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Assessment of Physicochemical Properties of the Ovwian Section of the Warri River

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Abstract

This study evaluates the physical, chemical and heavy metal properties of the Ovwian Section of Udu River, Delta State, Nigeria with a view of ascertaining the water quality and establishing the correlation with national and international standards and activities around the water body. The physicochemical properties analyzed include pH, temperature, dissolved oxygen, total solids, total suspended solids, biological oxygen demand, salinity, alkalinity, total hardness amongst others. Some of the heavy metals studied include copper, chromium, iron, zinc, manganese and lead. The mean temperature (25.92±0.50^{o}C), total dissolved solid (mean concentration - 22.53±5.46 mg/L), electrical conductivity (35.27±8.60 µS/cm), dissolved oxygen (mean concentration of 7.23±0.31 mg/L), biological oxygen demand (mean concentration - 2.01±0.84 mg/L), total hardness, nitrates (mean concentration - 1.06±0.52 mg/L), sulphate (mean sulphate concentration - 13.90±0.86 mg/L) and total alkalinity (8.00 mg/L - 12.00 mg/L) values were found to be within the permissible limits of WHO and FEPA. On the other hand, the total suspended solid (7.09 mg/L), turbidity (mean concentration - 34.54±14.18 NTU), pH and total coliforms were above the permissible limits of the regulatory agencies used in the study. Among the heavy metals present, Lead showed a very high concentration above the tolerance limit of WHO and FEPA. The result shows that some level of pollution is associated with the Ovwian section of the Udu River and adequate treatment is thus recommended before it can be used for any purpose.

Keywords: Assessment, Physiological Properties, River Water

Introduction

After air, water is the most important requirement for life existence [1]. It is a renewable resource that is significant and necessary for the survival of all kinds of life on earth, economic progress, and general well-being [2, 3]. Water is one of the most manageable natural resources due to its capabilities for diversion, transport, storage, and recycling [2]. Sources of water on earth include rivers, streams, lakes, wells, boreholes, springs etc. [3]. Through its important and significant role in agriculture, hydropower generation, cattle production, industrial operations, forestry, fisheries, navigation, and leisure activities, water has become an integral component of man's life as well as the earth's surface [4, 2]. However, water security has become a concern for almost 80% of the world's population [5]. As a result, the United Nations (UN) designated access to clean and safe drinking water a human right in 2016 [6].

About 70% of the earth's surface is covered by water in the form of rivers, lakes, streams, seas, oceans, etc., yet, only a small portion of that water is fresh [7]. It has been reported that this little portion of the world's freshwater ecosystem has a volume of 2.84 x 10^5 km^3 [2]. It was also estimated that 2.55 to 3 percent of the total volume of these aquatic bodies are considered freshwater, with the remainder being classified as salty [8]. Additionally, it was reported that just about 5% (or 0.15 percent) of the world's water is easily available for useful purposes [9]. According to World Water Council, only 0.3% of the freshwater on earth's surface can be found in rivers and lakes; the remainder is frozen [9]. Rivers cover about 0.1 percent of the land area, while only 0.01 percent of the world's water is found in river channels [2]. This shows that, despite the high volume of water on the planet's surface, only a small percentage of it is available for human consumption, resulting in water shortage. Unfortunately, despite the importance of clean water to the environment, surface water is still subjected to high atmospheric pressure [9]. Due to contamination, an estimated population of

780 million people does not have access to clean and safe water [6]. As a result, man has a limited supply of fresh water for his activities.

Water pollution can come from a variety of causes, including geological conditions, industrial activity, agricultural activities, water treatment plants etc. This includes both natural and anthropogenic activities have an impact on water quality [10]. Discharge of domestic wastes, untreated industrial effluents, illegally disposed garbage, and agricultural run-off (fertilizers and pesticides wash off by rain/flood) into water bodies are just some of the anthropogenic activities that contribute to water deterioration [4, 6, 10]. Floods, droughts, lack of awareness and education, and animal and human organic wastes (feces, crop trash, wood, etc.) are among the others contributors of water decay [10]. As a result of these factors, water quality has deteriorated, as well as climate-related changes to the hydrological cycle [6]. Thus, human health is greatly affected and impaired as well as the environment. They build up to dangerous levels in the animal/system organisms as they move up the food chain. Water consumption for diverse reasons has been hampered as a result of freshwater's vulnerability to contamination [10]. This makes water quality control a key policy issue in many parts of the world.

This study therefore aims at evaluating and monitoring the physic-chemical water quality parameters and some selected heavy metals of the Ovwian Section of the Warri River with a view to ascertain the water quality standards in accordance with set standards from some regulatory agencies.

The Study Area

According to literature, with a population range of 500,000–1,000,000, Warri is one of the densely inhabited cities in Delta State, Nigeria [11]. It can be found between latitudes $5^{o}30$ and $5^{o}35$ in the north and $5^{o}29$ and $5^{o}48$ in the east [12]. The city is specifically situated between latitude $5^{o}35^{I}45^{II}$ North and longitude $5^{o}45^{I}08^{II}$ East. It has an intricate network of streams, rivulets, ponds, ditches, lakes, rivers, and estuaries as well as a distinctively shallow water table [13]. One of the main coastal rivers in Nigeria's Niger Delta is the Warri River. As a supply of water for numerous residences (domestic use), agricultural needs (irrigation and animal feeding), and industrial needs, it is significant commercially. It is an illustration of an inland body of water that receives effluents and sewage from various factories, marketplaces, and industries. The Warri River flows through a mangrove swamp forest area adjacent to it in the southern section of Nigeria, where the catchment and drainage areas are likely particularly rich in humus and decomposing organic matter. The Warri River is located between latitudes $5^{o}21^{I}$ and $6^{o}00^{I}$ N and $5^{o}21^{I}$ and $6^{o}2^{I}$ E [14].

