SPATIAL AND MONTHLY CHANGES IN INTERSTITIAL WATER PHYSICO-CHEMISTRY OF BODO CREEK

Abstract

Water plays a key role in the survival, growth and reproduction of aquatic organisms. Therefore maintaining good quality of water physico-chemical parameters would ensure optimum productivity of aquatic fauna. The study evaluated water physical and chemical parameters (temperature, hydrogen ion concentration (pH), conductivity, dissolved oxygen (DO) and biochemical oxygen demand (BOD) of Bodo Creek. Sample was collected for 5 months (July 2020 – November 2020) at locations previously studied (before-spill baseline studies, 3 years, 5 years, and 7 years after-spill); by using the sampling methods used in previous studies. Spatially, there was no statistically significant difference in temperature ($p > 0.05 = 0.997$), pH ($p > 0.05 = 0.496$), DO ($p > 0.05= 0.34$) and BOD ($p > 0.05 = 0.644$). However, the difference in conductivity between the stations was statistically significant ($p < 0.05 = 0.006$). On monthly basis, there was a significant difference in temperature ($p < 0.05 = 0.000$) and pH ($p < 0.05 = 0.005$). In contrast, there was no statistically significant difference in conductivity ($p > 0.05 = 0.633$), DO ($p > 0.05 = 0.559$) and BOD ($p > 0.05 = 0.75$). Most of the physico-chemical parameters were not within the WHO recommended levels for the survival of aquatic lives, indicating a high level of environmental pollution in Bodo Creek. This study provides dataset for future evaluation of the water physico-chemistry of Bodo Creek.

Keywords: *Water quality, variations in space, interstitial, physico-chemical parameters and tide.*

I. Introduction

Bodo is a coastal community located in Gokana Local Government Area, Ogoni in Rivers State, Niger Delta, Nigeria. Other Local Government Areas that make up Ogoni are Khana, Tai and Eleme. Politically, the Bodo community is in the South East Senatorial District of Rivers State. Bodo is a rural community occupying (latitude 4836’N, longitude 7821’E) in the upper reaches of Andoni-Bonny estuarine ecosystem. Mangrove swamps, some island forests and brackish water creeks occupy over 65% of the community. This is generally called Bodo Creek. Every day, the creeks in Bodo are exposed and submerged due to the influence of low and high tide, respectively. The community is divided into 35 villages under the leadership of a monarch king and his council of chiefs [1]. According to [2] the bulk of periwinkle, *Tympanotonus fuscatus* that are sold in the markerts of Bodo, Bori and Onne communities come from Bodo Creek. They also reported that some industrial development such as an uncompleted 500 hectares fish farm owned by the Niger Delta Basin Development Authority (NDBDA) and Bodo West Oilfield are supported by the Creek.

Water is a basic life supporting system for the survival, growth and reproduction of aquatic organisms. Water also serves as a means by which fishing boats or fishing trawls are moved from one point to the other, for small scale fish farmers and industrial fishers respectively. According to [3], water is a basic component of the changing aquatic life-supporting system for the dissolution or suspension of organic and inorganic substances and which supports existence of and interactional relationship between a wide variety of organisms.

Water body pollution in the developing countries has reached an alarming state, Nigeria inclusive. There are several literatures for physico-chemical parameters of surface water in Nigeria (Vincent *et al*., 2020). According to [4], water bodies have been exposed to different forms of degradation as a result of pollution coming from domestic waste, industrial activities; run offs from agriculture and transportation activities. In 2008, there were two major oil spill incidence in Bodo Creek. Several studies have been carried out in Bodo Creek to assess water physico-chemical parameters pre-spill [1; 6; 7] and post-spill [8; 9; 10].

II. Material and Methods

Description of the study area

Bodo Creek is located between the river estuaries of Bonny and Andoni. The hydrology and complex of the creek have been described. The study area is a shallow mangrove ecosystem under tidal influence that supported fisheries for local residents before the oil spills [11; 1; 12]. There is an eight months rainy season, from April to November, while the short dry season spans from December to March (four months) with occasional rainfall [13].To determine the spatio-temporal variation in interstitial water physico-chemical parameters in the creek, four stations previously sampled before the oil spill, 3 years after the oil spill [11], 5 years after the oil spill [14] and 7 years after the oil spill [10] were re-sampled.

