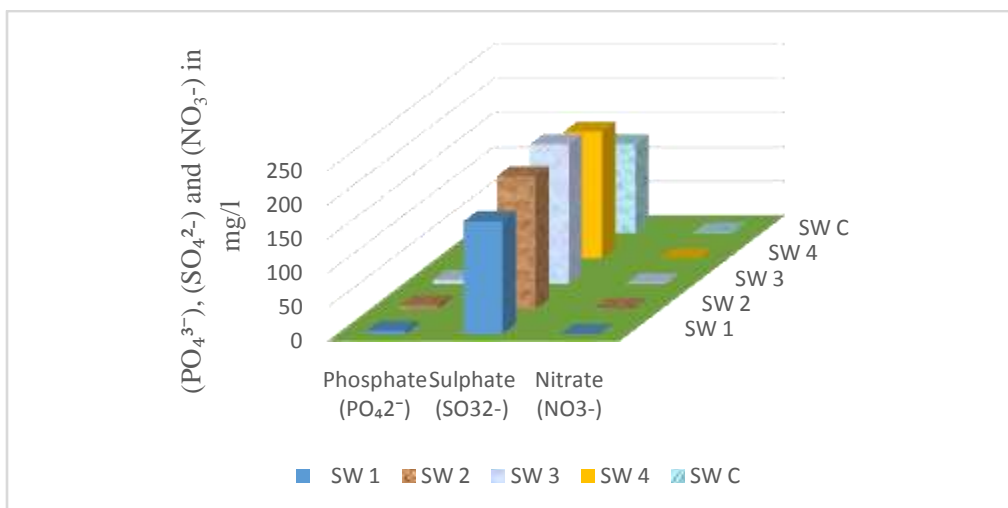


Fig 4.6:- Variations in Phosphate, Sulphate and Nitrates in the study area.

Total Nitrogen, Ammonia (NH₃)

Variations in total nitrogen and ammonia in the study area ranged from 0.08 – 0.16 mg/l, 0.14 mg/l at the control area, and 1.29 – 2.52 mg/l with 2.18 mg/l at the control location independently. This validates the results attained from nitrates. Nitrogen and Ammonia as products of Nitrification; hence the results show relatively low nitrification processes in the surface water.

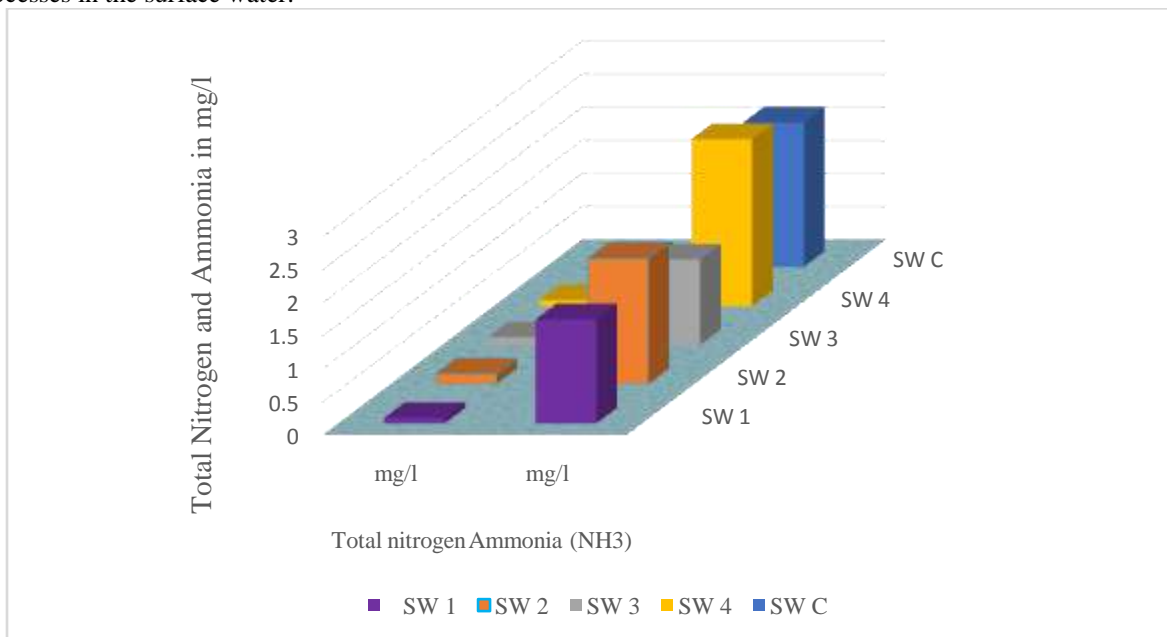


Fig 4.7:- Disparities of Total Nitrogen and Ammonia in the study area.