The river's source is in Utagba-Uno, and it flows southwest between Oviorie and Ovu-inland before turning south toward Effurun and forming a "W" between Effurun and Warri. It flows into the Atlantic Ocean after joining the Forcados estuary. It has a length of roughly 150 km and a surface area of about 255 km [15]. Enerhen, Igbudu, Ovwian, Aladija (steel town), Warri Ports, the main Warri market, NNPC Refinery, Globe Star, etc. are significant landmarks in this river stretch. A variety of creeks, rivers, and streams branch off from the river, all of which discharge water into the Atlantic Ocean [15].

Fig. 1: Map of Ovwian Section of Warri River indicating the Sampling Points (A - 5.495789 N, 5.781593 E; B - 5.497071 N, 5.781408 E; C - 5.498171 N, 5. 781654 E)

Sampling

A total number of 15 water samples were collected at different point of the river at 60m interval. A clean sampling can was used to collect each of the water samples. At the point of collection of each of the water samples, each of the sampling cans were properly rinsed with the water sample before collection. They were properly labelled after collection. However, samples for Dissolved Oxygen (DO) analysis were collected with DO bottles and fixed with Winkler A and Winkler B solutions. Similarly, samples for Biochemical Oxygen Demand (BOD) analysis were collected with BOD bottles (amber coloured bottle) while samples for metal analysis were collected with heavy metal analysis bottle and were preserved with 1:1 Nitric acid solution. All the water samples collected were placed in a cooler containing ice-chest and were transported to the laboratory for analysis.

Analytical Methods

The different water parameters were determined using the following methods [17]:
Determination of pH by Electrometric Method
Determination of Electrical Conductivity by Electrometric Method
Determination of Total Dissolved Solid (TDS) by Electrical Conductivity

Determination of Alkalinity by Titrimetric Method

Determination of Nitrate by UV-VIS Spectrophotometer

Determination of Sulphate by Turbimetric Method

Determination of Total Hardness by EDTA Titrimetrc Method

Determination of Total Suspended Solids (TSS) by Photometric Method

Determination of Oil and Grease by Extraction/Photometric Method

Determination of Dissolved Oxygen (DO) Using Winkler Azide Modification Titrimetric Method

Determination of Biochemical Oxygen Demand (Bod_5) Using Winkler Azide Modification Titrimetric Method

Determination of Ammonia by Direct Nesslerization Method

Determination of Salinity by Electrical Conductivity Method

Determination of Turbidity by Nephelometric Method

Determination of Heavy Metals by Atomic Absorption Spectrophotometer (Varian Spectraa-200)

Determination of Nitrite by Sulphanilamide Spectrophotometric Method

Source: APHA, 2012.

Data Analysis

Microsoft Excel 2013 was used in the analysis of all the data obtained in the adsorption study. It was also used to plot all the graphs used in the explanation of the results.

Results And Discussion

The physical properties, chemical properties and heavy metals of the 15 points sampled in the Ovwian River are shown in Table 1, 2 and 3 respectively. Points A, B, and C represents the areas close to the dredging site, oil factory and dumpsite respectively as maybe found around the sample location. Similarly, Table 4 shows the permissible limits by the World Health Organisation (WHO) and Federal Environmental Protection Agency (FEPA).

Physical Properties

Temperature Distribution

Temperature is a water property that helps in the regulation of metabolism in the aquatic environments and oxygen availability [18]. The temperature of the water body as shown in Fig. 2 ranged from 25.14^{o}C – 26.76^{o}C. The minimum temperature recorded was 25.14 at Point B2 while the maximum temperature was 26.76^{o}C at Point B3. It is observed that both the minimum and the maximum temperature levels were recorded at the oil factory sites of the river. While average (mean) temperature of the sampled water from the dredging sites, oil factory sites, and dumpsites with their respective standard deviations are 25.82±0.47^{o}C, 25.82±0.61^{o}C, and 26.13±0.46^{o}C respectively, the overall mean temperature was 25.92±0.50^{o}C. It is observed as well that there is no substantial difference in the average level of temperature of the water across the three sample points but a differential variation in temperature near oil factory sites is higher as shown by the highest value of the standard deviation of 0.61^{o}C. Similarly, the values for skewness show that the temperature is positively skewed with no perceivable outliers as the values of kurtosis are relatively the same except for dumpsites. The overall distribution of the temperature across the three sites is normal as indicated by the insignificant values of the probabilities of Jarque-Bera statistics.

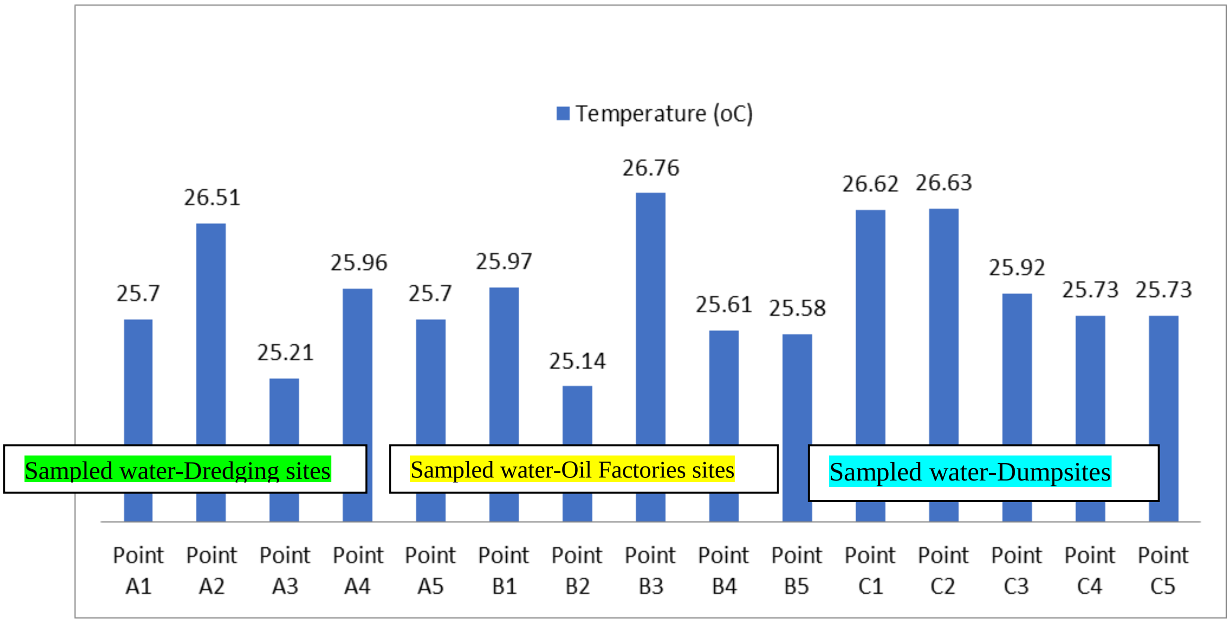

Fig. 2: Distribution of temperature across the sampled points of the Owvian section of Warri River

