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Changes in Water Physico-Chemical Properties Following the Dredging of an Oil Well Access Canal in the Niger Delta

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Abstract: In an attempt to study the environmental impacts of dredging on water quality, surface water was monitored for over one year, from December 1997 to December 1998. Samples were collected twice before dredging, in December 1997 and in June 1998, corresponding to dry and raining seasons, respectively. Samples were also collected immediately after dredging in July 1998 and were monitored in August, September and December 1998. Collected samples were analyzed from five stations within the study area, station 1 - 5. Station 1 was in the dredged canal, which was originally a side branch of the Warri River tributary. In the Warri River tributary, Station 2 was 500m upstream and Station 3 was 1000m upstream of the mouth of the dredged canal, whilst Stations 4 and 5 were respectively 500m and 1000m downstream of it. Stations 3 and 5 represented the reference situation to which possible dredging effects could be compared. The water physico-chemistry prior to dredging was consistent with that of other locations within the Niger Delta. As a result of dredging however, the pH of the dredged canal was decreased from 7.2 to 4.0, dissolved oxygen (DO) decreased considerably from 6.0mg/l to 0.4 mg/L, while BOD_5 was increased from 1.0 mg/l to 18.0 mg/L. COD, oil and grease, conductivity, TDS and sulphate values similarly increased, while nitrate and alkalinity values decreased after dredging. At the dredged canal, turbidity and TSS increased rapidly after dredging, attaining a value of 11,398 NTU and 8200 mg/l respectively. Results of the six-month post dredging monitoring of the river water revealed that the water quality improved significantly during this period. The pH and DO appreciated while COD, BOD_5, oil and grease, depreciated to values close to pre-dredging concentrations. We therefore conclude that the impact of dredging on water quality is localized and short term.

Key words: Dredging · Mangrove · Niger Delta · Oil exploration · Warri River · Water quality

INTRODUCTION

The Niger Delta is one of the most prolific oil and gas provinces along the Atlantic Coast of West Africa. Oil and gas exploration activities in the Niger Delta are often constrained by access difficulties. Due to anatomising network of creeks and river systems dominating the landscape of the Niger Delta, oil and gas development companies often times found it difficult to gain access to prolific hydrocarbon bearing zones. They often carry out dredging in order to overcome this constraint. During dredging, waterway sediment, soil, creek banks and vegetation along the way of are typically removed and deposited as dredge spoils at the bank of the newly dredged canal. Since the dredged materials are uncapped and unconfined leachates with high turbidity often return to the water body. This practiced have caused a number of environmental impacts including altered topography and hydrology [1-4], acidification and water contamination [5], which has resulted in vegetation damage and fish kills [1]. In addition, turbidity plumes created as a result of dredging have been reported to cause a reduction in the population of phytoplankton and zooplankton [6]. In the study carried out by Lewis *et al.* [7] in the Gulf of Mexico, environmental impacts of dredging included reduction in numbers of benthic species, increased turbidity, reduction of primary productivity and mobilization and increased bioavailability of sediment trace metals. But the study concluded that the effects of dredging on surface water pH, dissolved oxygen and temperature were negligible.

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In Niger Delta, following the dredging of a tributary of the Warri River to enable the drilling of an oil well has led to a number of impacts including algal bloom [8], impairment of benthic invertebrates [9] and destruction of zooplankton [10], whereas the impact on the Warri River water quality have not been reported. Being a habitat to aquatic organisms, it is therefore suspected that the impacts on plankton and other organisms may be related to changes in the water physico-chemistry. Hence, this study is aimed at assessing the impact of dredging on the water quality of the river and to monitor the recovery of the river system over a one year period.

MATERIALS AND METHODS

This study was carried out in and near a dredged canal (5°31"N, 5°31"E) leading off a tributary of the Warri River in the mangrove swamp of the Niger Delta about 20km from

Warri in Delta State, Southern Nigeria (Figure 1). The vegetation here is typical of mangrove swamp dominated by *Rhizophora* species. The area is characterized by high relative humidity (80-92%) and annual average rainfall exceeding 2800mm. Although, there are two seasons (wet and dry), measurable precipitation occurs in all the months of the year. Notwithstanding, the period of April to October is often regarded as raining season, while November – March is regarded as dry season. Atmospheric temperature ranged between 27°C to 29°C [11].