Trace Metals

The study assessed ten (10) heavy metals. They include Cadmium (Cd), Copper (Cu), Nickel (Ni), Lead (Pb), Zinc

(Zn), Iron (Fe), Aluminum (Al), Arsenic (As), Chromium (Cr) and Mercury (Hg).

Heavy metal concentrations were observed in the surface water across most of the assessed stations. Aluminum (Al), Arsenic (As), Chromium (Cr) and Mercury (Hg) were analyzed and found undetected in the samples in the study area. Cadmium (Cd), Copper (Cu), Nickel (Ni), Lead (Pb), Zinc (Zn), Iron (Fe) ranged from 0.3 – 0.4 mg/l and 0.3 at the control zone, 0.3 – 0.6 and 0.5 at the control zone, 0.2 – 0.4 mg/l and 0.4 at the control zone, 0.1 mg/l at the stations with 0.1 mg/l at the control zone, 0.01 – 0.11 mg/l and undetected at the control zone, 0.08 – 0.89 mg/l and 0.06 mg/l at the control zone respectively for the metals. The concentrations of heavy metals obtained in this study were generally lower compared to the findings of Vincent-Akpuet *et al.*, (2015) in a similar area within the Niger Delta. The findings of this study with respect to the concentrations of Cr, Cu, Ni and Zn in surface water corroborate the reports of Wokoma (2014) while the level of Pb observed in this study was lower compared to Wokoma (2014). Concentrations of Cd, Cu, Ni, Pb, Zn and Fe obtained in this study are a symbol of a potential water pollution if left uncontrolled though the values obtained could be from natural occurring metals or their compounds, anthropogenic sources within the study area.

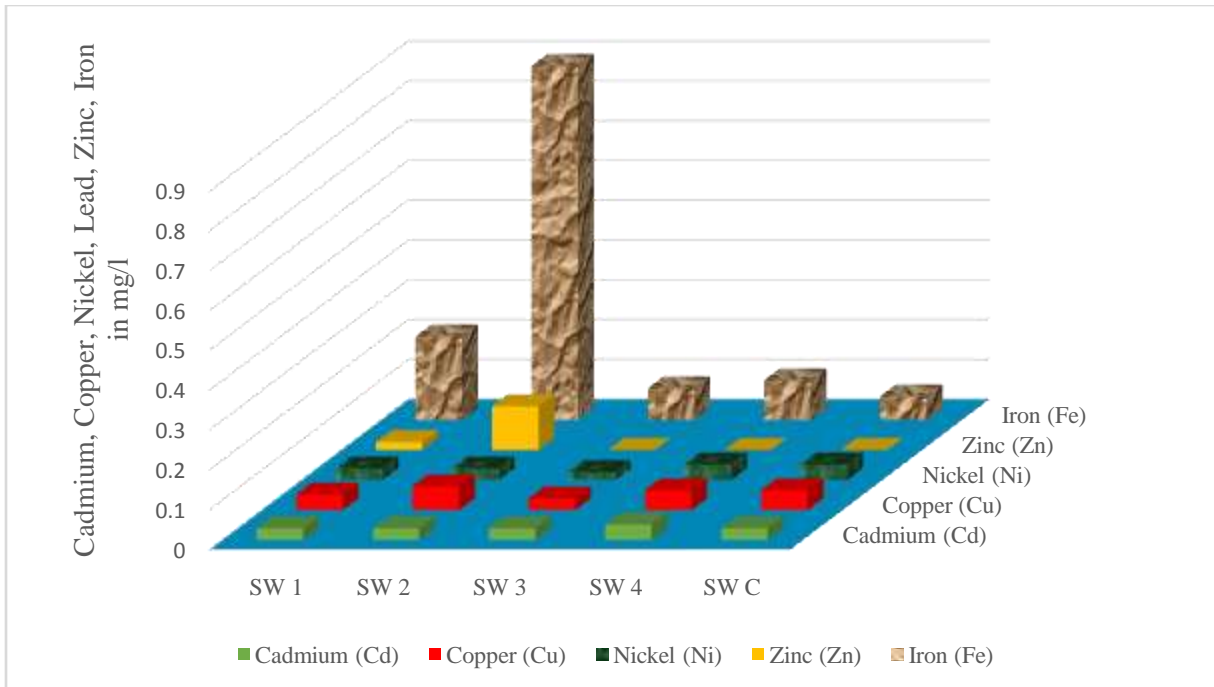


Fig. 4.8:- Distribution of trace metals in the study area.