This temperature is optimum for irrigation and drinking water as it fell above the WHO limit. This is in consonance with the results obtained preiously [4, 18]. Usually, high temperature engenders chemicals reactions and decreases gas (oxygen) solubility in water leading to decreased dissolved oxygen [4] as observed later in the study.

Total Dissolved Solids

The values of Total Dissolved Solids (TDS) ranged from 15.36 mg/L (Point B1) to 31.36 mg/L (Point A2). Across the sample points, it can be seen from Fig. 3 and Table 1 that one of the sample points with the highest rate of TDS is Point A2 at 31.36 mg/L. This is followed by Point B4 near oil factories at 28.8 mg/L, 28.2 mg/L (Point A1), 28.16 mg/L (Point C2) and 15.36 mg/L (Point B1) as the lowest. The sample points closer to the dredging site (Points A1-A5) appeared to have had higher dissolved solids than other sites with an average TDS of 25.22±5.17mg/L compared with dumpsite and oil factor sites with mean TDS of 22.52±5.31mg/L and 19.84±5.58mg/L respectively. Also, the mean value of TDS across all the sample points (overall) is 22.53±5.46mg/L and is similar to that of dumpsites. The higher rate of TDS closer to the dredging sites could be as a result of the fine particles from the site. The results show further that while the generated data for the TDS are normally distributed based on the non-significant probability values of the Jarqu-Bera, TDS in Dredging and dumpsites have negative skewness. Given the standards of the WHO and FEPA for portable water, the values were within the permissible limits. With the TDS being an indication of dissolved salt content of the water, the low values suggest low concentration of these salts in the water body [4]. This increases its palatable use. A similar range for TDS has been reported previously [19].

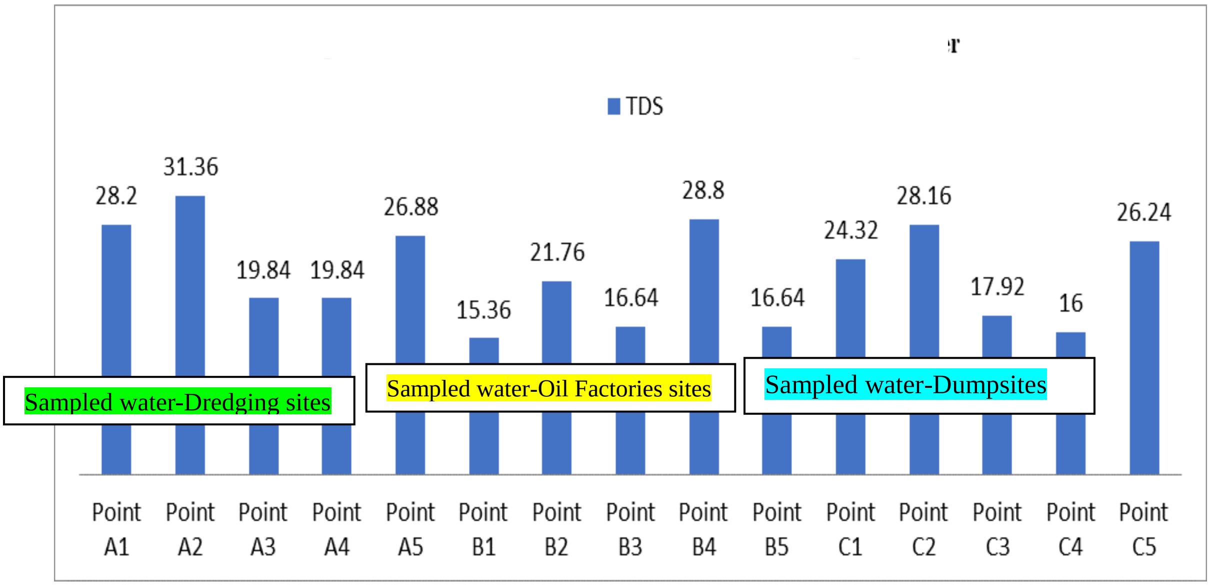

Fig. 3: Distribution of TDS of the sampled water

Total Suspended Solids

The average total suspended solids of the Ovwian Section of the Udu River are 7.09 mg/L. The values ranged from 1.72 – 29.85 mg/L. while the values in the first sample point in dredging site is below detection (Point A1 in the graph), average TSS in Dredging, oil factory, and dumpsites are respectively shown in Figure 3 as 18.34±13.02mg/L, 4.82.34±1.82mg/L, and 8.13±8.52mg/L. The highest suspended solids were recorded at the points closer to dredging sites and the dumpsites as a result of release and accumulation of solids in the region. These points are all within the permissible limit for FEPA. While some points were above the permissible limits of WHO, others were below the permissible limits (30 mg/L) for effluents discharge into surface water by FEPA. These high values maybe due to the proximity to the dredging site [4].