Sampling sites and their locations

Station 1: This station is located upstream with sandy mud as the substratum. This station is traditionally called "Sivibilagbara" and is located on the right-hand side of the main channel known as ‘’Dor Nwezor’’ at a latitude of 4˚36’29.7’’ N and a longitude of 7˚15’30.2’’E. Dead mangrove stumps occupy the mudflat. Large scale unvegetated muddy intertidal flat characterizes the station. Under the Bonny-Bodo overhead bridge located about 40 m from the station is a landing jetty. About 60 m from the station on the opposite side of the ‘’Dor Nwezor’’channel, there is a human settlement. There is fishing activity along the “Dor Nwezor” channel, on the left-hand side of station 1.

Station 2: This station is located downstream of station 1, about 1.2 km from station 1, with sandy mud as the substratum. This station is locally called “Si Eeva”, occupying a latitude and longitude of 4˚36’12.7’’N and 7˚16’08.1’’E, respectively. The riparian zone of the station is dominated by dead mangrove stumps. Toward the land, there are terrestrial plants such as mango, coconut, and palm trees. On the right-hand side of this station, along the “Dor Nwezor” channel, there is fishing activity.

Station 3: This station is located downstream of station 2, about 955.58 m from station 2. There is a large expanse of unvegetated sandy intertidal flats in this station. Located on the left of "Dor Nwezor" main channel, opposite a small fishing settlement known as ''Kozo'' occupying a latitude of 4°35'55.3''N and a longitude of 7°16'33.8''E. Traditionally this station is called ''Kozo''. Towards the land are terrestrial plants such as palm trees and mango. Kozo is located about 30 m away from the small fishing settlement. Station 3 is the most elevated of all the stations. Along the "Dor Nwezor" channel, located on the right-hand side of station 3, fishing activity goes on. Also, during low tide, sea foods such as periwinkles are picked on the intertidal flat at station 3.

Station 4: This station is located 994 m downstream of station 3, occupying a latitude of 4° 35'32.4''N and a longitude of 7°16'56.6''E. The site is characterized by a sandy mud substratum. The unvegetated sandy intertidal flat at this station is massive. This station is known as Sigberebala traditionally. Fishing activity goes on along the main channel of "Dor Nwezor" channel, located on the left-hand side of station 4. Periwinkles are also picked on the intertidalflat on station 4 during the low tide.

