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Physio-Chemical Status Of Flood And Rain Water In Wilberforce Island, Bayelsa State, Nigeria.

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Abstract

Water quality remains a major environmental and public health concern in flood-prone and coastal regions. This study assessed the physio-chemical properties of flood and rainwater in Wilberforce Island, Bayelsa State, Nigeria a region with increasing vulnerability to pollution due to urbanization and seasonal flooding. Using standardized collection and analytical methods, key water quality parameters including pH, conductivity, turbidity, total dissolved solids, chemical oxygen demand (COD), and concentrations of heavy metals (Pb, Cd, Hg) were evaluated. Results showed that floodwaters exhibited higher contamination levels across most parameters, especially sulfate (SO_4^{2-}), chloride (Cl^-), COD, and turbidity, compared to rainwater. While rainwater demonstrated relatively better quality, it still contained detectable levels of pollutants such as lead and nitrate, likely from atmospheric deposition. These findings underscore the need for regular water quality monitoring, effective watershed management, and community sensitization to mitigate health and ecological risks in the region.

Keywords: *Physio-Chemical, Floodwater, Rainwater, Contaminats, Anthropogenic,*

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I. Introduction

Water is a fundamental natural resource, essential for sustaining life, supporting ecosystems and enabling socio-economic development. Globally, water quality and accessibility have become pressing environmental and public health concerns, particularly in regions prone to extreme weather events, pollution, and rapid urbanization (Perry & Vanderklein, 2019). In coastal and flood-prone areas like Wilberforce Island in Bayelsa State, Nigeria, the quality of available water sources especially floodwater and rainwater is increasingly affected by both natural and anthropogenic factors, including climate change, land use practices, and inadequate waste management.

Wilberforce Island, home to the Niger Delta University and several surrounding communities such as Amassoma and Agudama-Ekpetiama, is situated within the humid tropical belt of southern Nigeria. It experiences heavy rainfall and seasonal flooding from April to October each year, which significantly impacts both surface and groundwater resources. Floodwaters can introduce various pollutants into water bodies, including agricultural runoff, industrial waste, and domestic sewage (Ibe, 2016). Rainwater, traditionally perceived as a cleaner alternative, can also become contaminated by atmospheric pollutants such as heavy metals, nitrogen oxides, and sulfur dioxide (McGregor *et al.,* 2021). These contaminants may affect the water's physio-chemical characteristics and its suitability for consumption and agricultural use.

The physio-chemical status of water refers to its physical and chemical attributes, including parameters such as pH, electrical conductivity, turbidity, temperature, total dissolved solids (TDS), and concentrations of various ions and metals like nitrate, chloride, sulfate, lead, and cadmium. These indicators not only reflect the aesthetic and functional quality of water but also determine its impact on human health and the environment (WHO, 2017). For example, elevated levels of nitrates and heavy metals can lead to severe health conditions such as methemoglobinemia and neurological disorders, especially in vulnerable populations like children and the elderly (ATSDR, 2020; WHO, 2021).

In recent years, the Niger Delta region has experienced intensified rainfall patterns and more frequent flooding events trends linked to global climate change. These phenomena exacerbate existing water quality issues by increasing the potential for contamination and reducing the effectiveness of natural purification processes (Miklos *et al.,* 2017). Furthermore, population growth and poor waste disposal practices in the area contribute to the degradation of water sources, compounding the risks associated with waterborne diseases and environmental damage (Adekola, 2013; Adjovu *et al.*, 2023).

Despite the critical role of water in sustaining livelihoods on Wilberforce Island, limited empirical data exist on the comparative quality of floodwater and rainwater in the region. This data gap hinders evidence-based water management strategies and public health interventions. Consequently, there is a need for systematic monitoring and assessment of the physio-chemical parameters of these water sources to evaluate their safety and usability.

This study, therefore, aims to assess the physio-chemical status of flood and rainwater in Wilberforce Island by analyzing various water quality indicators using standardized laboratory methods. The findings will be compared with World Health Organization (WHO) and Food and Agriculture Organization (FAO) guidelines to determine the suitability of these water sources for drinking and irrigation. This research is critical not only for protecting public health but also for informing policy decisions and environmental management practices in flood-prone regions.