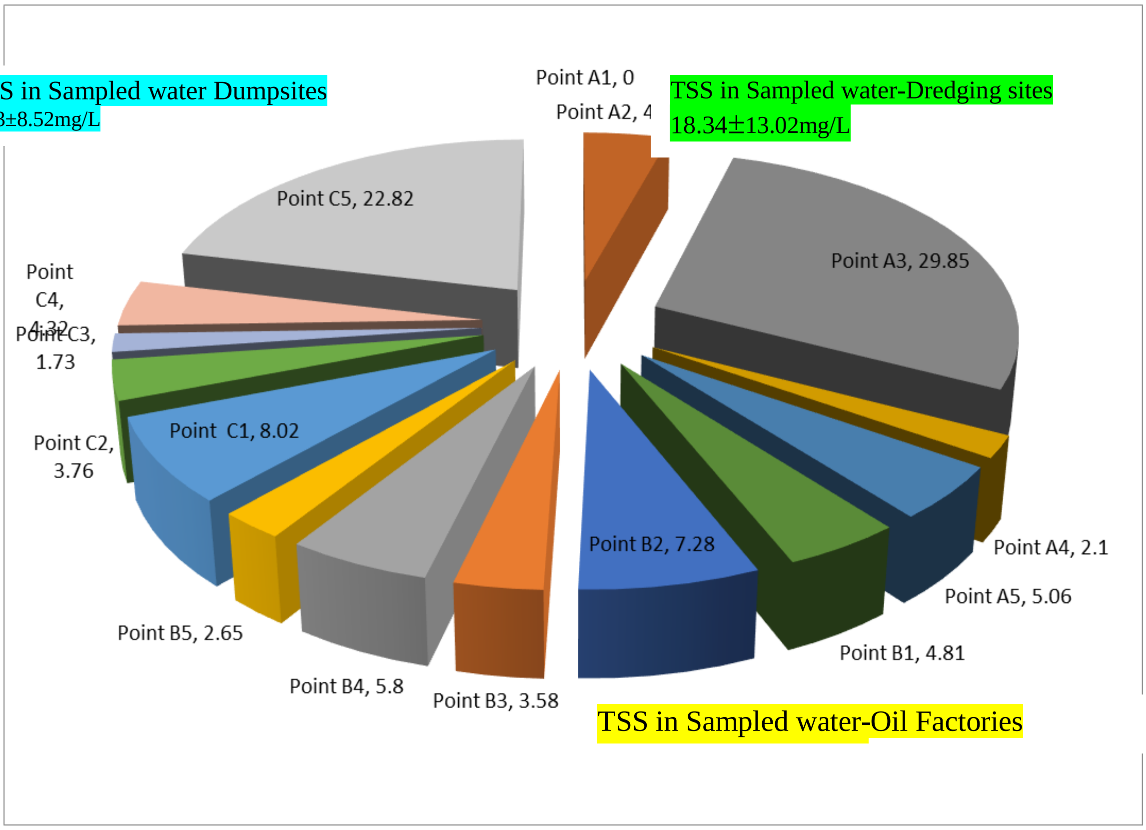

Fig. 3: Distribution of TSS in the water samples

Electrical conductivity

Similarly, the electrical conductivity (EC) property of the water is seen to be within the limits of portable water set by the WHO. The EC values ranged from 24.00µS/cm to 49.00µS/cm with an overall mean value of 35.27±8.60µS/cm. It is important to further examine the level of electrical conductivity across the sample units in relation to the overall average. Figure 4 shows that water section near the dredging site is more charged electrically with average electrical conductivity of 39.6±8.23µS which is higher than dumpsite's conductivity rate of 35.20±8.29µS and that of oil factor sites at 31.00±8.72µS. In all, the dumpsite and overall average electrical conductivity are not significantly different while the dredging sites sample points of the water have more average electrical charge.

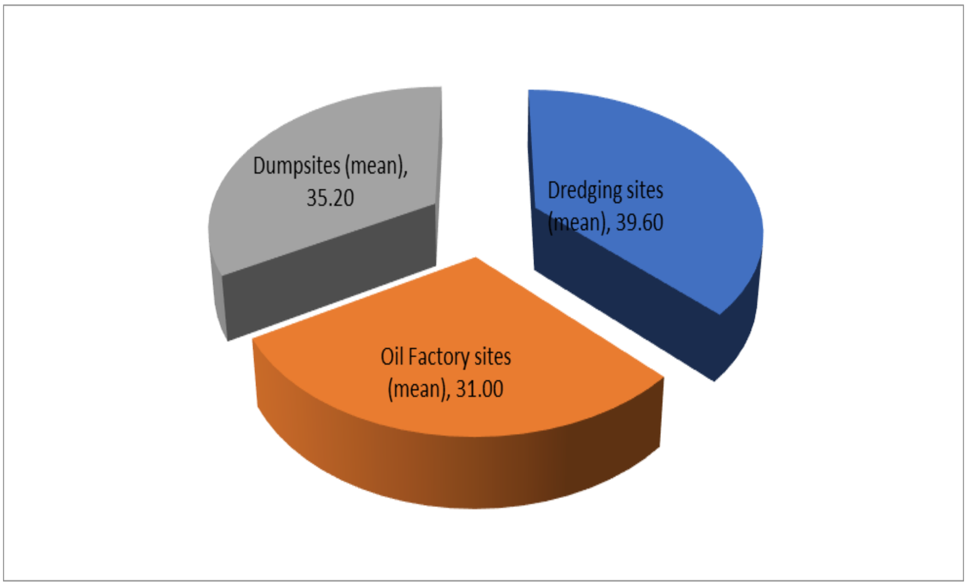

Figure 4: Electrical conductivity rate of the sample points of the sampled water.

These low values correlate with the low values of TDS as it is the ions of the dissolved salts that are responsible for electrical conductivity. Similar range of electrical conductivity is found in literatures [4, 14, 18]. This confirms its usability as drinking water and for irrigation purposes following its low salinity [14]. Furthermore, since electrical conductivity has a direct proportion with total dissolved solids [20] and an indicator of mineralization and salinity or total salts in water [21], the value of the correlation coefficient between TDS and EC has been estimated through the Pearson Product Moment Correlation Coefficient (PPMCC) and the result is 0.999636 (99.96%). the values of recorded in the parameters are in agreement as they fell within the limits of the standards with coherent values. According to a previous study [21], high EC is indicative of low water quality. Thus, the low EC of the water can be said to a measure of good quality of the water.

Turbidity

According to the US Geological survey [22], Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher would be the level of turbidity of the water sample.