The surface water of the study area was monitored for over one year, from December 1997 to December 1998. Samples were collected from five stations within the study area, station 1-5. Station 1 was in the dredged canal, which was originally a side branch of the Warri River tributary. In the Warri River tributary, Station 2 was 500m upstream and Station 3 was 1000m upstream of the mouth of the dredged canal, whilst Stations 4 and 5 were respectively 500m and 1000m downstream of it. Stations 3 and 5 represented the reference situation to which possible dredging effects was compared. From each station, samples were collected twice before dredging, in December 1997 and in June 1998, corresponding to dry and raining seasons respectively. Samples were also collected immediately after dredging in July 1998 and were monitored in August, September and December 1998.

During sampling, pH, temperature, turbidity, conductivity and total dissolved solids (TDS) were determined in-situ using digital pH meter/ thermometer (Hach EC 20), turbidimeter (Hach 2100) and conductivity/TDS meter (Hach CO. 150) respectively. Separate samples were collected for dissolved oxygen (DO) and biochemical oxygen demand (BOD_5) (using 125ml reagent bottles with ground stopper), oil and grease and chemical oxygen demand (COD) (using 500 ml glass bottles) and for other physico-chemical parameters (sulphate, nitrate, ammonia, chloride, bicarbonate) using 2.5litres plastic containers.

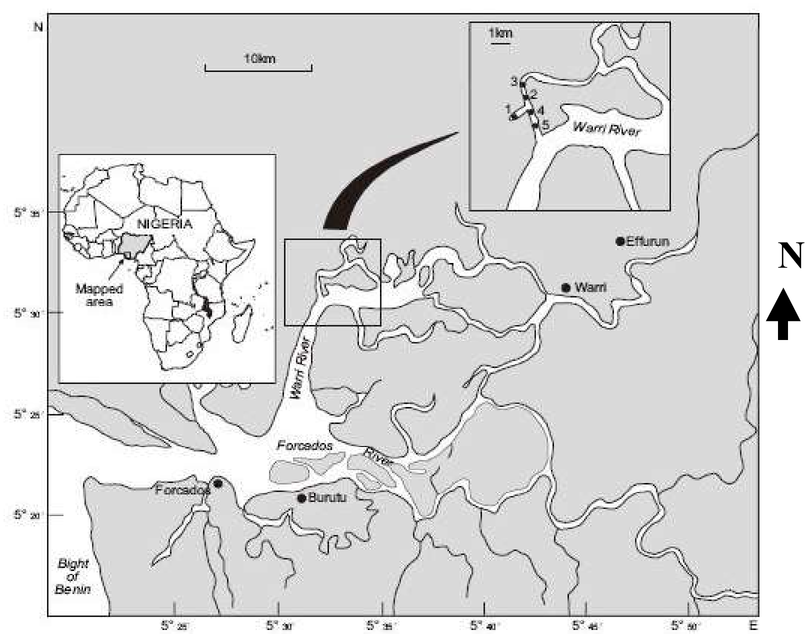

Fig. 1: Map of Warri River showing the study area

Standard methods [12] were used for the laboratory analysis. Titrimetric method was used for the determination of alkalinity, gravimetric method was used for suspended solids, Winklers' method was used for BOD_5 and DO, turbidimetric method was used for sulphate, open reflux dichromate oxidation method was used for COD, Mohr's argentometric titration method was used for chloride, Nessler's method was used for ammonia, brucine method was used for nitrate, xylene extraction followed by gravimetric method was used for oil and grease.

RESULTS AND DISCUSSION

The pH at all the stations before the dredging were quite similar ranging from 6.8 - 7.4, which is essentially within the neutral pH range (Fig. 2). The pH reduced drastically following dredging. The lowest pH (4.0) was recorded at the dredged canal in July 1998. At 500 m and 1 km downstream, pH values of 4.2 and 5.0 were recorded respectively. At the upstream location (500 m and 1 km) pH values of 4.6 and 5.8 were obtained respectively. The upstream locations that served as control stations also showed decrease in pH values. Acidity improved gradually throughout the remaining sampling period. pH improved considerably at the downstream and upstream locations in December 1998. However, at the dredged canal the recovery was slower as the pH was 5.5 in December 1998. Alkalinity showed an inverse relationship to acidity, being higher in the pre-dredging periods (December 1997, June 1998). Low alkalinity values were generally recorded ranging from 0.10 to 41.1 mg/L as $CaCO_3$. There was no significant variation in temperature in all the stations throughout the study period. Temperature ranged from 29.1 to 32°C (Fig. 2). Similar trends were observed in all the stations monitored. The effect of temperature on the acidity is minimal, since temperature remained relatively stable during the study period. However, previous studies indicated that the Niger Delta water is well buffered with pH ranging from neutrality to slightly alkaline [1]. Therefore, it is the presence of the unconfined dredged materials deposited adjacent to the canal that is helping to sustain the acidity of the canal via pyrite oxidation [13,14].