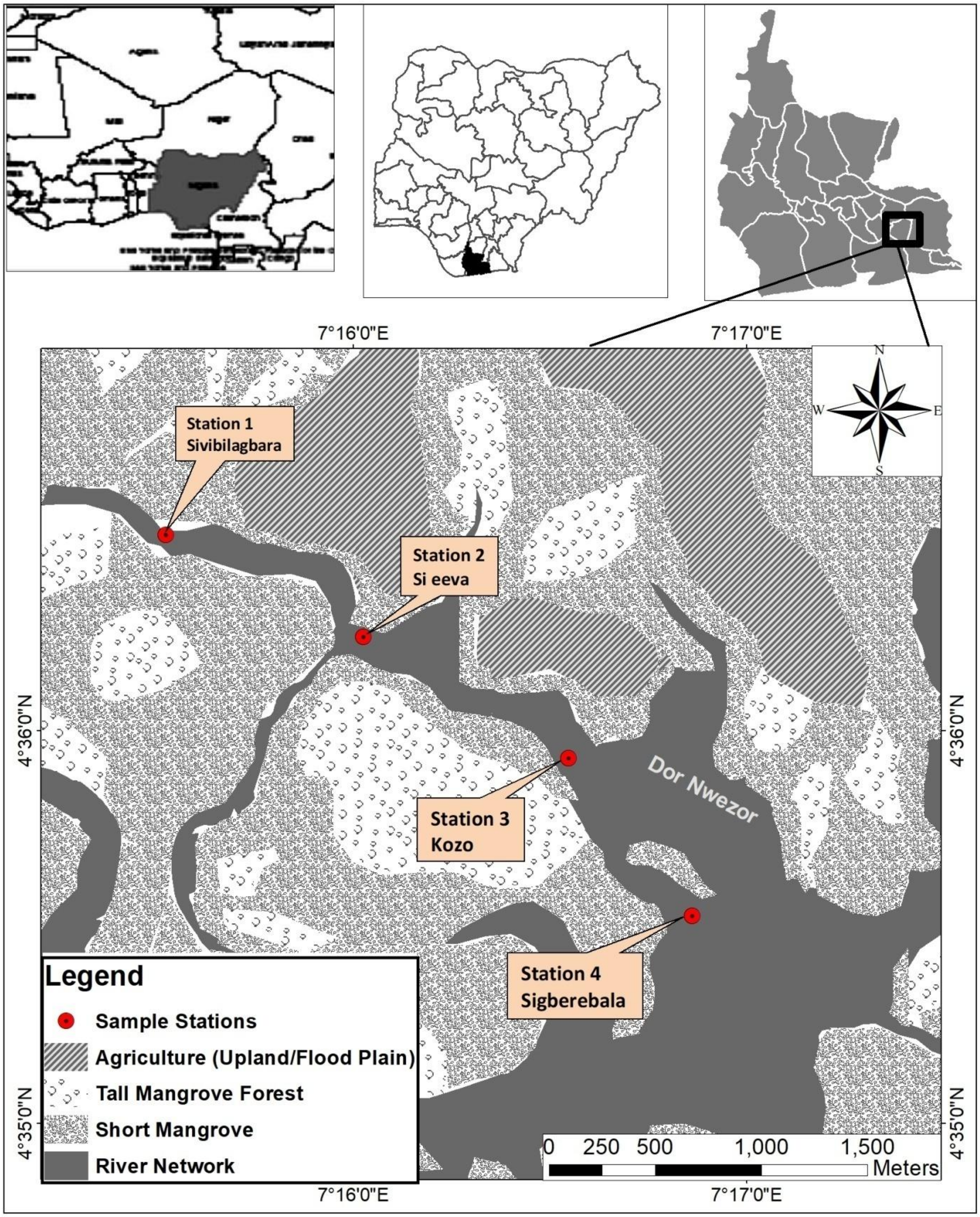

Fig 1: Map of Bodo Creek showing sampled station

Field and laboratory procedures

Samples were collected from the designated stations every month for five months (July 2020 – November 2020). The monthly sample collection was done at low tide because during this period, the intertidal flats were exposed. The sample was collected during spring and neap tide to be an actual representative. A 30 cm × 30 cm quadrat was randomly thrown to dig sediments with a spade, to allow interstitial water enter the dug-out holes. The dug-out hole was limited to 20 cm depth. Interstitial water samples in the infauna dug-out holes was collected and analyzed as follows for the physico-chemical parameters:

A hand held digital multimeter (Go n DO multimeter CTS-406) was used in measuring temperature, pH and conductivity in-situ. The probe was dipped about 5cm into the interstitial water, allowed for an interval of 2 minutes for stability; the reading of temperature was to the nearest 0.1^{o}C. Dissolved oxygen (DO) was measured with a Milwaukee DO meter (MW 600). One amber 250ml BOD bottle (Winchester bottle) per station was used to collect the interstitial water, transported in ice-chest to the laboratory for BOD analysis.

Statistical analysis

Analysis of Variance (ANOVA) in SPSS version 22 at 95% confidence limit was used to show the variation in physico-chemical parameters between stations and months.

