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Assessment of the Physicochemical Parameters of Bodo Creek, Rivers State, Nigeria: A Pre-spill, Post-spill and Post-clean-up Review

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ABSTRACT: Water bodies are a source of ecosystem services such as water supply, production, recreation, and aesthetics. In 2008, two major oil spills took place in Bodo creek. A major challenge with the assessment and monitoring of an environment is the lack of baseline data. However, Bodo Creek has been studied extensively. This paper, therefore, reviews pre-spill, post-spill, and post-clean-up studies on physicochemical parameters in Bodo Creek. This paper revealed that the difference in the levels of the physicochemical parameters including pH, salinity, dissolved oxygen (DO), biochemical oxygen demand (BOD), and temperature in Bodo Creek, before and after the oil spill was not statistically significant ($P > 0.05$); other physicochemical parameters examined in this paper are alkalinity, total hardness, chemical oxygen demand (COD) and total dissolved solids (TDS). This paper also revealed that pH and temperature were higher in the post-cleanup study, while DO and conductivity were higher in the pre-cleanup study. BOD was significantly higher in the post-spill study than the pre-spill study, indicating a high level of pollution as a result of the oil spill. This review also shows that there are higher pH and temperature levels in post-clean-up studies than the pre-cleanup studies. Pre-clean-up DO and conductivity were higher than the levels in the post-clean-up study.

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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 Awah (2008), water is a basic component of the changing aquatic life-supporting system for the dissolution or suspension of organic and inorganic substances and supports the existence of an interactional relationship between wide varieties of organisms. According to a study by Onwugbuta-Enyi *et al*. (2008), water bodies are a source of ecosystem services, for example, water supply, production, recreation, and aesthetics; the availability of water inadequate quality and quantity contributes to health maintenance,human activities deteriorate surface water. Zabbey and Arimoro (2017) identified hydrology, Physico-chemical parameters, and biological communities as the three basic components of water quality studies. According to their report, sediment and interstitial water environmental quality are linked mutually to the changing conditions of the overlying water column, due to bottom-up and top-down fluxes between the ecological parameters of the two components, depending on the surrounding ambient conditions. According to Onwugbuta-Enyi *et al*. (2008), Physicochemical and biological factors determine the quality of any given water body, as there is an interactional relationship between these factors and with an intrinsic parameter of each variable to highly determine the water quality characteristics. Water quality affects the composition of species, distribution, and assemblages of plankton, benthos, and fish. Water body pollution in the developing countries has reached an alarming state, Nigeria inclusive. There are several works of literature for Physico-chemical parameters of surface water in Nigeria (Vincent et al., 2020). According to Vincent-Akpu and Nwachukwu (2016), water bodies have been exposed to different forms of degradation as a result of pollution coming from domestic waste, industrial activities; runoffs from agriculture and transportation activities.They further stressed that recently, transportation activities have been associated with increasing levels of environmental impact.Their study also revealed that using waterways for inland navigation may be a source of threat to aquatic organisms and can have significant

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impacts on the water bodies.The impact includes the change in hydrological conditions; water quality deterioration and as a source of pollutant emission. They also reported that there is an increase in the demand for water transport; resulting in chemical substances (especially oil) spills from ships, the release of nutrient overload, and invasion by species representing an important aspect of water quality. Some of the wastes from water transportation are sewage, gray and bilge water, gas emissions, solid and hazardous waste, with metals, mineral oil and lubricants, and organic substances as main constituents.

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, Bodo community is in the southeast Senatorial District of Rivers State. Bodo is a rural community occupying (latitude 4836'N, longitude 7821'E) in the upper reaches of the 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 the low and high tide, respectively. The community is divided into 35 villages under the leadership of a monarch king and his council of chiefs (Onwugbuta-Enyi *et al.,* 2008).