Turbidity and total suspended solids (TSS) showed similar trends (Fig. 2). Turbidity and TSS values in all the stations were less than 20 NTU and 20mg/L respectively prior to dredging. Soon after dredging, turbidity plumes were observed with the turbidity and TSS values increasing drastically to 11398 NTU and 8200 mg/L at the dredged canal and 7986 NTU and 6600 mg/L at the 500 m downstream locations respectively. Lower values were recorded at the upstream location. The TSS and turbidity decreased sharply one month after dredging (August 1998) and sequentially reduced up to December 1998. Turbidity correlated strongly (positively) with TSS ($r = 1.000$). Previous studies in the area suggest that the increased turbidity, TSS and acidity and the depletion of oxygen tension of the water is the cause of the observed 91% and 72% reduction in zooplankton population and taxa respectively following the dredging [10]. Turbidity plumes have been reported to negatively impact estuarine organisms during dredging and disposal of dredged spoils, causing the reduction of primary productivity [15, 16]. The study carried out during the dredging of the Cross River Estuary, south east of the Niger Delta shows that water transparency decreased by over 50% [17]. Reavell [18] also reported that dredging could cause decrease in light penetrations by between 25-50% for over a distance of 12 km and that this effect was still persistent 18 months after dredging. The reason for the prolonged effect was attributed to the washing of leachates into the river from unconfined spoil dumps. Other studies have reported similar impacts following dredging [19-21].

The variation in TDS, conductivity and chloride in all the sampling locations throughout the study period are shown in Fig. 2. In the dredged canal and 500 m downstream, TDS increased sharply after dredging and declined up to September 1998 and later increased again in December 1998. Variation in water salinity (as chloride) was unusually different from that of TDS and conductivity. From the result, salinity decreased in all the locations following dredging and up till December 1998. TDS correlated with turbidity ($r = 0.848$) and TSS ($r = 0.848$). TDS correlated strongly (positively) with conductivity ($r = 0.999$), sulphate ($r = 0.905$) suggesting that the increase in turbidity following dredging is related to the re-suspension of sediments and the oxidation of pyrite causing the formation of sulphuric acid and increase in conductivity and TDS. However, the observed fluctuation in chloride is not related to pyrite oxidation, but due to the tidal and seasonal changes in the river.

Variations in dissolved oxygen (DO) and BOD_5 values are presented in Figure 3. The graphs depicted an inverse relationship between DO and BOD_5. The DO of most of the stations prior to dredging ranged from 3 to 6 mg/L, while BOD_5 generally ranged from 1 to 2 mg/L. After dredging the DO values decreased sharply (at the dredged canal and 500m downstream station) and gradually at the other sampling stations. But at these