III. Results

Table 1: Variations in spatial mean and ranges of physico-chemical parameters in Bodo Creek interstitial water (July 2020 – November 2020)

Parameter	STATION 1	STATION 2	STATION 3	STATION 4	P-Value
Temp.(^{o}C)	27.88 (25.4-32.1)	28.14 (25.8-34.3)	28.16 (25.6-34.3)	28.38 (23.8-35.6)	0.997
pH	8.40 (7.8-8.8)	8.50 (7.3-9.3)	8.82 (7.5-9.6)	8.94 (8.1-9.5)	0.496
Cond.(ms/cm)	9.49^{b} (9.48-10.04)	8.64^{b} (7.61-9.49)	5.57^{a} (0.43-8.1)	8.84^{b} (8.22-9.25)	0.006
DO (mg/L)	2.60 (1.6-3.5)	2.44 (1.4-2.9)	2.04 (0.9-2.8)	1.66 (0.2-2.8)	0.34
BOD (mg/L)	1.34 (0.5-4.1)	1.40 (0.5-4.2)	2.20 (068-4.5)	2.78 (0.8-7.0)	0.644

*Means with different superscript in the same rows are significantly different ($p<0.05$)
**Means with the same superscript in the same rows are not significantly different ($p>0.05$)

Table 2: Temporal variation in mean and ranges of physico-chemical parameters in Bodo Creek (July 2020 – November 2020)

Month	Temp.(^oC)	DO (mg/L)	pH	Cond.(ms/cm)	BOD(mg/L)
July	27.20^a	2.83	8.98^{bc}	8.17	0.73
	(27.0-27.4)	(2.6-3.2)	(8.6-9.3)	(5.63-9.49)	(0.6-0.8)
August	26.80^a	2.43	8.65^b	8.89	2.20
	(26.6-27.0)	(0.2-3.5)	(8.4-8.9)	(7.45-9.62)	(0.5-7.0)
September	26.60^a	1.90	8.75^b	8.88	1.80
	(23.8-28.1)	(0.9-2.5)	(8.2-9.1)	(8.1-10.04)	(0.8-4.4)
October	26.03^a	1.98	7.73^a	6.77	2.45
	(25.4-27.3)	(1.4-2.8)	(7.3-8.3)	(0.43-9.48)	(0.6-4.2)
November	34.08^b	1.93	9.30^c	7.73	2.45
	(32.1-35.6)	(0.9-2.9)	(8.8-9.6)	(6.25-8.82)	(0.5-4.5)
p-Value	0.000	0.559	0.000	0.633	0.75

*Means with different superscript in the same column are significantly different ($p<0.05$)
**Means with the same superscript in the same column are not significantly different ($p>0.05$)

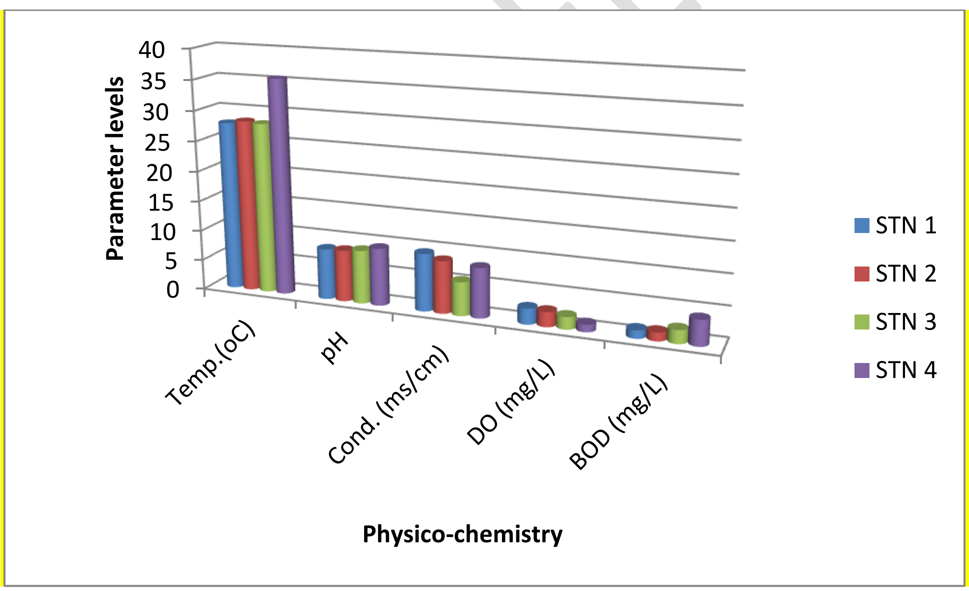

Figure 2: Spatial variations in physico-chemistry of Bodo Creek (July 2020- November 2020)