The Ovwian Section of the Udu River recorded a high turbidity above the permissible limits of WHO and FEPA The range of turbidity of the sampled water obtained in this study is from 12.46 NTU to 58.74 NTU. The mean turbidity of the river is 34.54±14.18 NTU and it is important to cross examine the level of turbidity of the water across the three sample points. The results in Table 1 reveals that the level of turbidity of the sampled water is high in dumpsites with average mean of 37.46±9.29 NTU. This is higher than the turbidity rate in dredging and oil factory sites. The implication here is that the more debris is dumped into the water, the more the water becomes turbid and useless for household use. Also, the turbidity rate of the section of the water near oil factories and dumpsites negatively skewed as seen from the values of skewness. High turbidity corresponds to the high values of suspended solids and faecal coliforms observed. The corresponding correlation coefficient of turbidity with TSS in this study is estimated as: It confirms that turbidity is a reflection of the total suspended solids [20]. This could be as a result of runoff effect from the dredging site, oil factory and dump site, as well as effluents discharges from the oil factory. These tallies with the results obtained by other researchers [12, 18, 20]

Table 1: Physical Properties of the Ovwian River

Parameters	Temperature (°C)	Total Dissolved Solid (mg/L)	Total Suspended Solid (mg/L)	Electrical Conductivity (μS/cm)	Turbidity (NTU)
Point A1	25.7	28.2	BDL	45	23.26
Point A2	26.51	31.36	4.69	49	58.74
Point A3	25.21	19.84	29.85	31	18.12
Point A4	25.96	19.84	2.1	31	48.46
Point A5	25.7	26.88	5.06	42	12.46
Point B1	25.97	15.36	4.81	24	23.78
Point B2	25.14	21.76	7.28	34	15.04
Point B3	26.76	16.64	3.58	26	46.4
Point B4	25.61	28.8	5.8	45	43.83
Point B5	25.58	16.64	2.65	26	40.75
Point C1	26.62	24.32	8.02	38	42.8
Point C2	26.63	28.16	3.76	44	21.21
Point C3	25.92	17.92	1.73	28	43.83
Point C4	25.73	16	4.32	25	40.75
Point C5	25.73	26.24	22.82	41	38.69

BDL – Below Detection Limit

Chemical Properties

The water pH

It can be observed from Fig. 5 that the Ovwian Section of Udu River has a mean pH of 5.60±0.31 which ranged from 5.34 at Point C5 to 6.56 at Point B5. Only Point B5 fell within the range by the WHO and FEPA standards of 6.5-8.5 and 6.0-9.0 respectively except for Point B5. This makes it harmful for human consumption. The points close to the Oil Factory (Points B1 to B5) have higher average pH values of 5.80±0.45, while the points closer to the dumpsites (C1 to C5) and the dredging site (A1 – A5) recorded lower pH values of 5.40±0.06 and 5.60±0.15 respectively. The pH of the water at the dredging sites and the overall average pH of the water are the same. This shows that the water is more acidic in nature. This may not constitute a serious issue when ingested since the contents of the stomach are naturally acidic. Contrarily, it will pose significant problems in industries and domestic wares because of its potential to aid corrosion [12]. This acidic nature is a characteristic of coastal groundwater which is controlled by the hydro-geological setting [19]. Also, wastes generated and dumped into the water body from the activities (dredging, oil factory and dumpsite) happening around the water body could also have a significant contribution to the acidic nature of the water body. The lower pH values can also be linked with the entrance of humic materials from the dredging site and gas flares from the oil factory into the river, as well as some organic materials [4]. Similar trend on the low hydrogen ion concentration was also observed in previous research [4, 14]. It is also noteworthy that the Ovwian Section of the Udu River has a pH of 5.98 according to previous work [4].

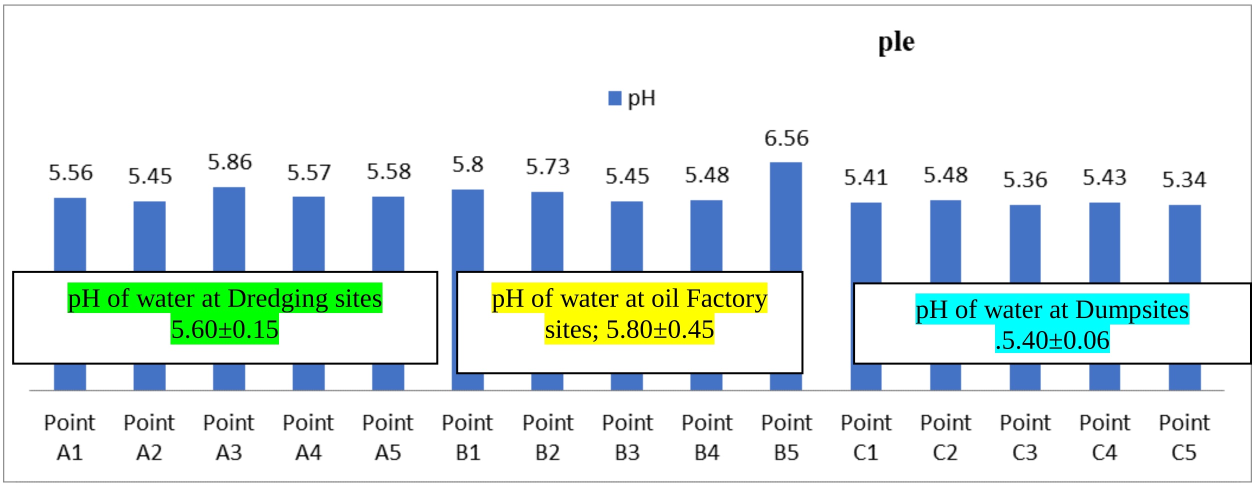

Fig. 6: Distribution of pH of the water sample

Dissolved Oxygen

The values of dissolved oxygen varied from 6.70 mg/L – 7.65 mg/L with a mean dissolved oxygen of 7.23±0.31 mg/L. These values were within the permissible limits of the WHO with the exception of Points A5, with points B2 and C5 on the boundary. As indicated in Table 2, the level of DO at the Dredging sites is greater than the average DO of the sampled water across the three sampling points. The low values observed for DO at all the sampling points could be as a result of incessant introduction of organic materials into the water bodies from the oil factory and dredging site. This results in oxygen uptake or oxidation and decomposition of the organics. Aghoghovwia [14] recorded similar results in his seasonal assessment of Warri River. In the same vein, the results of DO by Okobiebi & Okobiebi and Aliyu *et al.*, [4, 18] fell in the same range.