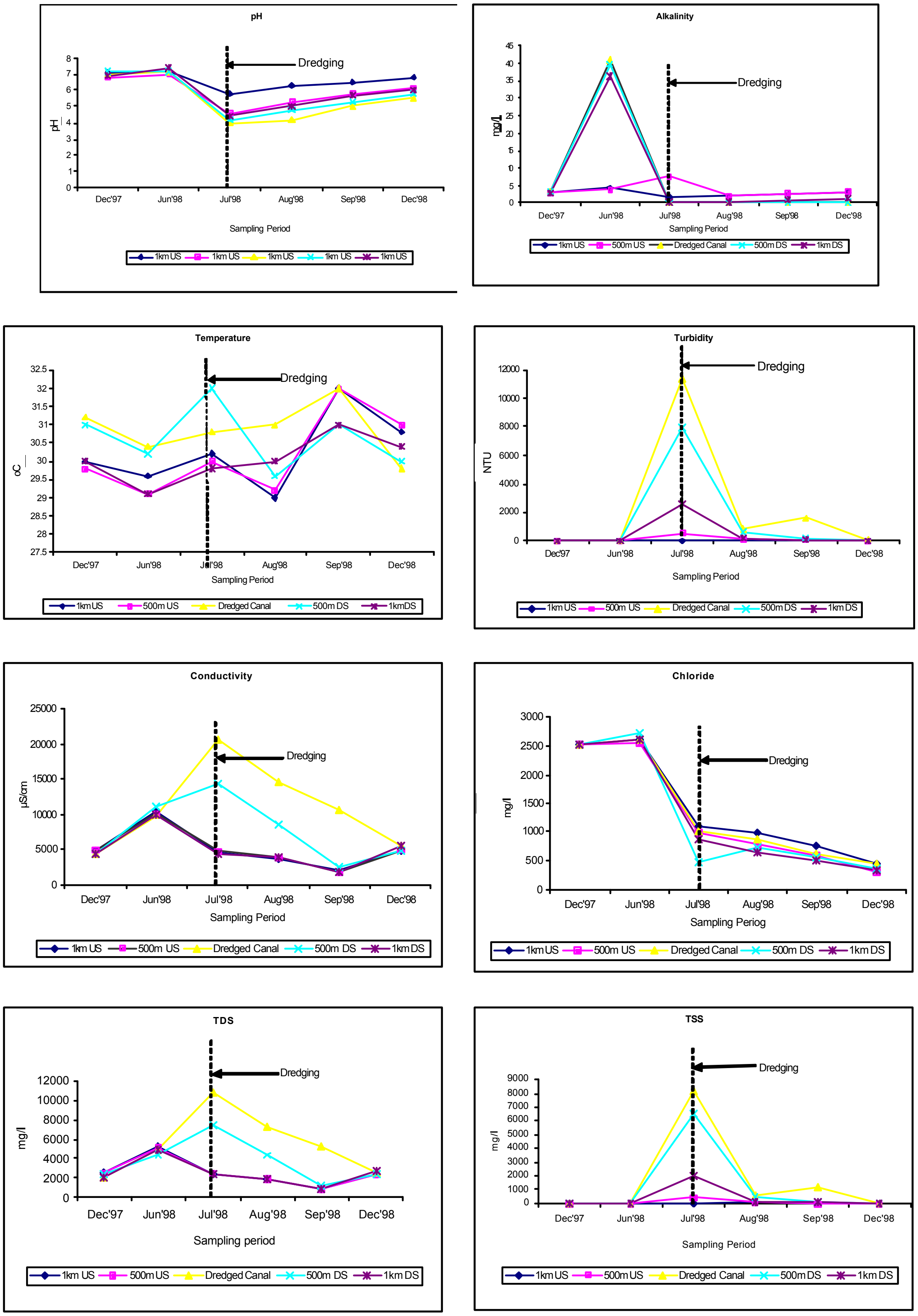

Fig. 2: changes in pH, temperature, alkalinity, suspended solids and salinity-related parameters