II. Materials And Methods

Materials

1. Multi-functional Water Quality Tester. Model Number: P-3
2. Beaker
3. Vision Scientific Drying Ovum (model: LDO - 20Y-E, Japan)
4. Desiccator
5. Whatman filter paper
6. 1 litre Volumetric flask
7. 500ml round bottomed flask
8. Test tubes
9. 1 litre plastic bottles
10. Top Weighing Balance: M311L (M-METLAR)

Chemicals and Reagents

i. Rain Water
ii. Flood Water
iii. To prepare the indicator solution, 5g of potassium chromate was dissolved in deionized water and the final volume was adjusted to 100mL, yielding a 5% concentration.
0.01M $AgNO_3$ Solution. This was prepared by dissolving 17g of $AgNO_3$ crystals in $1dm^3$ of distilled deionized water
iv. Calcium carbonate powder
v. Spectrophotometer
vi. Gelatin
vii. Barium chloride dihydrate
viii. Gelatin-Barium chloride Reagent: This was prepared by dissolving 0.6g of gelantin in 200ml of distilled water at 65^oC, it was kept in the refrigerator for 16 hours. After this period, it was brought to room temperature and 2g of $BaCl_2$ was added and mixed properly.
ix. Standard Sulphate stock solution (100ppm) prepared by dissolving 0.5344g of Potassium Sulphate per dm^3 of water from which the working standard was prepared.
x. 4M NaOH prepared by dissolving 160g of NaOH in $1dm^3$ of water
xi. 5% Salicylic acid in 95ml of conc. H2SO4
xii. Potassium nitrate standard solution: 0.722g of dry potassium nitrate crystals were dissolved in water and made up to $1dm^3$ in a volumetric flask. This is equivalent to 100ppm stock solution. Working standards of 0, 2, 4, 6, 8 and 10 were prepared from this stock.
xiii. Mercuric Sulphate
xiv. Silver Sulphate
xv. Conc. Sulphuric acid
xvi. 0.125m potassium dichromate ($K_2Cr_2O_7$) solution was prepared by dissolving 12.259g of the compound in distilled water and diluting to a final volume of 1 liter.
xvii. 0.125M $FeSO_4(NH_4)_2SO_4·6H_2O$ solution was obtained by first dissolving 49g of the salt in distilled water, then adding 20 milliliters of concentrated sulfuric acid before volumetric dilution to 1000mL.
xviii. To prepare the buffer system, 40g of sodium borate (borax) was dissolved in 800mL distilled water. In parallel, 10g sodium hydroxide and 5g sodium sulfide were dissolved in 100mL distilled water, after which both solutions were mixed.
xix. The two solutions were allowed to cool before they were mixed. The mixtures were made to 1 litre mark with distilled water.
xx. Sodium cyanide as masking agent.
xxi. To prepare the calcium solution, 1.0 g of $CaCO_3$ was placed in an Erlenmeyer flask and dissolved by slowly adding a 1:1 HCl solution. Once fully dissolved, the mixture was transferred to a 1L volumetric flask and made up to volume with distilled water.

xxii. To prepare the indicator, 0.5g of Eriochrome Black T was dissolved in a 3:1 (v/v) mixture of triethanolamine and methylated alcohol.

xxiii. EDTA Solution: 3.723g of disodium ethylene-diamine tetra acetic acid dehydrate was weighed and Dissolved in 1 litre volumetric flask with distilled water. This was standardized against standard calcium solution.

xxiv. 0.02M HCl: This was prepared by dissolving 8.3ml conc. HCl in 1 litre of distilled water.

xxv. Methyl orange indicator: The preparation involved dissolving exactly 0.05 grams of methyl orange in 100 mL of specially prepared distilled water (free from carbon dioxide).

xxvi. 0.0125M $Ba(OH)_2$: This was prepared by dissolving 3.994g hydrated $Ba(OH)_2$ in 1 litre distilled water which was boiled and cooled. It was shaken well to ensure that all the crystals Dissolved. It was allowed to stand for 2 days to allow all the $Ba(OH)_2$ to precipitate. The clear solution was standardized against a standard 0.025M HCl using phenolphthalein indicator.

xxvii. Mixed indicator: To prepare the mixed indicator solution:

0.10 grams of thymol blue was dissolved in 100 milliliters of 50% ethanol,

0.10 grams of phenolphthalein was dissolved in a separate 100 mL portion of 50% ethanol, The two solutions were mixed in a 1:3 volumetric ratio (thymol blue:phenolphthalein).