Biological Oxygen Demand

Likewise, the concentration of biological oxygen demand ranged from ND to 3.1 mg/L with a mean value of 2.01±0.84 mg/L. Figure 6 shows that the average BOD at the Dredging sites of the sampled water was 2.50 ± 0.52 mg/L, 1.98 ± 0.81 mg/L, for oil factory sites, and 1.54 ± 0.99 mg/L, for dumping sites. Dredging sites' BOD is greater than that of the oil factory sites and the dumping sites. As an index for water quality assessment, it is the amount of oxygen required for biological decomposition of organic matter in an anaerobic condition by microbes. The highest values of DOB occurred at sample point A1 and B5 at The values recorded were below the permissible limits for all the standards. Since high BOD values are noted for threatening aquatic lives through depletion of oxygen [18], the low BOD of the sampled water body will enhance their growth. Also, based on the BOD classification where 1-2 mg/L is very clean, 3-5 mg/L as moderately clean and 6-9 mg/L as poor [20], the range of BOD obtained in the water sample showed that the water is clean. Okobiebi and Okobiebi [4] recorded similar result in the study of Udu river.

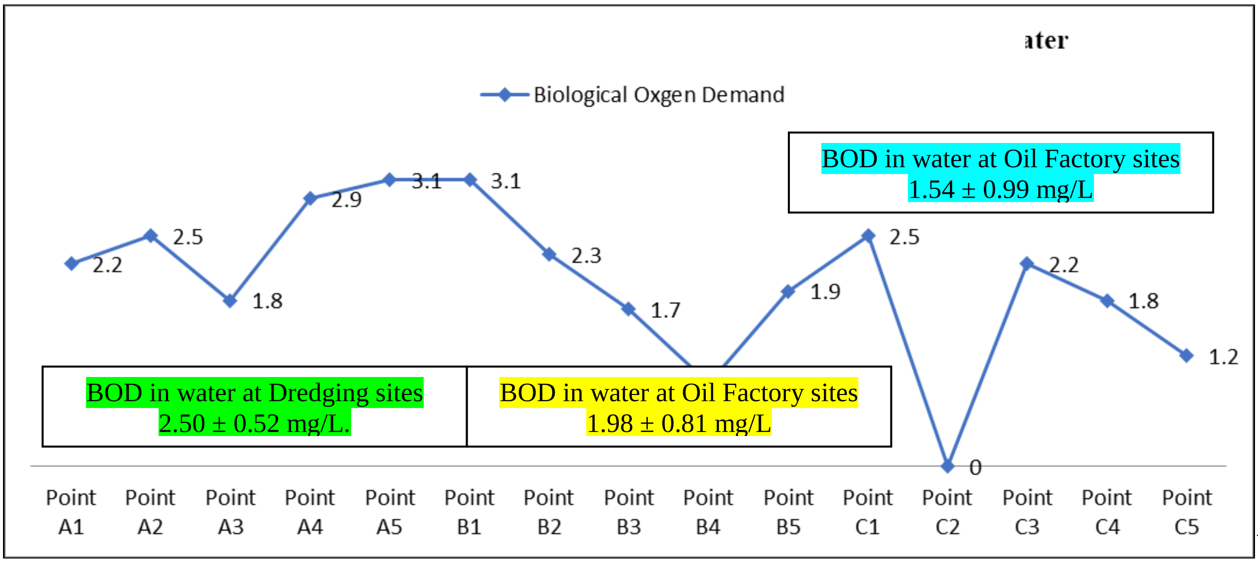

Fig. 7: Distribution of BOD in the sampled water

Water Hardiness

Low levels of total hardness were observed. This ranged from below detection limit to 19.00 mg/L. These concentrations were below the WHO permissible limit. As seen in Table 2, the low levels recorded were in consonance with the TDS values. This shows that very little or no metals were dissolved [20]. It can also be noted that hard water does not lather easily with soap and contributes to incrustation and scaling in boilers and industrial equipment [4]. Following the classification to categorise water where 0-60 mg/L is soft, 61-120 mg/L is moderately hard, 121-180 mg/L is hard and above 280 mg/L is very hard ($CaCO_3$) [20, 23]. The water can thus be said to be a soft water.

Nitrogen Distributions in the sampled water

Nitrogen can be found in the form of nitrites and nitrates in different forms in aquatic and terrestrial ecosystem (Onozeyi, 2013). The nitrite concentrations ranged from 0.062 mg/L to 0.118 mg/L. The nitrates values of the sampled points were below the recommended values of the WHO and FEPA. These values ranged between 0.30 mg/L to 2.15 mg/L and the mean nitrate concentration is 1.06±0.52 mg/L while the mean nitrite concentration is 0.08±0.02 mg/L. Table 2 further reveals that average concentrations of nitrate for dredging and oil factory sites were higher than average nitrate distribution. Since, nitrates contaminates surface water as a consequence of agricultural activities, majorly through the excessive usage of inorganic fertilizers, manures, human or animal wastes, sewage etc.[23, 24] it can be said that less agricultural activities occurs in the region. The low values could also be attributed to utilization by species in the absence of sufficient oxygen [4].

Sulphate Distribution in the water

From Table 2, the sulphate values ranged from 13.01 – 15.21 mg/L. The mean sulphate concentration is 13.90±0.86 mg/L. The concentrations were within the maximum permissible limits of WHO and FEPA. The mean salinity value of the Ovwian section of Warri river is 0.014 ± 0.006 mg/L with variation from 0.00 mg/L – 0.02 mg/L. Oil and Grease values as seen in Table 2 are below the highest permissible limit of FEPA with a range of 0.001 mg/L -- 0.004 mg/L and an average Oil and Grease concentration of 0.005±0.01 mg/L.