Organic Indicators

The spatio-temporal variations of the hydrocarbons THC-Total Hydrocarbon Content, TPH-Total Petroleum Hydrocarbon in the surface water from the surveyed stations ranged from 3.43 – 3.60 mg/l and 3.61 mg/l at the control position showing no difference across the zones. Analysis crminated by a significant part of the fractions of the THC were of petroleum origin. There were remarkable variations in the Polycyclic Aromatic Hydrocarbons (PAH) in the surface water across the stations ranging from 1.33 – 1.70 mg/l and 1.55 mg/l at the control zone, the results indicated that there was only minimum impurity with fragments of hydrocarbon. Oil painting and grease analysis also showed that significant part of the ‘organic pool’ was also of petroleum derivative with its values showing analogous trend with those of the PAH 0.08 –0.16 mg/ 1 and generally lower, not obvious at the control zone 0.05 mg/l. Petroleum product or its derivations leaks and spill from vessels could have influenced the results hence the activities of the vessels within the study needs to be checkmated and put under control.

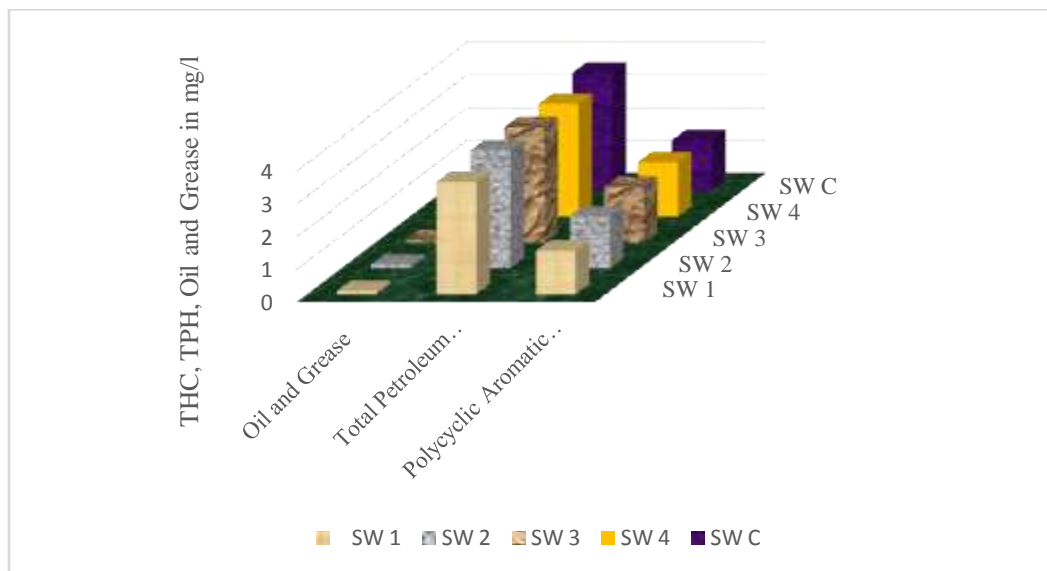


Fig 4.9:- Hydrocarbon content in the study area.

Microbiological indicators

Total Coliforms

For total coliform count, the original inoculum was transferred in a series of five 10-fold serial dilutions using physiological saline (Willey *et al.*, 2011). Decimal dilutions were conducted and 0.1 ml aliquot of 10^{-1} , 10^{-2} , 10^{-3} dilutions were inoculated by spread plate system onto MacConkey agar plates in duplicates. The plates were incubated at 35 °C for 24 hrs. Coliform bacteria can be used as an index of seawater quality and have a long history of being used for assessing seafood safety. *Serratiasp*, *Klebseillasp*, *Enterobacter sp*, *Escherichia sp*, *Salmonella sp*, and others were among the microbes isolated from the samples gotten from the study locations, their abundance ranged from 1.165×10^4 - 4.8×10^4 cfu/ml and as much as in the control area 2.083×10^4 cfu/ml. Animal dung and other wastes ditched into or around these areas at the period of this study could be the likely cause of the high proliferation of these microbes of fecal origin.