Methods

SAMPLING

WATER SAMPLES

For metal analysis, samples were collected in pre-cleaned 1-liter wide-mouth plastic bottles that had been acid-washed with 1:1 hydrochloric acid. Prior to filling, each bottle was rinsed three times with the sample water.

The samples were then preserved with 5ml of conc. HNO_3 per litre an kept in the refrigerator prior to analysis (George *et al*., 1985).

Physicochemical parameter analysis utilized 2-liter pre-washed plastic bottles with double caps. Field measurements included temperature and color, while conductivity, pH and dissolved oxygen were analyzed immediately upon laboratory arrival. Remaining samples were preserved according to George *et al*., (1985) methods and refrigerated. Microbiological samples were processed within one hour of collection following Ademoroti (1996) protocols.

PHYSIO-CHEMICAL ANALYSIS

(I) Determination of Temperature

The temperature was determined in situ at the site using multi-functional water quality tester (pH meter). The thermometer was placed vertically in the sample with the bulb fully suspended in it.

Temperature readings were taken only after allowing sufficient time for stabilization, ensuring accurate measurement of the equilibrium temperature.

(ii) Determination of pH

Prior to sample analysis, the pH meter was calibrated using standard buffer solutions at pH 4 and 9. Water sample pH values were then measured by immersing the electrode in each sample and recording the stabilized reading after equilibration.

(iii) Determination of Electrical Conductivity

After homogenizing the samples, an aliquot was transferred to the instrument's sample chamber. The measurement button was promptly engaged, and the resultant values were documented for each sample.

(iv) Determination of Total Solids, Dissolved Solids and Suspended Solids

The parameters were determined using the AOAC Methods of analysis (1984)

Total Solid

The water sample was thoroughly shaken and a 50 mL aliquot of unfiltered sample was precisely measured into a pre-weighed evaporation dish. The dish was placed in a drying oven at 150°C, subsequently cooled in a desiccator and weighed. This cycle of drying, cooling and analytical weighing was repeated until constant mass was achieved.

The total solid is expressed as:

$$\text{Total solid (mg/l)} = \frac{\text{mg total solid} \times 1000}{\text{ml of sample}}$$

(b) Total Dissolved Solids

Following filtration with Whatman filter paper, precisely 50 mL of filtered sample was placed in a tared evaporation dish. After complete evaporation at 150°C, the total dissolved solids were determined gravimetrically using the formula:

$$\text{Total dissolved solid (mg/l)} = \frac{\text{mg total dissolved solid x 1000}}{\text{ml of filters taken}}$$

(c) Total Suspended Solid

This was obtain by difference

Total suspended solid (mg/l) = Total solid - Total Dissolved solid

(v) Determination of Chloride

The Mohr method as described by AOAC (1984) was used

(a) A 5% w/v potassium chromate (K_2CrO_4) indicator solution was prepared by dissolving 5.00 grams of the salt in deionized water, followed by dilution to a final volume of 100.0 mL in a volumetric flask..

(b) 0.01M $AgNO_3$ Solution. This was prepared by dissolving 17g of $AgNO^3$ crystals in $1dm^3$ of distilled deionized water

(c) Calcium carbonate powder

Procedure

50mL t of the sample was transferred to a conical flask, followed by addition of a small quantity (approximately 0.1 g) of calcium carbonate powder. After adding 2 mL of potassium chromate indicator, the solution was titrated with standardized silver nitrate ($AgNO_3$) solution until the appearance of a persistent reddish-brown endpoint (Ag_2CrO_4 precipitate).

A blank titration was equally carried out by substituting the sample with deionized water.

$$Ag+ \quad + Cl \longrightarrow AgCl$$

$$2Ag+ \quad + CrO_4^{2-} \longrightarrow Ag_2CrO_4$$

The Chloride content was expressed as:

$$Cl^- \text{ (mg/l)} = \frac{\text{(A - B) x M x 70, 900}}{\text{ml of sample}}$$

Where A = ml of $AgNO_3$ for sample

B = ml of $AgNO_3$ for blank

M = molarity of $AgNO_3$

(vi) Determination of Sulphate

The turbidimetric analysis followed the established procedures of Jackson (1964) and Tabatabai (1974), employing barium chloride ($BaCl_2$) as the precipitating agent for sulfate determination.