Water Alkalinity

Total alkalinity for the water body in this study were low and within the permissible limits of the WHO and FEPA. This ranged from 8.00 mg/L to 12.00 mg/L. Alkalinity and its cultural significance showed that 0-9 is strongly acidic, 10-50 is low alkalinity, and 50-200 is high alkalinity and 211-500 is optimum alkalinity [20]. Given this classification, 46.7% of the sampled points in the Ovwian section of Udu River can be said to be acidic and the rest with very low alkalinity. This was also in conformity with the pH values which indicated acidic and very low alkaline region. The study by Keke *et al*. [20] agreed with this.

Total Coliforms of the Water

The total coliforms analysis showed the presence of microbial activities in all the points sampled. In 46.7% of the sampling points, much growth of the coliform was detected. The others ranged from 21 to 980 CFU/100 mL. Points closer to the dredging site has the highest coliform concentration followed by points closer to the dumpsites and then the oil factory. These are indications of high level of microbial activities or loads on the surface of the water body. This makes it unfit for drinking [12].

Table 2: Chemical Properties of the Ovwian River

Parameters	pH	DO (mg/L)	BOD (mg/L)	Total Hardness (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)	Salinity (mg/L)	Alkalinity (mg/L)	Oil & Grease (mg/L)	Ammonia (mg/L)	Total Coliform CFU/100ml
Point A1	5.56	6.7	2.2	10	0.079	1.051	13.51	0.02	11	0.003	0.012	350
Point A2	5.45	7.1	2.5	7	0.071	0.913	13.31	0.02	9	0.004	BDL	>1600
Point A3	5.86	7.7	1.8	1	0.062	1.899	13.11	0.01	10	0.003	BDL	>1600
Point A4	5.57	7.15	2.9	7	0.065	1.079	14.81	0.01	9	0.003	BDL	>1600
Point A5	5.58	7.65	3.1	3	0.068	1.116	13.31	0.02	9	0.003	BDL	210
Point B1	5.8	7.45	3.1	19	0.107	1.116	15.31	0.01	10	0.002	BDL	48
Point B2	5.73	7.5	2.3	4	0.071	1.023	13.81	0	10	0.004	BDL	920
Point B3	5.45	7.1	1.7	7	0.068	0.36	14.41	0.01	9	0.001	0.012	25
Point B4	5.48	6.7	0.9	10	0.073	1.494	15.51	0.02	10	0.001	0.012	>1600
Point B5	6.56	7	1.9	8	0.069	2.158	13.11	0.01	9	0.003	BDL	24
Point C1	5.41	7.2	2.5	BDL	0.084	0.682	13.51	0.02	12	0.003	BDL	>1600
Point C2	5.48	7.4	0	9	0.078	1.346	13.81	0.02	11	0.007	BDL	>1600
Point C3	5.36	7.05	2.2	8	0.081	0.682	13.1	0.01	8	0.003	BDL	>1600
Point C4	5.43	7.2	1.8	BDL	0.118	0.304	14.91	0.01	10	0.002	BDL	21
Point C5	5.34	7.5	1.2	11	0.065	0.655	13.01	0.02	8	0.04	BDL	26

BDL – Below Detection Limit

Heavy Metals Concentration

The heavy metals concentration in water is a very important parameter owing to their detrimental effects to human on consumption. Chromium was not detected in the water body. Similarly, copper, manganese, cadmium and zinc were not detected in 73.3%, 46.7%, 26.7% and 20% of the samples respectively. For the points where cadmium was detected, the values were above the permissible limit of the WHO while Points A5 and B4 where within the FEPA standard. Zinc values were below the WHO and FEPA standards as seen in Table 3. Lead (Pb) showed a very high concentration above the WHO and FEPA tolerance limits. It was observed in the water samples with concentration ranging from 0.350 mg/L to 3.938 mg/L. Similarly, the iron concentration ranged from 0.254 mg/L to 3.096 mg/L except for Point B4 where it was below detection limit. The values observed were above WHO and FEPA permissible limits with the exception of Point B4. The high values maybe attributed to the different wastes components from the dredging site and the oil factory. Also, there is possibility of leachates from the dumpsites contaminating the water body as a result of disposal of batteries, lead-based paints, lead pipes and scraps found at the dumpsite [19]. Copper was only detected at three points with concentrations of 0.041 mg/L (Point A2), 0,052 mg/L (Point B4) and 0.088 mg/L (Point C3). Points B4 and C3 were above the WHO standard. For zinc, the concentrations were within the WHO and FEPA set limits. It was also below the detection limits at three points (A3, B1 and C2). Similar values were also obtained for cadmium. While Points A1 to A4 were below detection limit, other concentrations obtained ranged from 0.028 mg/L to 0.092 mg/L. The recorded values were above the maximum limits set by the WHO.

Some of the concentrations recorded are similar to the results by Okobiebi and Okobiebi in the Ovwian section of the Udu River [4]. However, the variation could be attributed to some factors such as pH, temperature, chelating agents etc. [24].

Table 3: Heavy metal distribution in the Ovwian River

Parameters	Lead, (mg/L)	Iron, (mg/L)	Copper, (mg/L)	Zinc (mg/L)	Chromium (mg/L)	Manganese (mg/L)	Cadmium (mg/L)
Point A1	0.938	1.664	BDL	0.035	BDL	BDL	BDL
Point A2	2.023	1.834	0.041	0.085	BDL	0.021	BDL
Point A3	2.433	2.986	BDL	BDL	BDL	0.133	BDL
Point A4	0.488	2.758	BDL	0.013	BDL	0.128	BDL
Point A5	1.443	0.703	BDL	0.022	BDL	0.022	0.028
Point B1	2.346	2.486	BDL	BDL	BDL	BDL	0.092
Point B2	2.845	2.439	BDL	0.017	BDL	0.189	0.066
Point B3	3.119	1.318	BDL	0.071	BDL	0.79	0.065
Point B4	2.498	BDL	0.052	0.061	BDL	BDL	0.033
Point B5	2.101	0.254	BDL	0.019	BDL	0.899	0.067
Point C1	0.35	1.65	BDL	0.097	BDL	BDL	0.053
Point C2	2.179	0.943	BDL	BDL	BDL	BDL	0.057
Point C3	2.539	3.096	0.088	0.006	BDL	BDL	0.073
Point C4	2.445	0.779	BDL	0.017	BDL	BDL	0.052
Point C5	3.938	2.048	BDL	0.002	BDL	0.667	0.157
Mean	2.112333	1.782714	0.060333	0.037083	#DIV/0!	0.356125	0.067545
St.dev.	0.966068	0.902352	0.024583	0.032684	#DIV/0!	0.365144	0.034584