Hydrocarbon Utilizing Bacteria and Fungi

Hydrocarbon compounds, their derivatives, and fragments, contain aromatic compounds that are toxic to most life forms. Marine environments are especially vulnerable, as oil spills near coastal regions and in the open sea are difficult to contain and make mitigation efforts more complicated despite its toxicity; a considerable fraction of petroleum oil entering marine systems is eliminated by the hydrocarbon-degrading activities of microbial communities. The microbes isolated in the surface water from the study area include fungi (*Aspergillus*, *Candida*, *Cladosporium*, *Fusarium*, *Mucor*, *Penicillium*, *Rhizopus*, and *Saccharomyces sp.*) and bacteria (*Bacillus sp.*, *Pseudomonas sp.*, *Flavobacterium sp.*, *Escherichia sp.*, *Acinetobacter sp.*, and *Enterobacter sp.*). The abundance of these bacterial isolates ranged from 8.3×10^1 - 1.266×10^3 cfu/ml including those in the control area, while the fungal isolates ranged from while surface water zones SW1 – SW4 had no fungal isolates with hydrocarbon degrading capacity.

SW3 and SW4 had fungal isolates ranging from 4.0×10^1 - 1.6×10^2 cfu/ml. The abundance of these species of microorganisms confirms the presence of hydrocarbons and their numbers indicates their evolution to convert the fragments as their sole source of carbon and energy for metabolic processes.

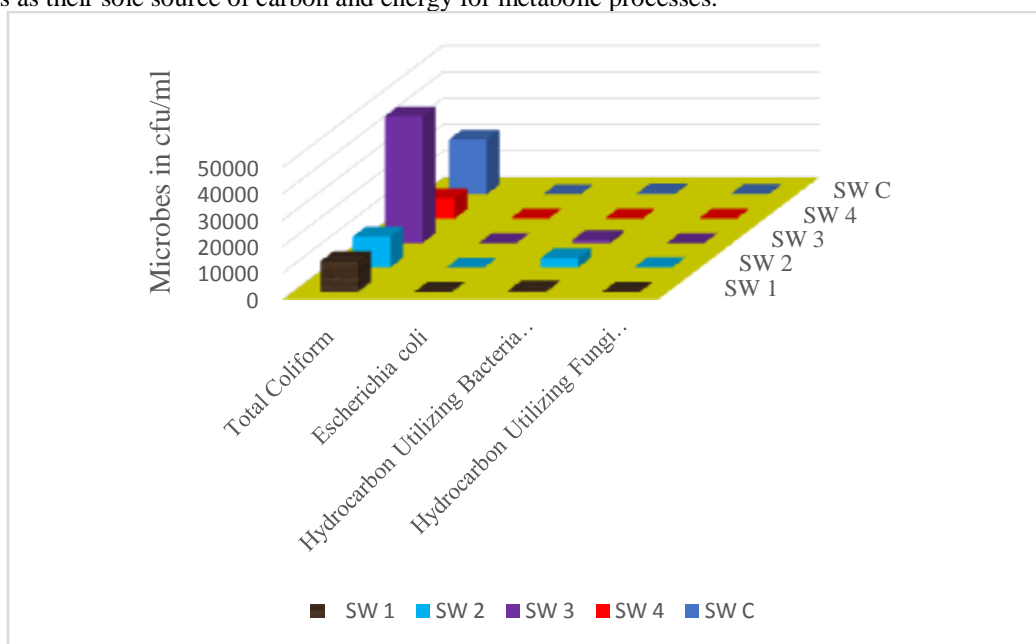


Fig. 4.10:- Microbial distribution in the study zone

Conclusion and Recommendations:-

Conclusion:-

All the study locations showed some position of impurity with hydrocarbons like TPH and PAH. The study locations had significant iron (Fe) situations, while the Surface water (SW2) had the highest concentrations of Iron and Nickel (Ni). Still, since Iron (Fe) is the most abundant metal in nature (soil and water) it had the highest concentrations in all study zones in the area, so, this miracle was anticipated.

A greater portion of the heavy metals analyzed were fairly low compared to analogous studies except values of Zn, Cu and Iron. This was due to suspected anthropogenic activities (industrial discharges) far or near to the study area. Complete isolation of each point examined indicates discrepancy in the water quality with respect to contaminant levels in the study area including the zones suspected to have lower impurity used as control (SWC), hence regular monitoring of these locations is necessary to discover changes in water quality that could harm marine life consumed by the human community in these areas.

Recommendation:-

- i. Effluent should be treated before discharging on to the surface water
- ii. Constant support from the government sector
- iii. Improved legal and regulatory framework(s)
- iv. Increased capacity and skills of the regulators, and
- v. Adequate financial arrangements for both implementation of environmental policies and for amending appropriate treatment technologies.

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