ASSESSMENT OF THE IMPACT OF INCREASED HYDROCARBON RECOVERY ACTIVITIES ON SURFACE WATER QUALITY IN A BRACKISH COASTAL ENVIRONMENT

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Abstract: This study investigated the impact of hydrocarbon recovery project activities on the surface water quality of a brackish coastal environment. Water samples were collected during both the dry and wet seasons, and physico-chemical characteristics were analyzed. Results showed that pH values ranged from 5.52 to 7.69, with more acidic values during the dry season. Conductivity and salinity values were normal for this ecosystem, ranging from 1.10 to 10.03 MS/CM and 150.3 to 3553.90 mg/l, respectively. Dissolved oxygen (DO) levels ranged from 2.5 to 6.41 mg/l during the dry season and 5.2 to 7.6 mg/l during the wet season. Biochemical oxygen demand (BOD) levels ranged from 26.70 to 110.60 mg/l during the dry season and 2.9 to 4.4 mg/l during the wet season, indicating higher eutrophication during the dry season. Turbidity, total solids, and total suspended solids levels were higher during the wet season. Nutrient and heavy metal levels were generally low, consistent with the ecosystem. Total hydrocarbon (THC) levels ranged from 0.01 to 79.42 mg/l, with the highest value recorded in one sampling location around the wellhead areas during the dry season. Overall, this study found that hydrocarbon recovery project activities had minimal impact on the surface water quality of the brackish coastal environment, but it is important to continue monitoring to ensure that it remains at acceptable levels.

Keywords: Hydrocarbon Recovery, Surface Water Quality, Brackish Coastal Environment, Physico-Chemical Characteristics, Eutrophication

Introduction

Hydrocarbon recovery projects have been known to have significant environmental impacts, including water pollution. The surface water quality of the brackish coastal environment is of particular concern due to its sensitivity to pollution. The aim of this study was to assess the effects of increased hydrocarbon recovery project activities on surface water quality in this ecosystem.

Surface water quality is an important aspect of environmental management, particularly in areas where anthropogenic activities may impact water resources (Battaglin et al., 2016). The hydrocarbon recovery industry is one such activity that has the potential to impact surface water quality, particularly in coastal environments where water bodies are connected to the sea and are often sensitive to environmental changes (Khopkar et al., 2013).

The increase in demand for hydrocarbon energy sources has led to an increase in hydrocarbon recovery project activities globally. These activities can have significant impacts on the environment, including surface water quality. Surface water is a vital resource for various uses, such as irrigation, fishing, and domestic use, among others. Therefore, maintaining its quality is crucial for the well-being of the ecosystem and human health.

Several studies have been conducted to evaluate the impact of hydrocarbon activities on surface water quality. For instance, Inyang and Onyedikachi (2019) investigated the effect of oil exploration on the water quality of Imo River, Nigeria. Similarly, Al-Baldawi et al. (2020) assessed the impact of oil spills on the water quality of Shatt al-Arab River, Iraq. These studies found that hydrocarbon activities significantly affect water quality, leading to increased pollution levels.

Previous studies have shown that hydrocarbon recovery projects can have significant impacts on the environment, including surface water quality (e.g. Al-Baldawi et al., 2017; Hu et al., 2018; Lee et al., 2019). Surface water is an important natural resource that provides many ecosystem services, including drinking water, irrigation, and aquatic habitats for a variety of organisms (Dodds and Oakes, 2004; Carpenter et al., 2005). However, the extraction, processing, and transportation of hydrocarbons can lead to various forms of pollution, including spills, leaks, and runoff from drilling sites (Yuan et al., 2017). This can result in changes in water chemistry, reduced dissolved oxygen levels, increased turbidity, and accumulation of contaminants such as heavy metals and hydrocarbons in the sediments and biota (Sengupta, 2013; Yebra et al., 2016; Hu et al., 2018).

In the context of brackish coastal environments, which are characterized by the mixing of freshwater and seawater, these impacts can be especially concerning. Brackish water systems are important habitats for many species of fish, birds, and other wildlife, and are also used for aquaculture and other human activities (Kjerfve, 1994; Kjerfve et al., 2001). However, they are often sensitive to changes in water quality due to their unique physical, chemical, and biological characteristics (Valiela et al., 2000; Mazumder, 2007).

Furthermore, studies have reported the impact of hydrocarbon activities on surface water quality in other regions, such as the Niger Delta in Nigeria (Ejelonu et al., 2018; Onwurah et al., 2020), the Gulf of Mexico in the United States (Patzert et al., 2016), and the Caspian Sea in Iran (Hedayati et al., 2019). These studies have highlighted the need for regular monitoring of surface water quality to ensure the sustainability of these ecosystems.

However, there is limited research on the impact of hydrocarbon activities on the surface water quality of brackish coastal

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642

environments. The present study aims to fill this gap by investigating the impact of hydrocarbon recovery project activities on the surface water quality of a brackish coastal environment. The study area is of particular interest because of the proximity of hydrocarbon activities to the coastal environment and the potential impact on the ecosystem.

Therefore, it is important to investigate the potential impacts of hydrocarbon recovery projects on the water quality of brackish coastal environments. This study aims to contribute to this knowledge gap by examining the physico-chemical characteristics of surface water in a brackish coastal environment affected by hydrocarbon recovery project activities. The findings of this study could have implications for the management and regulation of hydrocarbon recovery projects in similar environments around the globe.

In this study, we investigated the impact of increased hydrocarbon recovery project activities on the surface water quality of a brackish coastal environment. Brackish coastal ecosystems are unique and complex, characterized by a mixture of fresh and saltwater. They are also vulnerable to pollution from anthropogenic activities, such as hydrocarbon activities. Therefore, it is essential to evaluate the impact of these activities on the water quality of such ecosystems.

The main objective of this study was to determine the physico-chemical characteristics of surface water in the study area and evaluate the impact of hydrocarbon recovery project activities on water quality. We collected water samples during both the dry and wet seasons and analyzed various physico-chemical parameters. The results of this study will provide insights into the impact of hydrocarbon activities on surface water quality in brackish coastal ecosystems.