Reagents and Materials

(a) Spectrophotometer

(b) Gelatin

(c) Barium Chloride dehydrate

(d) Gelatin - Barium Chloride reagent: This was prepared by dissolving 0.6g of gelatin in 200ml of distilled water at $65^{O}C$, it was kept in the refrigerator for 16 hours. After this period, it was brought to room temperature and 2g of $BaCl_2$ was added and mixed properly.

(e) Standard Sulphate stock solution (100ppm) prepared by dissolving 0.5344g of Potassium Sulphate per dm^3 of water from which the working standard was prepared.

Procedure

A 50 mL sample was transferred to a 250 mL volumetric flask, diluted with 50 mL of distilled water and treated with 1.0 mL of gelatin-$BaCl_2$ reagent. The solution was then brought to the 250 mL mark with deionized water.

The prepared mixture was allowed to stand for 30 minutes to allow complete precipitation and stabilization of the barium sulfate suspension The **optical density (turbidity)** was then measured at **420 nm** using a spectrophotometer.

Calculation

$$SO_4^{2-} \text{ (mg/l)} = \frac{\text{mass of } SO_4^{2-} \text{ from curve x 1 000 x D}}{\text{ml of sample}}$$

Where D is dilution factor.

(vii) Determination of Nitrate

Nitrate concentration was determined spectrophotometrically using a calibrated colorimeter, measuring absorbance of the sample at the characteristic wavelength for nitrate complexes.

Reagents and Materials

(viii) 4M NaOH prepared by dissolving 160g of NaOH in $1dm^3$ of water

(ix) 5% Salicylic acid in 95ml of conc. H_2SO_4

(xi) Potassium nitrate standard solution: 0.722g of dry potassium nitrate crystals were dissolved in water and made up to $1dm_3$ in a volumetric flask. This is equivalent to 100ppm stock solution. Working standards of 0, 2, 4, 6, 8 and 10 were prepared from this stock.

Procedure

Using a calibrated micropipette, 0.5 mL of each standard and sample was transferred to individual test tubes. Each tube received 1.0 mL of salicylic acid solution, followed by thorough mixing and a 30-minute reaction period. Subsequently, 10 mL of sodium hydroxide solution was added to develop the colored complex. After complete color formation, absorbance measurements were taken at 410 nm.

$$NO_3 \text{ -- } N\ (mg/l) = \frac{uN \text{ from Curve x Dilution factor x } 1\,000}{ml \text{ of sample}}$$

(viii) Determination of Dissolved Oxygen

The alkaline - azide modification of Winkler's method was used.
The reagents were already contained in the DO kit.

Procedure

The sample was poured into the DO bottle almost to the neck of the bottle. Then 5 drops of $MnSO_4$ solution followed by 5 drops of alkaline azide solution were added, corked and shake vigorously for some minutes. The cork was removed and 10 drops of conc. H_2SO_4 were added and shaken vigorously again. The cork was again removed and 5ml of the mixture was poured into the DO tank. The tank was covered and 3 to 4 drops of starch iodide solution were added to it.

This was then gently shaken. With the aid of titrator (a syringe - like graduated tube), a known volume of $Na_2S_2O_3.5H_2O$ was withdrawn and added gradually to the DO tank with shaking until the blue black colouration was discharged from the solution. The volume of the sulphate used was noted. This was used to calculate the DO.

$DO\ (g/liter\ O_2) = VNa_2S_2O_3.5H_2O \text{ x } 10$

(ix) Biochemical Oxygen Demand

The biochemical oxygen demand was quantified by measuring the dissolved oxygen concentration in water samples both before and after a 5-day incubation period in complete darkness at 20°C.

$$BOD\ (mg/l) = \frac{DOo - DOd \text{ x volume of BOD bottle}}{Ml \text{ of sample used}}$$

DO_0 represents the initial dissolved oxygen concentration measured in the sample on day 0,

DO_5 d represents the final dissolved oxygen level determined through titration after the 5-day incubation period.