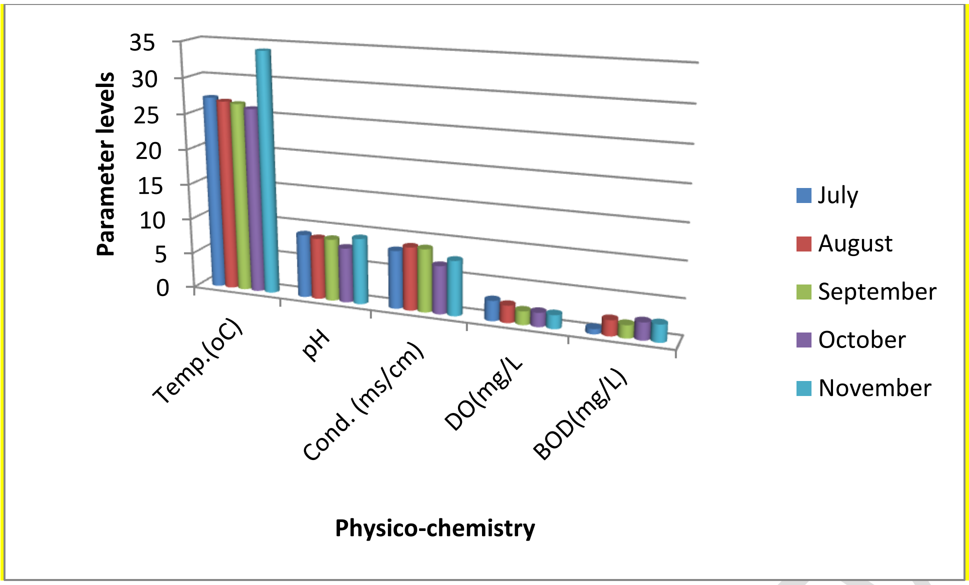

Figure 3: Temporal variations in physico-chemistry of Bodo Creek (July 2020- November 2020)

Temperature ranged from 23.8°C to 35.6°C, there was no statistically significant difference in ($P > 0.05 = 0.997$) in temperature, between the stations (Table 1). Temperature peaked at station 4 and was least at station 1 (Figure 2). Temporarily, temperature varied significantly ($P < 0.05 = 0.000$) between months (Table 2), having a peak in November and a minimum value in August (Figure 7). Hydrogen ion concentration (pH) ranged from 3.5 to 9.6 between the stations. pH did not vary significantly ($P > 0.05 = 0.496$) between stations (Table 1). pH was maximum in station 4 and minimum in station 1 (Figure 3). Between the months, pH ranged from 3.5 to 9.6, there was statistically significant difference ($P < 0.05 =0.000$) in pH (Table 2). Hydrogen ion concentration (pH) was lowest in October and peaked in November (Figure 8).

Spatially, conductivity ranged between 0.43 ms/cm and 10.1ms/cm, there was statistically significant difference ($P < 0.05 = 0.006$) in conductivity; conductivity peaked at station 1, while its lowest value was at station 3 (Table 1; Figure 4). On a monthly basis, there was no statistically significant difference ($P > 0.05 =0.633$) in conductivity, having a range from 0.43 ms/cm to 10.1 ms/cm (Table 2). Conductivity was maximum in August and minimum in October (Figure 9). Dissolved oxygen (DO) did no vary significantly ($P > 0.05 = 0.34$) between stations; DO ranged from 0.2mg/l to 5.8mg/l (Table 1). Dissolved oxygen (DO) was minimum in station 4 and maximum in station 1 (Figure 5). The value of dissolved oxygen (DO) between the months was not statistically significant ($P > 0.05 = 0.559$); DO was minimum in September and maximum in July (Table 2; Figure 10). Between stations, biochemical oxygen demand (BOD) ranged from 0.3mg/l to 7mg/l; there was no statistically significant difference ($P > 0.05 = 0.373$) in BOD (Table 1). Biochemical oxygen demand (BOD) was maximum in station 4 and minimum in station 1 (Figure 6). The value of biochemical oxygen demand (BOD) between the months was not statistically significant ($P > 0.05 = 0.75$); BOD was minimum in July and maximum in November (Table 2; Figure 11).