In conclusion, this study is of significant importance as it contributes to the body of knowledge on the impact of hydrocarbon recovery project activities on surface water quality in a brackish coastal environment. The results of this study will be useful to policymakers, hydrocarbon industries, and other stakeholders in formulating strategies to mitigate the adverse effects of these activities on the environment.

Materials and Methods
Table 1 shows the Principle of Methodology and Major Equipment used for Chemical Analysis of Water Samples in the study area.

Study area and Location
The study area (Figure 1) is situated in the tidal brackish wetland ecosystem of the western part of the Niger Delta in Delta State, Nigeria. The area falls under the jurisdiction of the Warri South West Local Government Area of Delta State, as depicted in Figure 2. The study site comprises numerous meandering creeks and creeklets with multiple dredge slots leading to wellhead areas. The predominant vegetation in the study area is mangrove swamps, with secondary freshwater vegetation type occurring around wellheads/slots areas.

The study area spans between Latitude 1180000N-190000N and Longitude 320000E – 335000E and is flanked and drained by Nana Creek to the west, Escravos River to the south, and Jones Creek to the north. The artificially deposited dredge spoil, a common peripheral feature of the dredge slot, causes an artificial topographical disturbance on the initially flat surface, which remains elevated above the varying tidal surface water levels permanently.
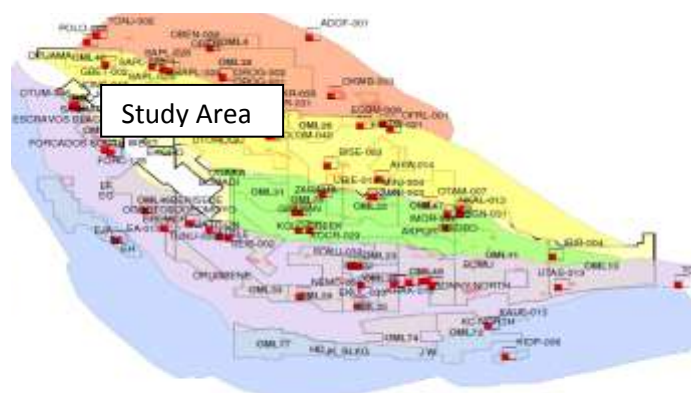

Figure 1 Location of the Study Area in the Niger Delta Depo Belt

Figure 2 Map of Delta State showing Warri South LGA.
(Igiekhume *et. al.*, 2021)

Aim and Objectives of study
The aim of the study is to investigate the potential impact of hydrocarbon recovery project activities on the surface water quality of the brackish coastal environment in the study area. The objective is to identify potential impacts, contribute to the development of measures to mitigate any adverse effects, and ensure that hydrocarbon extraction activities are conducted in an environmentally sustainable manner.

The specific objectives of this study are:
1. To determine the physicochemical properties of surface water in the Valz Creek study area.
2. To investigate the impact of hydrocarbon recovery project activities on surface water quality in the study area.
3. To identify the potential sources of pollutants in the study area and their contribution to surface water quality degradation.
4. To evaluate the effectiveness of existing measures for mitigating the impact of hydrocarbon recovery activities on surface water quality.
5. To recommend appropriate measures for the sustainable management of surface water quality in the "Valz" Creek study area.

Overall, the aim of this study is to contribute to the knowledge of the potential environmental impacts of hydrocarbon recovery activities on surface water quality in a brackish coastal ecosystem. By achieving the specific objectives, this study will

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643

provide useful information to guide the sustainable management of water resources in similar ecosystems.

Procedures for Field Work

Water samples were collected from the main water body, Valz Creek, and smaller creeklets in the field. The samples were collected using a 2-litre hydrobios water sampler. At each sampling location, five water samples were taken using the hydrobios sampler and combined to form a composite sample. Each composite sample was made up of five separate portions, which were collected and stored in appropriate containers for the analysis of (i) general physicochemical properties, (ii) heavy metals, (iii) total hydrocarbons, and (iv) in-situ measurements. This approach allowed for the collection of representative samples from each sampling location, which were then analyzed for different parameters of interest. The use of the hydrobios sampler ensured that the samples collected were not contaminated and were representative of the water body at the time of sampling. The analysis of the different parameters will provide valuable information on the water quality of Valz Creek and the surrounding creeklets, which will be useful in assessing the environmental impact of human activities in the area.

For the general physicochemical analysis, the samples were collected using clean plastic (polythene) bottles that had been rinsed with portions of the samples prior to collection. The samples were then packed into an ice chest and transported to the laboratory for analysis.

The samples for heavy metal analysis were collected into clean plastic containers that had also been rinsed with portions of the samples. To preserve the samples, each one was spiked with analar grade nitric acid to a pH of ≤ 2.0.

The samples for total hydrocarbon analysis were collected using clean glass bottles that had been pre-rinsed with portions of the samples. To preserve the samples, each one was spiked with a small amount of sulphuric acid to achieve a pH of ≤ 2.0. All the water samples were then packed into an ice chest and transported to the laboratory for analysis.

This careful collection and preservation process ensured that the samples remained uncontaminated and were representative of the water body at the time of sampling. The samples were then analyzed in the laboratory, providing valuable information on the physicochemical properties, heavy metal concentrations, and total hydrocarbon levels in the water body.

The use of different types of containers for the collection of samples was necessary to prevent contamination and ensure the accuracy of the analysis. The plastic containers used for general physicochemical analysis and heavy metal analysis were free from any contaminants and rinsed with the water samples before use. The addition of analar grade nitric acid as a preservative for the heavy metal samples was important to prevent any changes in the concentration of the metals during transportation and storage.

For the total hydrocarbon analysis, clean glass bottles were used to prevent any leaching of hydrocarbons from plastic containers, which can lead to false readings. The addition of a small amount of sulphuric acid to the samples helped to preserve them by reducing the pH and inhibiting microbial growth.