(x) Determination of Chemical Oxygen Demand

The titrimetry method was used for the COD determination (Dbbs *et al.*, 1963, APHA 1965)

Reagents and Materials

(a) Mercuric Sulphate
(b) Silver Sulphate
(c) Conc. Sulphuric acid
(d) 0.125M $K_2Cr_2O_7$ solution was prepared by dissolving precisely 12.259 grams of the anhydrous salt in distilled water, then making up to a final volume of 1.000 liter.
(xvi) The standard solution was prepared by:

1. Dissolving 49.0 g ferrous ammonium sulfate hexahydrate in distilled water
2. Adding 20.0 mL concentrated H_2SO_4 (96-98%)
3. Diluting to 1000 mL final volume

Procedure

A measured portion of sample was diluted to 50 mL and placed in a 500 mL round-bottom flask. To this, 25 mL of standard $K_2Cr_2O_7$ solution was added, followed by 1 g $HgSO_4$ and 5 mL concentrated H_2SO_4. After gentle swirling to dissolve the mercuric sulfate, 70 mL concentrated H_2SO_4 and 0.75 g Ag_2SO_4 were introduced along with porcelain chips to prevent bumping during reflux.

The reaction flask was attached to a reflux condenser and heated continuously for 2 hours using a Gallenkamp heating mantle, maintaining steady boiling throughout the digestion period.

After 2 hours, the mixture was cooled and diluted with distilled water with the condenser washed in the flask 5 drops of ferroin indicator were added to the cooled mixture, which was then titrated with standardized ferrous ammonium sulfate (FAS) solution until the endpoint was reached

A blank titration was carried out in a similar manner.

$$\text{COD (mg/l)} = \frac{(Vb - Vs) \text{ x } M \text{ x } 16\,000}{\text{ml of sample}}$$

Where Vb = ml of FAS used for blank
Vs = ml of FAS used for sample
M = molarity of FAS

(xi) Hardness

The analysis was performed following the titrimetric procedures outlined in AOAC (1990) and Ademoroti (1996b) standard methods.

Reagents and Materials

(a) The buffer solution was prepared by first dissolving 40g of sodium borate decahydrate ($Na_2B_4O_7 \cdot 10H_2O$) in 800 mL of distilled water. Separately, a solution containing 10g sodium hydroxide and 5g sodium sulfide was prepared in 100 mL distilled water, which was then combined with the borax solution.

The two solutions were allowed to cool before they were mixed. The mixtures were made to 1 liter mark with distilled water.

(b) Sodium cyanide as masking agent.

(c) Calcium Solution; 1g of $CaCO_3$ was weighed into an Erlenmeyer flask. This was dissolved by adding 1:1 HCl gradually until all the $CaCO_3$ was dissolved. This was transferred qualitatively to 1 litre volumetric flask an filled to the mark with distilled water.

(d) The indicator solution was prepared by dissolving 0.50 grams of Eriochrome Black T powder in a solvent mixture composed of 75% (v/v) triethanolamine and 25% (v/v) methylated spirit.

(e) A standard EDTA solution was prepared by dissolving 3.723g of disodium EDTA dihydrate ($Na_2H_2Y \cdot 2H_2O$) in distilled water and diluting to the 1-liter mark in a volumetric flask. The solution was then standardized against a certified calcium carbonate reference standard.

Procedure

A 50.00 mL water sample was measured into a conical flask. Then, 4.00 mL of ammonium chloride-ammonia buffer (pH 10) and 4 drops of Eriochrome Black T indicator were added. Following the addition of a small quantity (~0.1 g) of sodium cyanide (as a masking agent), the solution was titrated with standardized EDTA (0.01 M) until the endpoint was reached, indicated by the disappearance of the final reddish hue (transition to pure blue).

$$\text{(a) Total Hardness (mg/}CaCO_3\text{)} = \frac{V \text{ x } A \text{ x } 1000}{\text{ml of sample}}$$

Where V = ml of titration of sample
A = mg $CaCO_3$ equivalent to 1ml EDTA titrant

(b) Hardness due to Calcium Ion

Procedure

For calcium determination, 50 mL of water sample was treated with 2 mL of 1 M sodium hydroxide solution and a small amount of murexide-NaCl indicator. The resulting pink solution was titrated with 0.01 M EDTA until a permanent purple endpoint was observed. Calcium concentration (as Ca^{2+} mg/L) was calculated from the titrant volume, while magnesium concentration was determined by subtracting the calcium hardness from the total hardness (previously measured at pH 10).

$$\text{Hardness due to } Ca^{2+} = \frac{VCa^{2+} \times A \times 1000}{\text{ml of sample}}$$

(c) Hardness due to Mg^{2+} = Total hardness - hardness due to Ca^{2+}

(xii) Total Alkalinity

This was determined by titrimetric method (AOAC, 1990).