IV. Discussion

There was a limited influence of sun heating on the sediment at station 1, due to the shade provided by the thick mangrove canopy in the station. This was responsible for the lowest temperature level in station 1. There was a clear trend of increasing temperature values downstream between the exposed, unvegetated intertidal flats (stations 1-4), therefore mean temperature peaked at station 4. Maximum temperature at station 4 could be an indication that sampling at the station coincided with very high sun. According to [7], during low tide, the temperature of exposed pore water may rise too high or fall suddenly when the sun is shining or in rains respectively. The rise in temperature at station 4 could not have been as a result of intertidal flat elevation, since station 3 was the most elevated of all the stations sampled. As the air temperature increases, intertidal flat temperature increases as well (Eltringham, 1971; Kennedy *et al*., 1974). The mean monthly temperatures (23.8^{o}C-35.6^{o}C) over a period of 5 months were in conformity with the Niger Delta seasonal pattern [7]. A long rainy season is a major feature of the Niger Delta [17]. [7] reported maximum temperature in March, while working in the same sampled stations in Bodo Creek. However, maximum temperature in this study was in November.

Conductivity depends on changes in dissolved solids, especially mineral salts, indicating how fresh or otherwise is the water body (Egborge, 1994). Least conductivity value recorded in station 3, is in agreement with the conductivity level at station 3, in a previous study by [7]. The low conductivity values at station 3 could be as a result of groundwater freshwater seepages. Conductivity of the creek was within the range for brackish water. There was an inverse relationship between conductivity and pH. For example, conductivity was maximum in station 1, while pH was minimum in station 1. There was an inverse relationship between temperature and dissolved oxygen (DO). For example, DO was maximum at station 1 and minimum at station 4, while temperature was maximum at station 4 and minimum at station 1. The least DO concentration at station 4 could be attributable to least vegetation cover resulting from the death of existing mangroves as a consequence of oil spill from oil exploration activities in the creek. The lack of vegetation cover in the long run resulted in excessive heating of the intertidal flat at station 4, in comparison with other stations. Overheating of station 4 could have been responsible for the least dissolved oxygen concentration at the station.

Reduced concentration of DO can also be indicative of decaying organic matter presence, eventually evolving toxic gases such as methane and hydrogen sulphide [19]. Underground water seapage can also result in reduced salinity and eventually increase in dissolved oxygen level. There was an inverse relationship between dissolved oxygen (DO) and biochemical oxygen demand (BOD). For example, DO was maximum in station 1 and minimum in station 4, while BOD was maximum in station 4 and minimum in station 1. In comparison with the results on physico-chemical parameters from previous pre-spill studies by [7] as well as [6], temperature, pH, conductivity and BOD in this study are higher, while BOD is lower than the values recorded in their studies.

Generally, in comparison with the World Health Organization, WHO (2006) recommended standard of physico-chemical parameters for survival of aquatic lives, temperature (23.8^{o}C-35.6^{o}C) was a little above the WHO value (25^{o}C-32^{o}C), pH (3.5-9.6) was below the recommended value (6.50-8.50), conductivity (0.43ms/cm-10.1ms/cm) was above the recommended value (2ms/cm). Also, dissolved oxygen, DO (0.2mg/L-5.8mg/L) was below the

WHO recommended value (>4mg/L), while biochemical oxygen demand, BOD (0.3mg/L-7mg/L) was above the recommended value (0-6mg/L).

V. Conclusion

The physico-chemical parameters reported in this study show spatial and monthly fluctuation. In most cases, the measured variables were not within the WHO recommended levels for the survival of aquatic lives, indicating a high level of environmental pollution in Bodo Creek.

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