The samples were transported to the laboratory in an ice chest to maintain their integrity and prevent any changes in the physicochemical properties, heavy metal concentrations, or total hydrocarbon levels. The analysis of the samples will provide valuable information on the water quality of the Valz Creek and surrounding creeklets, and help to identify any potential environmental risks.

Overall, the careful collection and preservation of the water samples followed standard procedures to ensure the accuracy and reliability of the analysis, which will be used to assess the environmental impact of human activities in the study area.

In-Situ Measurements

In-situ measurements were determined for the following parameters;

Temperature	thermometers
pH	pH meter
Conductivity	Conductivity meter
Total Dissolved Solids (TDS)	TDS meter
Dissolved Oxygen (DO)	DO meter
Transparency	Secchi disc
Depth for small creeks	Graduated Hydrobios cord
Width of creeks	Using GPS (Global Positioning System)

Laboratory Analysis

The details of the various analyses are described below

pH (APHA 5400B/ASTM D1293B/API - RP45)

An ATI-Orion pH meter was used to measure pH of the water samples in-situ. The pH meter was calibrated with buffer solutions of 4.01, 7.00 and 10.01 pH units before and after measurement.

Temperature (APHA 2550B)

Temperature was determined in-situ using mercury filled Celsius thermometer.

Turbidity (APHA 214A)

Turbidity determination was done with the aid of a turbidity meter (turbidimetric method).

Total Dissolved Solids (APHA 2540C/ASTM D1868)

A well-mixed sample was filtered through standard glass-fibre filter and the filtrate was evaporated to dryness in a weighed dish and dried to constant weight at 180ºC. The increases in weight represent the total dissolved solids. The result was correlated with an Orion-TDS meter readings determined in-situ.

Conductivity (APHA 2520B/ASTM D1125)

Conductivity meter was used to determine electrical conductivity of the water samples. The meter was calibrated with a solution of 0.01M KCl having a conductance of 1413μS/cm at 25ºC.

Total Suspended Solids (APHA 2540D/ASTM D1868)

A thoroughly mixed sample was filtered through a weighed standard glass-fiber filter of 0.45μm pore size. The residue retained on the filter was dried to a constant weight at 103ºC-105ºC. The increase in weight of the filter represents the total suspended solids.

Dissolved Oxygen (APHA 4500)

Dissolved oxygen of the samples was determined in-situ using ATI-Orion DO meter which was calibrated with Winker's reagents A & B before and after determination.

Biochemical Oxygen Demand (APHA 507)

The method consists of filling an airtight bottle with sample to overflowing and incubating at 20ºC for 5 days. Dissolved oxygen is measured initially and after incubation and the BOD is computed from the difference between initial and final DO after allowance has been given for dilution. Initial DO was determined using an Orion DO meter for all the samples, dilution water, blanks and where appropriate, seed controls. All these samples were incubated in darkness for five days at 20ºC in an incubator using dark BOD bottles. Final DO was determined using DO meter.

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644

Calculation:

When dilution water is not seeded:-

$$BOD_5 \text{ (mg/l)} = \frac{D_1 - D_2}{p}$$

When dilution water is seeded:-

$$BOD_5 \text{ (mg/l)} = \frac{(D_1 - D_2) - (B_1 - B_2) f}{p}$$

Where:

D_1 = DO of diluted sample immediately after preparation (mg/l)

D_2 = DO of diluted sample after 5 days incubation at 20^oC (mg/l)

P = Decimal volumetric fraction of sample used

B_1 = DO of seed control before incubation (mg/l)

B_2 = DO of seed after incubation (mg/l)

f = Ratio of seed in diluted sample to seed in seed control, i.e.,

(% seed in diluted sample)/(% seed in seed control).

Chemical Oxygen Demand (APHA 5220B/ASTM D1252)

The open reflux method using the dichromate reflux method was used. Samples were refluxed in strongly acidic solution with excess potassium dichromate. After digestion, the remaining unreduced $K_2Cr_2O_7$ was titrated with ferrous ammonium Sulphate to determine the amount of $K_2Cr_2O_7$ consumed and oxidizable organic matter was calculated in terms of oxygen equivalent. A standard time of two hours for refluxing was used.

Calculation:

$$COD \text{ as mg } O_2/l = \frac{(A - B) M \times 8000}{\text{ml of sample}}$$

Where:

A=ml of ferrous ammonium sulphate (FAS) for blank

B=ml FAS for sample

M=molarity of FAS

Salinity as Chloride (APHA 2520B/API-RP 45)

Chloride content of the water samples were determined by titration with silver nitrate solution using potassium chromate as indicator.

Calculation:

$$Mg/l \text{ (Cl}^-) = \frac{35.5 \times C_b \times V_b \times 1000}{Vs}$$

Where: 35.5 = atomic mass of chlorin

C_b = concentration of AgNO

V_b = volume of $AgNO_3$ used (ml)

Vs = volume of sample (ml)

1000 = convert C_b to mmol

Bicarbonate (APHA 2320B)

Titrimetric method was used to determine bicarbonate alkalinity. A 0.02N H_2SO_4 solution was used as titrant with mixed bromocresol green – methyl red in 95% pure alcohol as indicator.

Calculation:

$$mg \text{ HCO}_3^- /l = \frac{A \times 1000}{B}$$

Where:

A = ml of 0.02N H_2SO_4 used for titration

B = ml of sample

Ammonium (APHA 4500D)

Ammonium in samples was converted to aqueous ammonia with a strong base. An ion-selective electrode meter for NH_3/NH_4+ was used to determine the concentrations in the water samples.

Nitrate (APHA 4500/ASTM D516)

Calorimetric method involving the use of sodium azide, ammonium chloride and borax solutions with addition of spongy cadmium and the absorbance of the colour that developed on addition of sulphanilamide and N-1 naphthylene diamine dihydrochloride is measured at 543nm using a UV-VIS spectrophotometer. A blank solution is also subjected to the same treatment as the sample.

Sulphate (APHA 427C)

Turbidimetric method was used to determine Sulphate content of the water samples. Sulphate in samples was precipitated in an acetic acidic medium with $BaCl_2$ to form $BaSO_4$ crystals of uniform size. Light absorbance of the $BaSO_4$ suspension was measured by a photometer and the Sulphate concentration was determined by comparison of the readings with a standard curve.