Table 4: Water Quality Standard Range by WHO and FEPA for Drinking Water [4, 12, 18, 20, 23]

Parameter	**WHO Standard**	**FEPA Standard**	**This present study**
pH	6.5 – 8.5	6.0 – 9.0	5.34 - 6.56
Total Hardness (mg/L)	75	-	BDL – 11
Total Hardness (mg/L)	500	100	BDL – 11
Total Dissolved Solids (mg/L)	7.5	-	15.36 – 31.36
Total Suspended Solids (mg/L)	20	30	BDL – 29.85
Electrical Conductivity (µS/cm)	300	-	24 – 49
Total Coliform Count	10	0	21 - > 1600
Alkalinity (mg/L)	500	100	131 – 15.21
Sulphate (mg/L)	250	250	13.01 – 15.21
Ammonium (mg/L)	1.5	0.01	BDL – 0.012
Temperature (^oC)	25	30	25.14 – 26.24
Biological Oxygen Demand (mg/L)	10	10	0.90 – 3.10
Turbidity (NTU)	5-25	5	12.46 – 58.74
Oil and Grease	-	10	0.001 – 0.04
Nitrate (mg/L)	50	20	0.304 –2.158
Copper (mg/L)	0.05	0.5	BDL – 0.088

Zinc (mg/L)	3.0 (0.1 – Drinking Water)	1.0	BDL – 0.085
Iron (mg/L)	0.03	0.3	BDL – 3.096
Lead (mg/L)	0.01	0.05	0.35 – 3.94
Chromium (mg/L)	0.05	0.05	BDL
Cadmium (mg/L)	0.003	0.05	BDL – 0.157
Manganese (mg/L)	0.1	0.3	BDL – 0.899

Source: Author's compilation from the literature

Physico-Chemical Parameters and Heavy Metal Concentration of the sampled water

There is a potential relationship among the level of heavy metal concentration in the water and the trend of some physic-chemical characteristics. Heavy metals can contaminate wells through groundwater movement and run-off. Hence, People that consume high levels of heavy metals risk acute and chronic toxicity, liver, kidney, and intestinal damage, anemia, and cancer. From the result in the correlation matrix in Table 5 shows that there is a negative relationship between electrical conductivity (EC), and some metal concentration. For instance, the coefficient of the correlation between EC and Iron (Fe) is -0.254 and -0.1179 for lead (Pb). This is however unexpected because, the level of metal concentration is expected to spur electrical conductivity of the water.

Also, the result in Table 5 reveals that there is positive correlation of 0.767 (76.7%) between EC and the level of salinity of the water. Here, the higher the level of water salinity, which denotes the amount of dissolved salt in the water, could enhance the extent of electrical conductivity of the water. The rate of Total Dissolved Solid (TDS), Temperature (TEMP), Total hardiness (TH), and Total Suspended Solid (TSSS) all exhibit positive correlation with electrical conductivity of the water at 0.999 (99.9%), 0.150 (15%), 0.004 (0.4%), and 0.0027 (2.7%) respectively. In terms of TDS, the correlation coefficient is high and this could mean that the higher the level of concentration of dissolved solids in the water, the higher the level of electrical conductivity. Turbidity of the water however shows negative correlation with the electrical conductivity of the water at -0.028 (-2.85).

Table 5: Correlation matrix of Physico-chemical parameters of the water and heavy metal concentration

	EC	Fe	Pb	pH	SALINITY	TDS	TEMP	TH	TSS	TURBIDITY
EC	1									
Fe	-0.254	1								
Pb	-0.179	0.004	1							
pH	-0.386	-0.175	-0.040	1						
Salinity	0.767	-0.411	-0.251	-0.389	1					
TDS	0.999	-0.256	-0.172	-0.388	0.766	1				
TEMP	0.150	-0.125	-0.201	-0.419	0.416	0.155	1			

TH	0.004	0.071	0.252	0.095	0.100	-0.001	0.093	1		
TSS	0.027	0.331	0.403	0.018	0.004	0.034	-0.368	-0.215	1	
TURBIDITY	-0.028	-0.074	-0.027	-0.220	0.149	-0.022	0.479	0.015	-0.238	1

EC: Electrical conductivity; Fe: Iron; Pb: Lead; pH: Potential of Hydrogen; TDS: Total Dissolved Solids, TEMP: Temperature; TH: Total hardness of the water, TSS: Total Suspended Solids.

Source: Author's compilation from the literature

Conclusion

Water is a very important natural resource in the environment with multivariate usage in the homes, agriculture, industries etc. Unfortunately, it is contaminated at various points and degrees causing varying degrees of pollution to the water body. This study revealed the current physical and chemical properties, as well as the heavy metals concentrations of the Ovwian section of the Udu River in Delta State. Through this, it was established that anthropogenic activities (dredging, oil factory and dump site) happening around the region are some of the important factors affecting the water quality of the water body. The physico-chemical properties of the water body were compared with the standards of national (FEPA) and international (WHO) regulatory agencies. While some of the parameters were within the permissible limits of the standards, others were above the permissible limits. Since, not all the parameters agreed with the set standards by the regulatory agencies, the water cannot be said to be fit for human consumption and other organisms. As such, the water can be said to be unsuitable for drinking. Appropriate treatment is therefore advised if it must be used for portability.

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