Reagents and Materials

(a) 0.02M HCl: This was prepared by dissolving 8.3ml conc. HCl in 1 litre of distilled water.

(b) A methyl orange indicator solution (0.05% w/v) was prepared by dissolving 50.0 mg of the sodium salt of methyl orange ($C_{14}H_{14}N_3NaO_3S$) in 100 mL of carbon dioxide-free distilled water that had been freshly boiled and cooled under nitrogen atmosphere.

Procedure

A 50 mL water sample was treated with 2 drops of methyl orange indicator (0.05% w/v) and titrated with 0.02 M hydrochloric acid standard solution. The endpoint was identified as the first permanent color transition from yellow (alkaline form) to orange-red (acidic form, pH ≈ 3.1-4.4).

$$\text{Total Alkalinity} = \frac{V \times M \times 100000}{\text{ml of sample}}$$

Where V = titer value of acid used

M = molarity of acid

(xiii) Acidity

This was also determined titrimetrically as described by AOAC (1990) and Ademoroti (1996b).

Reagents and Materials

(a) 0.0125M $Ba(OH)_2$: This was prepared by dissolving 3.994g hydrated $Ba(OH)_2$ in 1 litre distilled water which was boiled and cooled. It was shaken well to ensure that all the crystals Dissolved. It was allowed to stand for 2 days to allow all the $Ba(OH)_2$ to precipitate. The clear solution was standardized against a standard 0.025M HCl using phenolphthalein indicator.

(b) The composite indicator was prepared by first dissolving 0.10 g thymol blue in 100 mL of 50% ethanol, followed by separate dissolution of 0.10 g phenolphthalein in another 100 mL of 50% ethanol. These stock solutions were then combined in a 1:3 volume ratio (thymol blue:phenolphthalein) to create the final mixed indicator.

Procedure

A 50 mL water sample was treated with one drop of the thymol blue-phenolphthalein mixed indicator (1:3 ratio) and titrated with 0.0125 M barium hydroxide solution until the appearance of a permanent red-violet endpoint, indicating complete neutralization of acidic components.

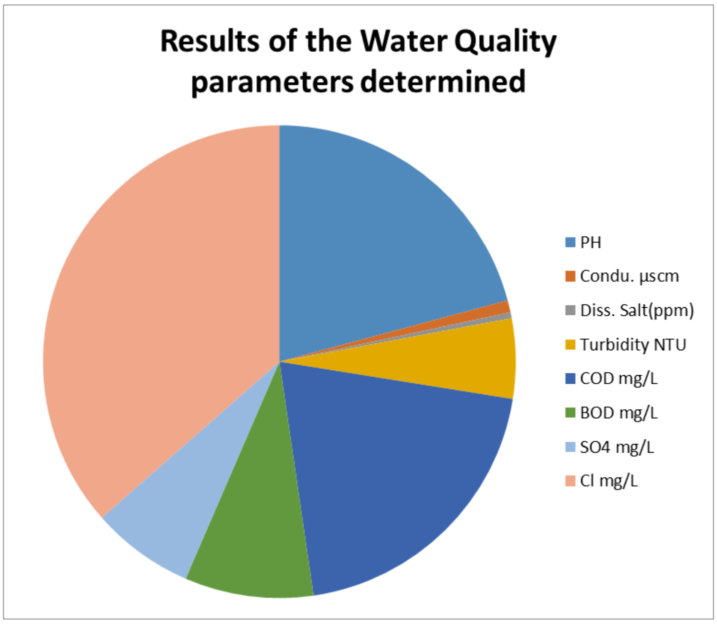
$$\text{Acidity (mg/l } CaCO_3) = \frac{V \times M \times 100000}{\text{ml of sample}}$$