Oil and Grease (ASTM D3921/API - RP 206)

Oil and grease was determined by extracting the samples using xylene in a separatory funnel and the organic phase content read at 450nm on a UV-flourescence spectrophotometer, Pharmacia Model Ultrospec III. Concentrations were read off a linear plot of the UV-F standard calibration curve.

Heavy Metals (APHA 4500F/ASTM D2036)

A hollow cathode lamp of the element of interest is aligned in atomic absorption spectrophotometer. The monochromator is adjusted for the appropriate wavelength and the required slit width. With the correct fuel and oxidant setting for the flame, the burner can now be positioned for maximum absorption and stability. Absorbance of blank and standard samples was used to plot the calibration curve from where the concentration of the sample was determined.

Total Hydrocarbon Contents (THC)

The total hydrocarbon in the sample was initially extracted with about 100 ml MIBK (methyl isobutyl ketone) Analar grade known weight of the extract was taken and spiked with an appropriate internal standard (usually 1-chlorooctadecane). A Gas Chromatograph, Varian model 3700, coupled with a flame ionization detector was used. A 200cm-glass column packed with 3% OV 101 chromosorb WHP on 80-100 mesh was used and the peak area analysis was done using a Perkin Elmer Recorder Model R50 Interfaced through PE NELSON 900 series to a Perkin Elmer Computer.

Table 1 Methodology and Major Equipment used for Chemical Analysis of Water Samples

CHEMICAL PARAMETERS	UNIT	PRINCIPLE OF METHODOLOGY	EQUIPMENT USED
PH	pH unit	Electrometric	pH meter
Conductivity at 25°C	$mScm^{-1}$	Electrometric	Conductivity meter
TDS at 105°C	mg/l	Gravimetric/Electrometric	Oven-Balance/TDS Meter
Salinity as Chloride (Cl^-)	mg/l	Titrimetric	$AgNO_3$-K_2CrO_4
Sulphate (SO_4^{2-})	mg/l	Turbidimetric	Colorimeter
Temperature	°C	Thermometric	Thermometer
Bicarbonate	mg/l	Titrimetric	Sulphuric Acid
Total Suspended Solids (TSS)	mg/l	Gravimetric	Oven/Balance
Heavy Metals (Fe, Cr, Cu, Pb and Zn)	mg/l	Atomic Absorption	AAS SP 2000
Nitrate (NO_3^-)	mg/l	Colorimetric	Spectrophotometer
Ammonium (NH_4^+)	mg/l	Colorimetric	Spectrophotometer
Turbidity	NTU	Turbidimetric	Turbidity Meter
Oil & Grease	mg/l	Colorimetric	Spectrophotometer
Dissolved Oxygen	mg/l	Titrimetric/ Electrometric	DO Meter
Biochemical Oxygen	mg/l	Titrimetric/Electrometric	Winkler's Method
Chemical Oxygen Demand	mg/l	Titrimetric	Open Reflux with $K_2Cr_2O_7$ and FAS
Phenol	mg/l	Colorimetric	Spectrophotometer
Cyanide	mg/l	Electrometric	Ion-Selective Electrometer
Total Organic Carbon	mg/l	Spectrometric	IR Spectrophotometer

Results and Discussion

Physico – Chemical Characteristics of Surface Water Bodies (rivers, creek / creeklets)

Valz Creek River and its tributaries provide the main system of creeks, creeklets and wetlands that drain the study area. These water bodies provide communication channels and harbor rich fisheries resources within the study area. The range of values of physico-chemical characteristics of surface water samples for dry and wet season in Valz Creek Study Field are presented in Table 2 and the detail results presented in Table 3 for dry season and Table 4 for wet season samples.

The pH results of surface water in Valz Creek Study Area ranged from 5.52 to 6.64 for dry season and 7.19 to 7.69 for wet season samples. The pH values can be described as slightly acidic for dry season and neutral to slightly basic for wet season samples, thus showing seasonal differences. This seasonal difference in pH values may be attributed to increased rainfall during the wet season pH is a function of hydrogen ion concentration, thus increased dilution of the water bodies during the wet season is likely to reduce the acidity of these water bodies. The temperatures of the water bodies for the various locations ranged from 28.4^0C to 30.4^0C (Table 2)

Table 2: Ranges of Physico – Chemical Characteristics of Surface Water Bodies in Valz Creek Study Area – Valz Creek River and Its Tributaries

	DRY SEASON	WET SEASON
Parameters	RANGES	RANGES
$_pH$	5.52 – 6.64	7.19 – 7.69
Temp.(0C)	28.4 – 30.4	26.1 – 28.2
TDS(mg/l)	276 – 5520	1036 – 6640
Cond.(ms/cm)	1.62 – 10.03	1.10 – 8.70
DO (mg/l)	2.5 – 6.41	5.2 – 7.6
BOD (mg/l)	22.0 – 110.60	2.9 – 4.4
Salinity (mg/l)	219.3 – 3553.90	150.3 – 3012.5
Turbidity (NTU)	17.5 – 22.6	20.5 – 55.8
Alkalinity (mg/l)	120.0 – 290.0	79.3 – 110.2
TS (mg/l)	545 – 5550.0	1060.6 – 6695.9
TSS (mg/l)	17.12 – 40.3	30.6 – 68.1
H_2S (mg/l)	0.01 – 0.28	0.001 – 0.09
COD (mg/l)	32.70 – 360	175 – 551
THC (mg/l)	0.09 – 7.42	0.01 – 3.98
NH_4 (mg/l)	2.66 – 7.42	0.40 – 2.01

FUW Trends in Science & Technology Journal, www.ftstjournal.com
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646