*Crude Oil Exploration and Exploitation, Oil Spill and Its Effects on Water Quality:*For over 5 decades, the exploration and exploitation of crude oil have been the major contributor to the economy of Nigeria. There is a significant oil reserve and natural gas, estimated at 37.4 billion barrels (OPEC, 2017) and 192 trillion standard cubic feet, respectively, in the Niger Delta region, which produces the oil. Crude oil in marketable quantity was first discovered in Oloibiri, Bayelsa State, Nigeria in the year 1956 (NDDC, 2001; Okonta, 2008). Twenty years later (1958), crude oil was discovered in second commercial quantity at the oil field in Bomu, Ogoni, Rivers State. The later discovery of oil made a significant contribution to the first export of oil from Nigeria to other countries. This was later expanded to fifty-seven oil wells, having five flow stations in Ogoni. There is a flow station called Bodo West field located in Bodo Creek mangrove mainland, Ogoni (UNEP, 2011; Linden and Palsson, 2013; Zabbey and Uyi, 2014). In 2008, two major oil spills occurred in Bodo Creek (Nkeeh *et al*., 2021). Although two major oil spills resulted from the activity of oil multinationals in Bodo Creek in 2008, oil spill from artisanal refining of crude oil is also a major challenge impacting negatively on Bodo Creek. According to a study by Sibe *et al.* (2019), artisanal refining is used to describe the illegitimate distillation of crude oil in locally constructed stills. This activity has greatly heightened the level of environmental pollution and degradation as a result of oil exploration and exploitation. The study further stated that artisanal refinery is usually cited on the coastline of creeks, lakes, seas, e.t.c., thus destroying the biodiversity and leading to ecological imbalance. Also, in Bodo West, in Bonny LGA, an increase in artisanal refining between 2007 and 2011 has been accompanied by 10 percent of healthy mangrove cover, or 307,381m^2.According to Sibe *et al*. (2019), crude oil is released into the sea, creeks, during bunkering, transportation of the crude to site, and during the refining process. Bunkered oil is transported by canoe which mostly has leakages that allow for seepages into the river. Their study, however, reported that the main source of hydrocarbon contamination from artisanal refining is accidental disposal of crude oil, refined fractions, and indiscriminate storage of the heavy and bottom fractions of the petroleum refining process. Heavier fractions such as bitumen and lubricating oil cannot be processed by the refinery facilities. Therefore, they are usually stored or disposed of in pits around the refining sites. According to Attah (2012), the process is highly inefficient that most likely as much as 80 percent of the bottom fractions of the crude oil cannot be refined and are therefore discharged indiscriminately into the environment; which are eventually washed into the sea, river or lake when the tide is high and are deposited at the foreshore and seabed (Sibe *et al*., 2019).The Niger Delta over the years has experienced several oil spill incidents. According to Dan-Kalio and Braide (2002), there could be disastrous consequences following oil pollution and Nigeria has experienced some disasters from oil blowouts in addition to oil pollution from other sources. This includes blowouts and pipeline leakages from the Shell-Bp Bomu 11 in 1970, the Safran (now Elf) Obagi 21 blowout of 1972, the Texaco blowout of 1980, and the AgipOyakama pipeline leakage of 1980, have all led to disastrous impacts on land, freshwater swamps, and the marine environment. Globally, there have been recorded incidents of major oil spills. This ranges from the World's largest known oil spill known as the Persian Gulf War Oil Spill in 1991, to BP's Deepwater Horizon oil spill in 2010. Other major oil spills include; the Ixtoc 1 Oil Spill (1979), the Atlantic Empress Oil Spill (1979) and the Mingbulak (or Fergana Valley) Oil Spill (1992), the Kolva River Spill (1994), the Incidents at the Nowruz Oil Field, the Castillo de Bellver Oil Spill (1983) and the Amoco Cadiz Oil Spill (1978) (EBI, 2021). Oil spills have a potential negative impact on the stability of freshwater and marine ecosystems, having been reported to impact negatively on near-shore biodiversity (Smeltz *et al*. 2017) and functioning (Kotta *et al*. 2007; Venosa and Zhu 2005). In the Niger Delta region of Nigeria, reputed as the Nation's oil and gas region, there is the frequent occurrence of oil spills and the impacts persist as a result of the poor management regimes for clean-up and remediation (UNEP 2011; Sam et al. 2017a). Studies have shown that contamination resulting from oil spill incidents have the potential to alter the hydrology, disrupt plant-water relation, reduce the exchange of oxygen, lead to growth inhibition and reduction in fish production, and interfere with the ecological food chain and web (Ko and Day 2004; Nwipie *et al*., 2019).