III. Results

Physiochemical properties

Table1. Results of the Water Quality parameters determined

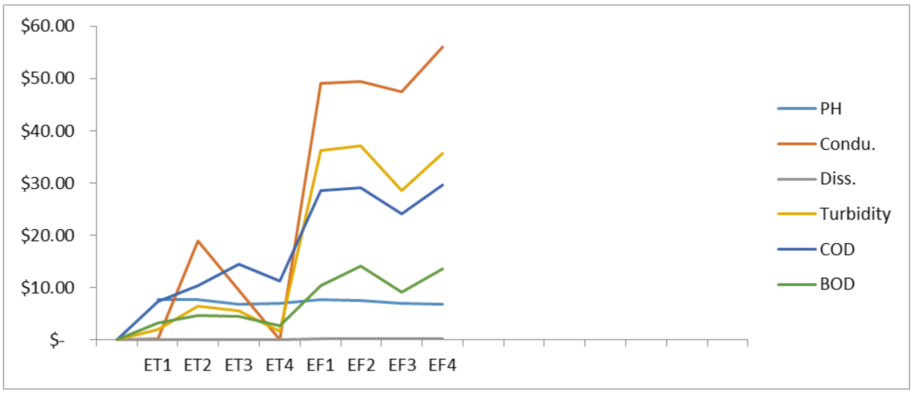
Samples	P^H	Condu. µscm	Diss. Salt(ppm)	Turbidity NTU	COD mg/L	BOD mg/L	SO_4 mg/L	Cl mg/L
ET1	7.69	0.305	0.15	2.02	7.45	3.25	2.60	13.47
ET2	7.77	19.00	0.06	6.56	10.36	4.64	5.22	21.27
ET3	6.86	9.50	0.04	5.64	14.50	4.55	4.88	16.31
ET4	7.06	0.02	0.01	1.78	11.33	2.75	1.59	27.65
EF1	7.73	49.00	0.24	36.33	28.56	10.33	15.22	35.45
EF2	7.63	49.50	0.25	37.12	29.13	14.11	21.35	27.65
EF3	7.07	47.54	0.23	28.54	24.16	9.23	1678	39.70
EF4	6.86	56.01	0.24	35.63	29.68	13.56	12.55	38.12



The results above are means value for P^H, electrical conductivity, Dissolve salt, turbidity, COD, BOD, SO_4, and Cl in rain and Flood water from Bayelsa State in 2023-2024. These results depend on factors like; site location, the intensity of rainfall, activities on the site and surrounding environment. Chemical Oxygen Demand= mg/L, Biochemical oxygen demands= mg/L, Turbidity= NYU (Nephelometric Turbidity units)

Table 2. Results of sum

Samples	Pb	Cd	Hg	Ca	K	Na
ET1	0.0053 ±0.001	0.0001 ±0.001	0.0001 ±0.001	3.4565 ±0.023	1.4093 ±0.037	3.2085 ±0.022
ET2	0.0015 ±0.001	0.0001 ±0.001	0.0001 ±0.001	3.6434 ±0.031	1.2875 ±0.025	4.1324 ±0.018
ET3	0.0001 ±0.001	0.0001 ±0.001	0.0001 ±0.001	2.7435 ±0.017	1.1766 ±0.021	2.1054 ±0.015
ET4	0.0001 ±0.001	0.0001 ±0.001	0.0001 ±0.001	3.2085 ±0.025	0.9185 ±0.031	2.1827 ±0.022
EF1	0.0032 ±0.001	0.0001 ±0.001	0.0001 ±0.001	3.6189 ±0.025	1.5997 ±0.026	4.1398 ±0.023
EF2	0.0051 ±0.001	0.0001 ±0.001	0.0001 ±0.001	2.0698 ±0.033	1.7178 ±0.024	4.2627 ±0.025
EF3	0.0001 ±0.001	0.0001 ±0.001	0.0001 ±0.001	2.3848 ±0.032	1.0182 ±0.011	3.1783 ±0.016
EF4	0.0001 ±0.001	0.0001 ±0.001	0.0001 ±0.001	2.8086 ±0.036	1.4093 ±0.021	3.0913 ±0.032



% /w - Percentage weight by weight
BLD - Below detected.
mg/l - Milligram per Kilogram
µg/kg - Microgram per kilogram
ppm - part per million

IV. Discussion

The analysis of water quality parameters in the given samples reveals significant variations, highlighting the diversity of water sources or potential contamination levels. Below is an extensive discussion of each parameter, comparing the findings with results from other scientific studies.