PO_4 (mg/l)	0.38 – 1.77	0.01 – 0.04
NO_3 (mg/l)	20.97 – 32.37	1.50 – 6.00
NO_2 (mg/l)	0.0082 – 0.810	0.004 – 0.071
$S1O_4$ (mg/l)	0.01 – 0.84	0.005 – 0.03
SO_4 (mg/l)	75.88 – 91.01	33.8 – 57.7
Na (mg/l)	201.2 – 350.57	73.6 – 192.5
K (mg/l)	42.10 – 80.19	9.36 – 21.36
Ca (mg/l)	19.7 – 35.55	5.34 – 15.16
Mg (mg/l)	256.1 – 455.08	98.5 – 210.1
HEAVY METALS		
Cd (mg/l)	0.001 – 0.01	< BDL
Cr (mg/l)	0.003 – 0.28	<BDL
Cu (mg/l)	0.007 – 0.05	< BDL – 0.015
Pb (mg/l)	0.006 – 0.05	<BDL – 0.01
Fe (mg/l)	0.025 – 0.375	0.01 – 0.39
Ni (mg/l)	< BDL	< BDL
V (mg/l)	<BDL	<BDL
Zn (mg/l)	0.316 – 4.91	0.025 – 2.16
Mn (mg/l)	0.01 – 0.84	0.002 – 0.15

The TDS values vary widely and ranged from as low as 276 mg/l to as high as 5520mg/l for dry season and 1036 to 6640 for the wet season. The higher values recorded for wet season could be attributed to run offs and siltation as a result of high rainfall. These varying values are as a result of localised altered and disturbed environment in some locations due to E & P activities and remote and undisturbed environment in other locations. The Valz Creek Field is a brown one. The turbidity levels for the different sampling locations ranged from 17. 8 NTU to 22. 6 NTU, these values are similar among sampling locations.

The conductivity values of the surface water bodies were elevated and ranged from 1. 62MS/cm to 10.03MS/cm for dry season and 1.10 to 8.70 MS/cm for wet season (Table 2). The widely varying values obtained typify the varying pockets of ecosystems within the field and also the varying river, creeks and crecklets that characterised the Valz Creek Field. Similar results obtained here have been reported for rivers and water bodies of this area (RP1, 1985; Courant et al, 1987, Edokpayi, 1999). The high levels of conductivity values of the waters are a reflection of the high chemical richness of the water bodies of the study area (Wetzel, 1975; Ikasima et al, 1982).

The salinity levels were slightly elevated and similar for both seasons (Table 2). The physcio-chemical characteristics indicate that the waters of Valz Creek are brackish. This is expected as the study area lies between the hinterland freshwater water bodies and the saline waters of Atlantic Sea. These slightly elevated levels of salinity are reflected in the conductivity values earlier described above.

FUW Trends in Science & Technology Journal, www.ftstjournal.com
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647

Table 3 The Mean Values of Physico-Chemical Characteristics of Surface Water Bodies for Dry Season

S/N	PARAMETERS	SAMPING LOCATIONS											
		WS1	WS2	WS3	WS4	WS5	WS6	WS7	WS8	WS9	WS10	WS11	WS12
1.	P^H	6. 146	6. 03	6. 09	5. 53	6. 31	5. 52	6. 51	5. 538	6. 15	6. 54	6. 13	6. 644
2.	Temp.(^{0}C)	29. 0	29. 3	29. 4	29. 1	29. 3	29. 4	29. 0	30. 4	29. 5	29. 2	28. 6	28. 4
3.	TDS(mg/l)	525	3160	4020	537	875	934	3770	3590	315	276	489	5520
4.	Cond.(ms/cm)	1. 62	5. 83	7. 46	5. 32	3. 67	2. 06	7. 02	7. 42	4. 72	5. 38	9. 35	10. 03
5.	DO (mg/l)	3. 20	2. 5	2. 80	3. 50	4. 00	3. 40	3. 80	3. 60	3. 10	5. 10	6. 41	4. 60
6.	BOD (mg/l)	40. 00	66. 5	77. 50	40. 29	53. 6	26. 70	38. 78	50. 78	35. 0	22. 0	27. 8	110. 60
7.	Salinity (mg/l)	310. 52	219. 3	.3553. 90	2450. 0	1673. 8	530. 00	3503. 85	2120. 00	261. 2	2513. 7	2941. 9	3056. 65
8.	Turbidity (NTU)	19. 4	20. 5	18. 2	20. 5	17. 5	18. 9	22. 6	19. 1	19. 3	18. 7	20. 0	17. 8
9.	Alkalinity (mg/l)	290	160	120	150	139	180	180	120	200	130	250	190
10.	TS (mg/l)	545. 00	553. 3	4048. 0	2317. 1	1966. 8	954. 00	3810. 0	3608. 0	569. 7	3840. 0	4135. 5	5550. 0
11.	TSS (mg/l)	20. 0	40. 3	28. 00	30. 5	25. 8	20. 00	40. 00	18. 00	22. 6	17. 12	35. 3	30. 00
12.	H_2S (mg/l)	0. 08	0. 03	0. 12	0. 09	0. 03	0. 25	0. 10	0. 08	0. 05	0. 01	0. 07	0. 28
13.	COD (mg/l)	60	113	190	70	53	50	60	90	46. 3	32.70	51. 10	360
14.	THC (mg/l)	79. 42	0. 35	79. 42	0. 102	0. 09	0. 165	0. 247	0. 496	0. 15	0. 99	0. 15	1. 736
15.	NH_4 (mg/l)	7. 0	3. 8	7. 42	6. 69	3. 77	7, 17	4. 42	5. 40	3. 67	2. 66	3. 46	5. 48
16.	PO_4 (mg/l)	0. 38	1. 35	1. 15	1. 32	0. 91	1. 18	1. 74	0. 96	0. 67	1. 77	1. 66	0. 78
17.	NO_3 (mg/l)	27. 66	28. 10	32. 37	29. 65	20. 97	28. 07	29. 70	30. 50	29. 10	27. 53	30. 12	29. 70
18.	NO_2 (mg/l)	0. 528	0. 0136	0. 5457	0. 0137	0. 610	0. 1007	0. 0082	0. 0504	0. 718	0. 539	0. 810	0. 5304
19	SiO_2 (mg/l)	0. 32	0. 01	0. 15	0. 09	0. 32	0. 84	0. 25	0. 18	0. 05	0. 10	0. 24	0. 10
20	SO_4 (mg/l)	82. 14	80. 32	84. 29	75. 88	90. 09	84. 71	81. 14	84. 43	91. 01	85. 21	80. 56	85. 0
21	Na (mg/l)	221. 98	201. 2	284. 88	250. 13	269. 2	272. 18	270. 32	264. 11	301. 3	281. 50	271. 5	350. 57
22.	K (mg/l)	45. 30	53. 1	73. 01	54. 36	42. 10	54. 18	56. 25	52. 94	45. 95	55. 72	80. 19	74. 48
23.	Ca (mg/l)	21. 96	19. 7	29. 17	26. 13	30. 76	27. 96	27. 32	27. 77	30. 91	33. 65	35. 55	35. 47
24.	Mg (mg/l)	288. 08	256. 1	342. 74	310. 69	396. 0	324. 06	324. 82	380. 50	351. 2	273. 9	301. 2	455. 08
	HEAVY METALS												
25.	Cd (mg/l)	0. 008	0. 003	0. 008	0. 001	0. 002	0. 003	0. 010	0. 003	0. 001	0. 005	0. 004	0. 001
26.	Cr (mg/l)	0. 018	0. 003	0. 020	0. 01	0. 009	0. 010	0. 026	0. 012	0. 007	0. 01	0. 005	0. 028
27.	Cu (mg/l)	0. 032	0. 011	0. 032	0. 023	0. 022	0. 030	0. 050	0. 030	0. 033	0. 009	0. 007	0. 020