*Global Overview of Physicochemical Parameters of Water***:** In a study on the evaluation of Physico-chemical parameters of Manchar Lake water, Pakistan, and their comparison with other global published values by Arain *et al*. (2008), they concluded that the water samples of the study area are polluted; they attributed this to wastewater coming from agricultural land as well as domestic wastes of Urban areas. The correlation study on Physico-chemical parameters and quality assessment of Kosi River Water, Uttarakhand, India, revealed that all the measured physico-chemistry of the study area are within the WHO maximum permissible limit. The only exemptions were turbidity and BOD (Bhandari and Nayal, 2008). According to Simpi *et al.* (2011), in the analysis of water quality using Physico-chemical parameters of Hosahali Tank in Shimoga District, Karnataka, India, stated that all measured Physico-chemical parameters were within the permissible limits. Gereyohannes *et al*. (2015) in the investigation of Physico-chemical parameters and its pollution implications of Ella River, Mekelle, Tigray, Ethiopia reported that throughout the river, there was pollution generally. Their study further stated that the pollution poses a danger to aquatic lives, the river as well as those who use it for domestic applications and other activities. According to Mezegbe *et al*. (2015) in the assessment of physico-chemical parameters of TsaedaAgam River in Mekelle City, Tigray, Ethiopia stated that most of the Physico-chemical parameters exceeded the WHO permissible limit for drinking water. The study however noted that the water can be used for irrigation because most of the parameters are within the FAO permissible limit. Adeyemo *et al.* (2008) evaluated the seasonal changes in Physico-chemical parameters and nutrient load of river sediments in Ibadan City, Nigeria. They reported that the Physico-chemical quality of water in the study area was deteriorating at an alarming rate. Edori *et al.* (2020) evaluated the variation of some Physico-chemical parameters in surface water of Elelenwo River, Rivers State, Niger Delta, Nigeria. Their study observed that the levels of conductivity and turbidity were above the limit recommended for domestic water by WHO. The study however noted that other variables including TSS, TDS, temperature, pH, and salinity were within acceptable limits. Etim *et al.* (2013) reported the water quality index for the assessment of water quality from different sources in the Niger Delta region of Nigeria. Their report revealed that all the borehole and pipe-borne water samples analyzed are fit, potable, and can be used for other domestic purposes. The stream water samples were found unfit and thus not potable, going by the water quality index standard applied in the study.

Assessment of the Physicochemical Parameters of Bodo Creek, Pre-Spill, and Post-Spill: Traditionally, Bodo Creek is a strong livelihood support base for the people of the area and even beyond. The creek is used for fishing and subsistent agriculture, transportation, cassava fermentation, production of fuel wood, and disposal of domestic waste. Also, the quietness around the mangrove-sheltered waterfronts provides the necessary haven to relax and for solitude. Moreover, mangrove canopy and moveable spaces under the shade are a source of benign defecation environment for the locals (Onwugbuta-Enyi *et al*., 2008). According to Zabbey and Hart (2014) the bulk of periwinkle, *Tympanotonus fuscatus* that are sold in the markets 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 is supported by the Creek.Their study further revealed that the interaction of environmental factors structures biological communities. Also, biotic and abiotic variables influence one another, mostly in complicated fashions that cannot be easily explained. A major challenge facing the assessment and monitoring of fluvial systems and wetland restoration is the paucity of pre-impact data. How biotic components recover is linked directly to improvement in Physico-chemical variables of the focal catchment (Zabbey and Arimoro, 2017). However, several studies have been carried out in Bodo Creek to assess Physico-chemical parameters pre-spill (Onwugbuta-Enyi *et al*., 2008; Zabbey and Arimoro, 2017; Zabbey, 2012) and post-spill (Vincent-Akpu *et al*., 2015; Eludoyin et al., 2018;Nwipie et al., 2019). From figure 1, there was a decrease in mean dissolved oxygen (DO) and an increase in mean biological oxygen demand (BOD) post-spill. After the oil spill, there was a marginal increase in mean pH. There was a decrease in mean salinity and mean temperature after the oil spill.To compare the pre-spill and post-spill levels of pH, salinity, DO, BOD, and temperature in Bodo Creek, the average values of these parameters in tables 1 and 2 were subjected to a t-test in SPSS version 23.