The measured pH values (6.86-7.77) across sampling sites indicated near-neutral to slightly acidic water conditions, falling within WHO's acceptable drinking water range (6.5-8.5). Notably, samples ET3 and EF4 exhibited marginally lower pH (6.86), potentially reflecting impacts from acid deposition or industrial effluents. These findings align with Aremu *et al*.,'s (2020) Nigerian study documenting similar pH depression in agricultural runoff-affected waters, possibly attributable to organic acid leaching from soils. Conductivity, which reflects ionic content, showed considerable variation, with values ranging from 0.02 µS/cm in ET4 to 56.01 µS/cm in EF4. Samples from the EF series exhibited notably higher conductivity, suggesting contamination from industrial effluents or domestic runoff, which often introduce dissolved salts and ions (Bohdziewicz *et al.,* 2021). These findings are consistent with research by Adekunle *et al*., (2019), where water bodies near industrial zones recorded conductivity values exceeding 50 µS/cm, correlating with high levels of dissolved solids.

Dissolved salt concentrations were highest in EF2 and EF4 (0.25 ppm and 0.24 ppm, respectively), while ET4 had the lowest value (0.01 ppm). These differences could stem from varying degrees of evaporation and saltwater intrusion. According to Olayemi *et al*., (2021), salt intrusion in coastal areas significantly raises salinity, as seen in their study in the Niger Delta, where salt levels reached up to 0.3 ppm in brackish water.

Turbidity values ranged from 1.78 NTU in ET4 to 37.12 NTU in EF2. High turbidity in EF samples likely results from suspended particles or organic matter, potentially indicating poor water treatment or surface runoff contamination (Chapra, 2018). Comparatively, Idowu *et al*., (2020) found turbidity levels of 25-40 NTU in streams receiving agricultural runoff, aligning with the EF samples in this study. COD, a measure of organic and inorganic pollutants, was highest in EF2 (29.13 mg/L) and lowest in ET1 (7.45 mg/L). High COD in EF samples suggests greater pollution loads, likely from urban or industrial discharges. These findings align with a study by Singh and Gupta (2019), which reported COD values exceeding 25 mg/L in industrial zones. The BOD values ranged from 2.75 mg/L in ET4 to 14.11 mg/L in EF2. The increased biochemical oxygen demand (BOD) measurements in EF samples suggest significant organic contamination, potentially from untreated wastewater or decomposing organic matter. These findings align with Adeyemi *et al*., (2018), who documented comparable BOD elevations (10-15 mg/L) in urban aquatic systems receiving substantial pollution inputs. The sulfate concentrations in EF3 (1678 mg/L) were significantly higher than in other samples, which ranged from 1.59 to 21.35 mg/L. Elevated sulfate levels in EF3 could result from industrial discharges, as reported in studies by Johnson *et al*., (2020), which identified sulfate levels above 1500 mg/L near mining areas. High sulfate concentrations can lead to laxative effects in humans and are a concern for water quality (WHO, 2017).

Chloride concentrations ranged from 13.47 mg/L in ET1 to 39.70 mg/L in EF3. Elevated chloride levels in EF samples could indicate contamination from saline intrusion or industrial effluents, consistent with findings by Olatunji *et al*., (2019), who observed chloride levels exceeding 30 mg/L in water sources affected by saltwater intrusion.

The trends observed in this analysis are consistent with findings from other studies in similar ecological zones. For instance, high conductivity, turbidity, and BOD levels in the EF samples echo patterns observed in polluted water bodies in urban-industrial areas (Adekunle *et al.*, 2019; Singh & Gupta, 2019). The elevated sulfate levels in EF3 are particularly alarming, as similar levels have been linked to industrial contamination (Johnson *et al.*, 2020). Conversely, the ET samples generally exhibited better water quality, likely reflecting less exposure to anthropogenic influences. The analysis reveals significant variability in water quality parameters across the samples, with EF samples generally showing higher contamination levels. These results emphasize the critical necessity for enhanced water quality management and stricter pollution mitigation measures, especially in industrialized zones. The consistent correlation with findings from comparable studies reinforces the validity of these observations, demonstrating recurrent contamination trends in similar environmental contexts. Future research should focus on identifying specific pollution sources and implementing targeted mitigation strategies.

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