FUW Trends in Science & Technology Journal, www.ftstjournal.com
e-ISSN: 24085162; p-ISSN: 20485170; August, 2020: Vol. 5 No. 2 pp. 642 – 654

648

28.	Pb (mg/l)	0. 020	0. 015	0. 025	0. 013	0. 020	0. 018	0. 030	0. 018	0. 034	0. 008	0. 006	0. 050
29.	Fe (mg/l)	0. 250	0. 03	0. 025	0. 123	0. 230	0. 375	0. 125	0. 125	0. 051	0. 093	0. 213	0. 25
30.	Ni (mg/l)	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MD>
31.	V (mg/l)	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
32.	Zn (mg/l)	4. 91	1. 35	0. 655	0. 93	1. 36	0. 655	1. 721	0. 812	0. 55	0. 316	0. 93	2. 295
34.	Mn (mg/l)	0. 01	0. 02	0. 28	0. 11	0. 09	0. 16	0. 32	0. 48	0. 13	0. 213	0. 13	0. 84

Table 4 The Mean Values of Physico-Chemical Characteristics of Surface Water Bodies For Wet Season

S/N	PARAMETERS	SAMPING LOCATIONS											
		WS1	WS2	WS3	WS4	WS5	WS6	WS7	WS8	WS9	WS10	WS11	WS12
1.	P^H	6. 146	6. 03	6. 09	5. 53	6. 31	5. 52	6. 51	5. 538	6. 15	6. 54	6. 13	6. 644
2.	Temp.(^{0}C)	29. 0	29. 3	29. 4	29. 1	29. 3	29. 4	29. 0	30. 4	29. 5	29. 2	28. 6	28. 4
3.	TDS(mg/l)	525	3160	4020	537	875	934	3770	3590	315	276	489	5520
4.	Cond.(ms/cm)	1. 62	5. 83	7. 46	5. 32	3. 67	2. 06	7. 02	7. 42	4. 72	5. 38	9. 35	10. 03
5.	DO (mg/l)	3. 20	2. 5	2. 80	3. 50	4. 00	3. 40	3. 80	3. 60	3. 10	5. 10	6. 41	4. 60
6.	BOD (mg/l)	40. 00	66. 5	77. 50	40. 29	53. 6	26. 70	38. 78	50. 78	35. 0	22. 0	27. 8	110. 60
7.	Salinity (mg/l)	310. 52	219. 3	.3553. 90	2450. 0	1673. 8	530. 00	3503. 85	2120. 00	261. 2	2513. 7	2941. 9	3056. 65
8.	Turbidity (NTU)	19. 4	20. 5	18. 2	20. 5	17. 5	18. 9	22. 6	19. 1	19. 3	18. 7	20. 0	17. 8
9.	Alkalinity (mg/l)	290	160	120	150	139	180	180	120	200	130	250	190
10.	TS (mg/l)	545. 00	553. 3	4048. 0	2317. 1	1966. 8	954. 00	3810. 0	3608. 0	569. 7	3840. 0	4135. 5	5550. 0
11.	TSS (mg/l)	20. 0	40. 3	28. 00	30. 5	25. 8	20. 00	40. 00	18. 00	22. 6	17. 12	35. 3	30. 00
12.	H_2S (mg/l)	0. 08	0. 03	0. 12	0. 09	0. 03	0. 25	0. 10	0. 08	0. 05	0. 01	0. 07	0. 28
13.	COD (mg/l)	60	113	190	70	53	50	60	90	46. 3	32.70	51. 10	360
14.	THC (mg/l)	79. 42	0. 35	79. 42	0. 102	0. 09	0. 165	0. 247	0. 496	0. 15	0. 99	0. 15	1. 736
15.	NH_4 (mg/l)	7. 0	3. 8	7. 42	6. 69	3. 77	7, 17	4. 42	5. 40	3. 67	2. 66	3. 46	5. 48
16.	PO_4 (mg/l)	0. 38	1. 35	1. 15	1. 32	0. 91	1. 18	1. 74	0. 96	0. 67	1. 77	1. 66	0. 78
17.	NO_3 (mg/l)	27. 66	28. 10	32. 37	29. 65	20. 97	28. 07	29. 70	30. 50	29. 10	27. 53	30. 12	29. 70
18.	NO_2 (mg/l)	0. 528	0. 0136	0. 5457	0. 0137	0. 610	0. 1007	0. 0082	0. 0504	0. 718	0. 539	0. 810	0. 5304