Table 1: Pre-spill Physicochemical parameters of Bodo Creek

Reference and data collection date	Parameter	Range
Onwugbuta-Enyi et al. (2008)	Temperature	26.7-30.1ºC
December 2005-July, 2006	pH	6.5-8.6
	Salinity	11.6-16.1
	DO	4.6-11.8mg/L
Zabbey (2012)	Temperature	25-34ºC
May, 2006-April, 2008	pH	6.64-8.10
	Salinity	5-28psu
	DO	0-7.60mg/L
Zabbey and Arimoro (2017)	Temperature	25.3-34ºC
	pH	6.6-8.6
	BOD_5	10.89-14.64mg/L
	Alkalinity	Lowest (7.46mg/L)

Table 2: post-spill physicochemical parameters of Bodo Creek

Reference and data collection date	Parameters	Range
Vincent-Akpu et al. (2015)	Temperature	26.7-27.8ºC
September 2011-January, 2012	pH	8.8-8.9
	DO	4.7-5.5mg/L
	BOD	13-19mg/L
	COD	24-44mg/L
	Salinity	2580-16200mg/L
	TDS	3070-188000mg/L
	Conductivity	195-287ms/cm
	Total hardness	151-453mg/L
Eludoyin et al. (2018)	Salinity	8.12-15.31ppt
December 2017	DO	1.50-3.31mg/L
Nwipie et al. (2019)	pH	5.9-8.6
September 2015-February, 2016	Temperature	27.0-31.2ºC
	DO	1.1-4.5mg/L
	Conductivity	10.0-27.5ms/cm
	TDS	2.0-18.4ppt
	BOD	8.0-51.2mg/L

Table 3: Mean and standard error of the mean (SEM) for pre-spill and post-spill Physico-chemical parameters in Bodo Creek

Parameter	Pre-spill (Mean±SEM)	Post-spill (Mean±SEM)	P-Value
pH	8.60±0.00	8.75±0.15	0.423
Salinity	22.05±5.95	15.76±0.45	0.402
DO	9.70±2.10	4.41±1.10	0.155
BOD	11.42±3.22	35.10±16.10	0.286
Temperature	32.05±1.95	29.50±1.70	0.428

Table 3 shows the result of the statistical analysis. From table 3, the difference in pH between the pre-spill study and post-spill study was not statistically significant ($P > 0.05 = 0.423$). The difference in salinity between the pre-spill study and post-spill study was not statistically significant ($P > 0.05 = 0.402$). There was no statistically significant difference in DO ($P > 0.05 = 0.155$) between pre-spill and post-spill studies. There was no statistically significant difference in BOD ($P > 0.05 = 0.286$) between pre-spill and post-spill studies. The difference in temperature between the pre-spill and the post-spill study was not statistically significant ($P > 0.05 = 0.428$). Figure 1 shows that BOD was significantly higher after the oil spill. This higher level of BOD is a result of the pollution from the oil spill. From figure 2, a comparison of all the pre-spill and post-spill physicochemical parameters shows no statistically significant difference ($P > 0.05$).

*Pre-Spill Study***:** Before the two major oil spills in Bodo Creek in 2008, several studies were carried out in the creek to investigate the water quality of the creek. This review examines three of the pre-spill studies on the physico-chemical parameters of the creek.

*Case study 1:*Onwugbuta-Enyi *et al.* (2008) investigated the water quality of Bodo Creek in the Lower Niger Delta Basin. The study revealed that significant variations ($P<0.05$) in temperature occurred across the sampled months, with a peak in February; higher pH values were recorded in the wet months compared to the dry months. The study also reported a peak in salinity and BOD in February and

July respectively. Variations in dissolved oxygen (DO) between months were significant ($p<0.05$).

*Case study 2:*In a study on the environmental forcing of intertidal benthic macrofauna of Bodo Creek by Zabbey and Arimoro (2017), they reported that the monthly mean temperature varied significantly, with the highest mean value in March and least value in August. From the study, hydrogen ion concentration, pH, lowest values were recorded in September and November, while it peaked in June and December. The monthly mean salinity was highest in March, while the least mean values were reported in September and August. Conductivity decreased from May to November, at which time it was least, and started to increase in December with a peak in April. Monthly Mean DO values were almost similar except in September and April that recorded highest and lowest DO, respectively; DO in these months varied statistically from other months. The study also revealed that the mean alkalinity (mg/l) value fluctuated significantly (ANOVA = 2.85 >P (2.13)0.05) between months.