FUW Trends in Science & Technology Journal, www.ftstjournal.com
e-ISSN: 24085162; p-ISSN: 20485170; August, 2020: Vol. 5 No. 2 pp. 642 – 654

649

19	SiO$_2$ (mg/l)	0. 32	0. 01	0. 15	0. 09	0. 32	0. 84	0. 25	0. 18	0. 05	0. 10	0. 24	0. 10
20	SO$_4$ (mg/l)	82. 14	80. 32	84. 29	75. 88	90. 09	84. 71	81. 14	84. 43	91. 01	85. 21	80. 56	85. 0
21	Na (mg/l)	221. 98	201. 2	284. 88	250. 13	269. 2	272. 18	270. 32	264. 11	301. 3	281. 50	271. 5	350. 57
22.	K (mg/l)	45. 30	53. 1	73. 01	54. 36	42. 10	54. 18	56. 25	52. 94	45. 95	55. 72	80. 19	74. 48
23.	Ca (mg/l)	21. 96	19. 7	29. 17	26. 13	30. 76	27. 96	27. 32	27. 77	30. 91	33. 65	35. 55	35. 47
24.	Mg (mg/l)	288. 08	256. 1	342. 74	310. 69	396. 0	324. 06	324. 82	380. 50	351. 2	273. 9	301. 2	455. 08
HEAVY METALS													
25.	Cd (mg/l)	0. 008	0. 003	0. 008	0. 001	0. 002	0. 003	0. 010	0. 003	0. 001	0. 005	0. 004	0. 001
26.	Cr (mg/l)	0. 018	0. 003	0. 020	0. 01	0. 009	0. 010	0. 026	0. 012	0. 007	0. 01	0. 005	0. 028
27.	Cu (mg/l)	0. 032	0. 011	0. 032	0. 023	0. 022	0. 030	0. 050	0. 030	0. 033	0. 009	0. 007	0. 020
28.	Pb (mg/l)	0. 020	0. 015	0. 025	0. 013	0. 020	0. 018	0. 030	0. 018	0. 034	0. 008	0. 006	0. 050
29.	Fe (mg/l)	0. 250	0. 03	0. 025	0. 123	0. 230	0. 375	0. 125	0. 125	0. 051	0. 093	0. 213	0. 25
30.	Ni (mg/l)	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MD>
31.	V (mg/l)	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
32.	Zn (mg/l)	4. 91	1. 35	0. 655	0. 93	1. 36	0. 655	1. 721	0. 812	0. 55	0. 316	0. 93	2. 295
34.	Mn (mg/l)	0. 01	0. 02	0. 28	0. 11	0. 09	0. 16	0. 32	0. 48	0. 13	0. 213	0. 13	0. 84

FUW Trends in Science & Technology Journal, www.ftstjournal.com
e-ISSN: 24085162; p-ISSN: 20485170; August, 2020: Vol. 5 No. 2 pp. 642 – 654

650

The DO measurements ranged from 2. 5 mg/l to 6. 41mg/l for dry season and 5.2 to 7.6mg/l for wet season. The higher levels of DO recorded for wet season is due to increased aeration and constant mixing of water bodies (Table 2). Conversely, the BOD levels were elevated and ranged from 26. 70 mg/l to 110. 60 mg/l, during the dry season when compared with wet season values of 2.9 to 4.4mg/l.

For the dry season samples, the levels of nitrate, sulphate were fairly elevated and in contrast that of phosphates were low (Table 2 and Table 3).

The levels of exchangeable cations (Sodium, Potassium, Calcium and Magnesium) were slightly elevated (Table 2) and corroborate the elevated levels of conductivity concentrations earlier reported. These exchangeable cations are essential for the normal development of biological organisms.

The low DO levels might temporary affect fish population within Valz Creek, especially in the dry season, forcing the fishes to move to less stressful areas. However, the fishes return immediately the rains come (rainy season is a longer season) when DO levels are elevated.

For the wet season samples, the levels of nitrate, sulphate and phosphate were lower than that of dry season (Table 2 and Table 4). However, the turbidity, total solids and total suspended solids levels were higher for wet season than dry season. The run offs and situation during the wet season must have accounted for those high levels.

The levels of heavy metals in the surface waters (Table 2) were generally low. The dry season values were slightly higher than wet season values. However the water bodies are not totally free of heavy metals but are within the levels reported in other studies.

Microbiology of Surface Water

Range of results of microbiological investigations of surface water bodies (river, creeks/creeklets) are presented in Table 5 for dry and wet seasons. The detail results are presented in Table 6 and Table 7 for dry and wet season samples respectively.

Table 5 Bacterial population densities in surface water samples

	Dry Season	Wet Season
Parameters	Ranges	Ranges
Total Heterotrophic Bacterial Count	9.2 – 425.6 x 105 cfu/ml	40.5 – 229.1 x 103 cfu/ml
Total Hydrocarbon Degraders count	0.13 – 59.42 x 105 cfu/ml	0.1 – 30.4 x 103 cfu/ml
% Hydrocarbon Degraders	0.01 – 11.1%	0.001 – 0.15%

The results presented in ranges of surface water analysis for bacterial population densities generally showed higher heterotrophic density than hydrocarbon degraders (Table 5).

The dry season results of the surface water samples for heterotrophic bacterial counts ranged from 9.2 to 425.6 x 10^5 cfu/ml while that of hydrocarbon degraders ranged from 0.13 to 59.42 cfu/ml x 10^3. The % Hydrocarbon degraders were generally low and ranged from 0.01 to 11.1% (Table 6).