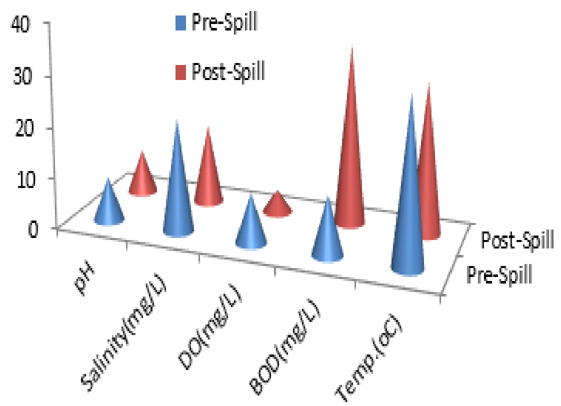

Fig 1: Average pre-spill and post-spill levels of Physico-chemical parameters in Bodo Creek

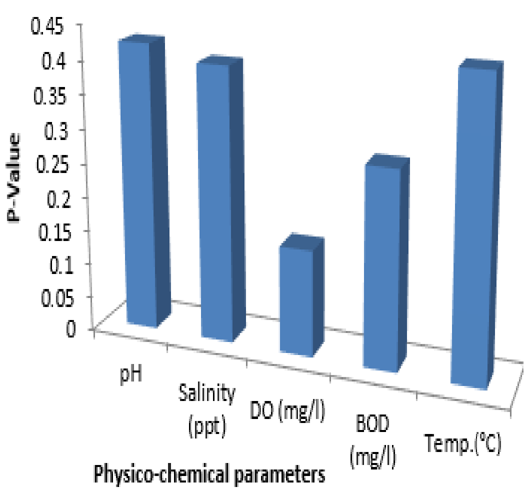

Fig 2: P-Value for pre-spill and post-spill physicochemical parameters

Case study 3: A study of the spatial and temporal variability in interstitial water quality of soft-bottom flats at Bodo Creek was conducted by Zabbey (2012). From the study, mean temperatures varied significantly between months, with a peak and least value in March and August respectively. Mean pH value was least in November, highest in December, and was similar in the wet and dry seasons. Salinity was highest in March and least in September. The dry season had significantly higher mean salinity. DO was highest in September.

Post-Spill Study: After the 2008 devastation of Bodo Creek by two major oil-spills, scientists over time have carefully assessed the physico-chemical parameters in the creek. Three of such studies are briefly reviewed below.

*Case study 1:*Vincent-Akpu et al. (2015), assessed the physicochemical properties of water in Bodo Creek. The study showed a temperature range that is typical for the Niger Delta region. Salinity increased with the onset of the dry season. The study also revealed that the mean BOD, COD, and total hardness were above the Department of Petroleum Resources (DPR) (2002) acceptable maximum permissible limits for domestic use in Nigeria.

*Case study 2:*The spatial assessment of heavy metal concentrations in giant tiger shrimps in Bodo Creek by Eludoyin *et al*. (2018), showed a weakly acidic pH of the water surface. The study further revealed a higher concentration of conductivity and salinity in the upstream, with the highest DO in the midstream. The pH was lower than the permissible levels except that of the upstream that was within the WHO/EPA permissible range. However, the mean DO, conductivity, salinity, and temperature of surface water in Bodo Creek was less than the EPA permissible levels.

Case study 3: Nwipie *et al*. (2019) investigated the recovery of infaunamacrobenthic invertebrates in oil-polluted tropical soft-bottom tidal flats of Bodo Creek, seven years after the spill and discovered that all the physicochemical factors followed a similar Spatio-temporal trend as recorded during the pre-spill baseline studies.

Pre-Cleanup and Post-Cleanup Physicochemical Parameters of Bodo Creek: After the two major oil spills in Bodo Creek in 2008, SPDC commenced the cleanup of the creek in 2019. After the cleanup, Nkeeh (2021), assessed the Physico-chemical parameters of the creek. The post-cleanup study was conducted at the four stations previously sampled by Nwipie *et al.* (2019) before the clean-up.