Table 6 The Mean Values of Bacterial Population Densities of Surface Water Samples for Dry Season

S/N	PARAMETERS/ SAMPLING LOCATIONS	TOTAL HETEROTROPHIC BACTERIAL COUNT CFU/ ML X 10^5	TOTAL HYDROCARBON DEGRADERS CFU / ML X 10^3	% HYDROCARBON DEGRADERS
1.	*WS1*	61. 40	11. 80	0. 19
2.	WS2	32. 5	3. 4	0. 01
3.	WS3	59. 30	10. 84	0. 18
4.	WS4	9. 2	0. 13	0. 014
5.	WS5	35. 1	6. 1	0. 017
6.	WS6	27. 40	2. 35	0. 09
7.	WS7	13. 36	1. 46	11. 1
8.	WS8	84. 3	11. 3	0. 13
9.	WS9	13. 6	0. 9	0. 06
10.	WS10	13. 14	1. 3	0. 10
11.	WS11	16. 13	2. 1	0. 13
12.	WS12	425. 6	59. 42	0. 14

The wet season results ranged from 40.5 to 229.1 x 10^5 cfu/ml for heterotrophic bacteria and 0.1 to 30.4 x 10^3 cfu/ml for the hydrocarbon degraders. Also the percentage hydrocarbon degraders ranged from 0.001 to 0.15% (Table 7).

Table 7 The Mean Values Of Bacterial Population Densities Of Surface Water Samples For Wet Season

FUW Trends in Science & Technology Journal, www.ftstjournal.com
e-ISSN: 24085162; p-ISSN: 20485170; August, 2020: Vol. 5 No. 2 pp. 642 – 654

651

S/N	PARAMETERS/ SAMPLING LOCATIONS	TOTAL HETEROTROPHIC BACTERIAL COUNT CFU/ ML X 10^5	TOTAL HYDROCARBON DEGRADERS CFU / ML X 10^3	% HYDROCARBON DEGRADERS
1.	WS1	170.80	6.2	0.036
2.	WS2	53.8	0.1	0.001
3.	WS3	40.5	0.3	0.007
4.	WS4	46.7	0.12	0. 003
5.	WS5	44.3	0.23	0. 005
6.	WS6	71.8	10.5	0. 15
7.	WS7	64.0	4.8	0.075
8.	WS8	120.1	0.46	0.004
9.	WS9	50.9	0.1	0.002
10.	WS10	165.0	20.2	0. 122
11.	WS11	66.7	5.3	0.079
12.	WS12	229.1	30.4	0.132

Generally, the percentage hydrocarbon degraders were low for both seasons. However the densities of these organisms during the dry season were higher than the wet season.

The results of this study indicate that increased hydrocarbon recovery project activities have minimal impacts on the physico-chemical characteristics of surface waters in this brackish coastal environment. The pH values were within normal ranges for this type of ecosystem, but more acidic during the dry season, which could be attributed to natural processes such as acid rain. Conductivity and salinity values were also normal, suggesting that the water bodies were not significantly affected by anthropogenic activities. However, DO and BOD levels indicated that the water systems were more eutrophic during the dry season, which could be attributed to increased nutrient inputs from agricultural and domestic sources. The higher levels of turbidity, total solids, and total suspended solids during the wet season were most likely due to runoffs and siltation.

Nutrient levels were generally low, consistent with Valz field and similar brackish coastal ecosystems. These findings are expected as nutrients in such ecosystems are often limited due to the interaction of freshwater and seawater. Heavy metal levels were also low, with slightly higher values during the dry season, which could be attributed to the release of metals from soils during the dry season. However, these values were still within acceptable limits, indicating minimal impact from anthropogenic activities.

THC levels were generally low, except for one location around the wellhead areas during the dry season, which recorded the highest value. This finding suggests that hydrocarbon recovery activities may have some impact on the surface water quality in the study area. The observed hydrocarbon level could be attributed to leaks or spills from pipelines or other sources during the dry season when water levels are low.

Conclusion
The study presents the physico-chemical characteristics of surface water bodies (rivers, creek/creeklets) in the Valz Creek Study Field during the dry and wet seasons. The pH values of surface water samples ranged from slightly acidic during the dry season to neutral to slightly basic during the wet season. The temperatures of the water bodies ranged from 28.4°C to 30.4°C. TDS values ranged widely from 276 mg/L to 5520 mg/L for the dry season and 1036 mg/L to 6640 mg/L for the wet season, with higher values recorded during the wet season. Turbidity levels were similar among sampling locations, ranging from 17.8 NTU to 22.6 NTU. The conductivity values of the surface water bodies were elevated and ranged from 1.62 mS/cm to 10.03 mS/cm for dry season and 1.10 mS/cm to 8.70 mS/cm for wet season. Salinity levels were slightly elevated and similar for both seasons, indicating that the waters of Valz Creek are brackish. The DO measurements ranged from 2.5 mg/L to 6.41 mg/L for dry season and 5.2 mg/L to 7.6 mg/L for wet season, with higher levels recorded during the wet season. Conversely, the BOD levels were elevated during the dry season compared to the wet season. The levels of nitrate, sulphate, and exchangeable cations were slightly elevated, while the levels of phosphates were low. The physico-chemical characteristics of the wet season samples indicated higher levels of turbidity, total solids, and total suspended solids, which could be attributed to run-offs and siltation. Overall, the study found that the physico-chemical characteristics of surface water bodies in the Valz Creek Study Field were typical of those reported in other studies of the Niger Delta region. Therefore, it is recommended that measures be put in place to prevent leaks or spills from hydrocarbon recovery projects and to control nutrient inputs to surface waters in the study area.

The study provides important baseline data on the physico-chemical characteristics of surface water bodies in the Valz Creek Field, which is essential for assessing the environmental impact of oil and gas exploration and production activities in the area. The data generated can be used to establish a monitoring program that will enable the detection of any changes in water quality and help to implement appropriate mitigation measures in case of any adverse impacts.

Furthermore, the study can serve as a reference for future research on the effects of oil and gas activities on aquatic ecosystems in the area. It can also be used to guide the development of best management practices that will help to minimize the impact of these activities on water quality.

FUW Trends in Science & Technology Journal, www.ftstjournal.com
e-ISSN: 24085162; p-ISSN: 20485170; August, 2020: Vol. 5 No. 2 pp. 642 – 654
652

Assessment of the Impact of Increased Hydrocarbon Recovery Activities on Surface Water Quality in A Brackish Coastal Environment

654

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