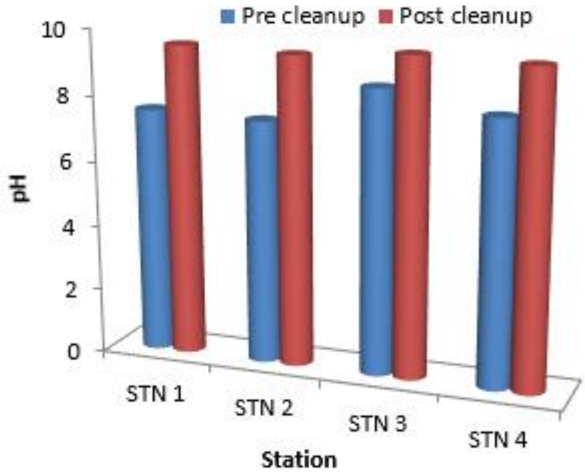

Fig 3: Pre-cleanup and post-cleanup variation in pH

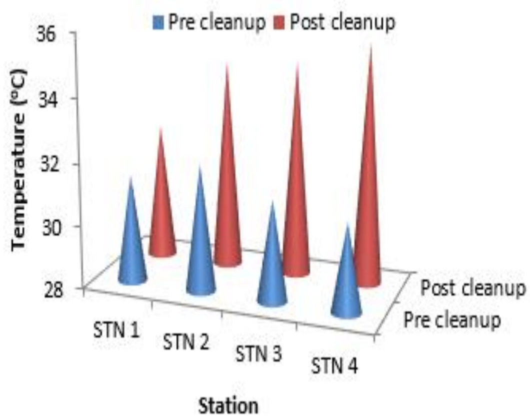

Fig 4: Pre-cleanup and post-spill variation in temperature

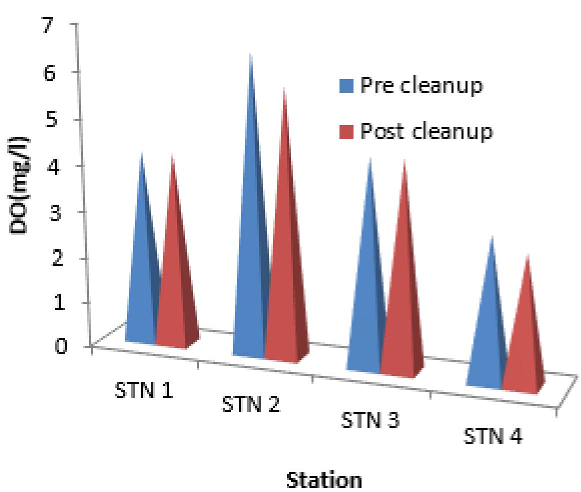

Fig 5: pre-cleanup and post-cleanup variation in DO

It is worthy of note that while Nkeeh (2021) evaluated the Physico-chemical parameters of the four study stations, oil spill cleanup was still going on in other parts of Bodo Creek outside the study stations. This review, therefore, compares the level of pH, temperature, dissolved oxygen (DO), and conductivity from the pre-cleanup and post-cleanup studies in the four sampled stations. From figure 3, the level of pH after the oil spill clean-up was higher than the pH level before the clean-up, in each of the four stations. Figure 4 shows that pre-clean-up temperature was lower than post-clean-up temperature, in each of the four stations. From figure 5, post-clean-up DO was relatively lower than pre-clean-up DO throughout the four study stations. Figure 6 shows that conductivity before the clean-up was higher than the conductivity after the clean-up, in each of the four stations.

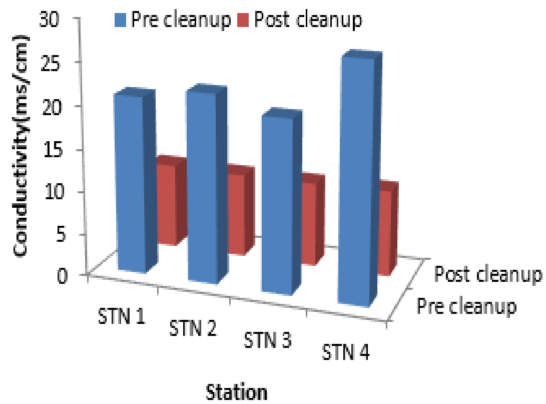

Fig 6: Pre-cleanup and post-cleanup Conductivity

Conclusion:The difference in the levels of the physic-chemical parameters in Bodo Creek, before and after the oil spill was not statistically significant. Generally, pH and temperature were higher in the post-clean-up study, while DO and conductivity were higher in the pre-clean-up study. This review, therefore, helps to better understand the changes in the environment as a result of any human intervention such as the oil spill clean-up.

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