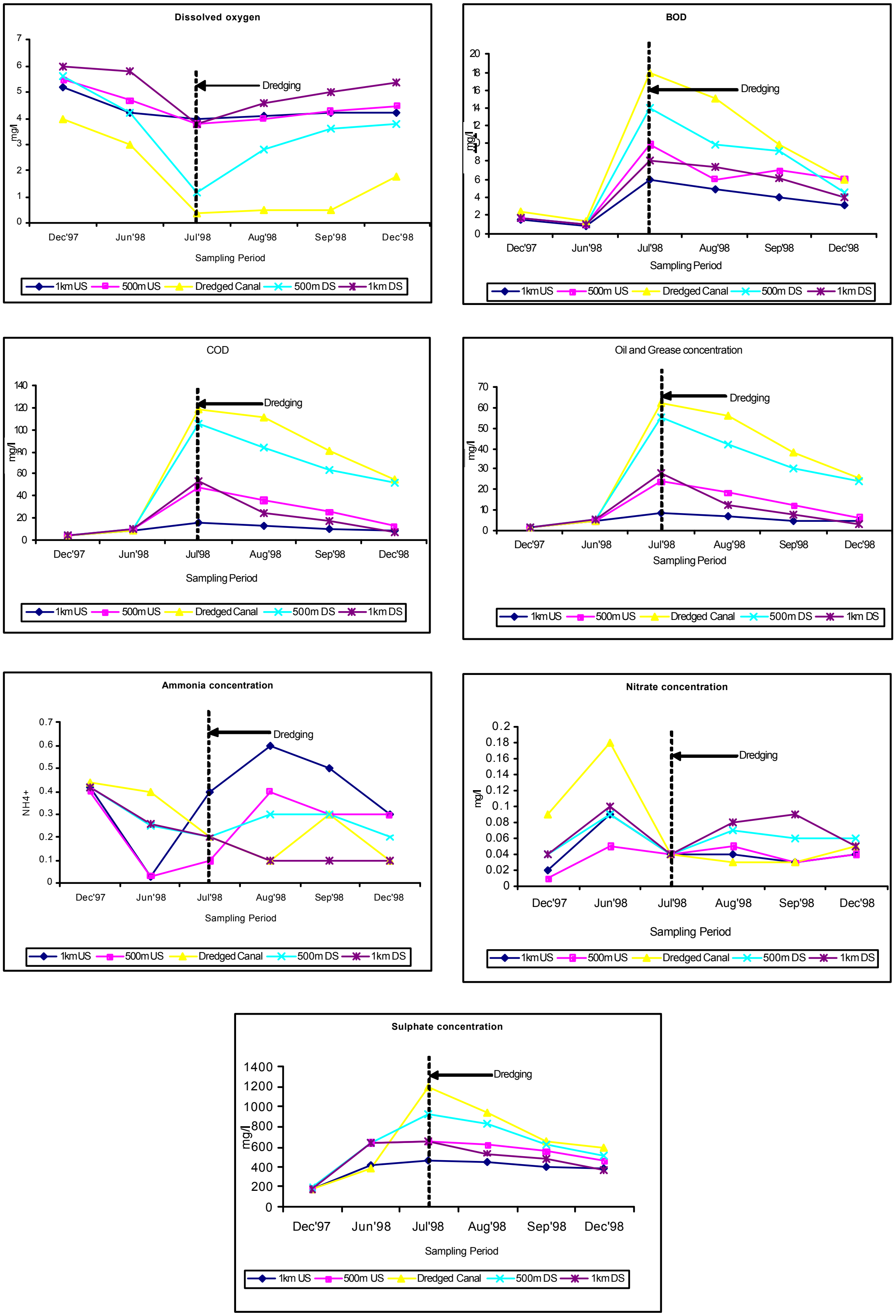

Fig. 3: Changes in oxygen related parameters, anions and oil and grease

other locations, it increased to its original values one month after dredging. In the dredged canal however, significant increase in DO was only recorded in December 1998. During this period of low DO (0.4 mg/L), BOD_5 values peaked at all the stations and had the highest concentration (18.0mg/L) in the dredged canal.

Variations in BOD_5, COD and oil and grease values exhibited similar trends (Fig. 3). These three parameters were quite low in all the sampling points prior to dredging, but increased sharply following dredging especially at the dredged canal and 500 m downstream location. The level of oil and grease; COD and BOD_5 decreased gradually (but more slowly in the dredged canal) from July to December 1998. DO correlated negatively with BOD_5 ($r = -0.887$), COD ($r = -0.956$) and oil and grease ($r = -0.943$). BOD_5 on the other hand strongly correlated positively with COD ($r=0.978$), oil and grease ($r = 0.986$). Thus, suggesting that the factors responsible for DO depletions are linked with oxidation of re-suspended organic matter and pyrite.

On the other hand, there were high concentrations of sulphate at all the locations prior to dredging (Fig.10). Sulphate content increased sharply in the dredged canal and 500 m downstream locations. After six months, the level of sulphate decreased at all the stations to values still higher than 400 mg/L. It is suspected that the dredged spoil that was abandoned at the creek bank is still undergoing weathering and leaching of sulphuric acid into the canal [13]. pH strongly correlated negatively with sulphate ($r = -0.93$), positively with DO ($r=0.942$) and strongly (negatively) with BOD_5 ($r = -0.968$).suggesting that the observed cause of acidity (low pH) in the area is linked to sulphate production through oxidation.

The concentration of ammonia did not seem to show any particular spatial variation during the period (Fig.3). Nitrates were quite low in the water column at all the sampling points (<0.2 mg/L). Nitrate concentrations decreased sharply after dredging at all the sampling points (Fig. 3).

CONCLUSION

The study shows that the dredging of an oil well access canal in a tributary of Warri Rivers triggered physico-chemical changes of the water body particularly pH, TDS, conductivity, TSS, turbidity, sulphate, DO, BOD and COD. These changes appeared to be the causal factors for the reduction in the population density and taxa of zooplankton [10]. Most of these physico-chemical changes were localized and short time (i.e. returning to pre-dredging levels in less that six months). However, the presence of unconfined spoil banks adjacent to the canal tends to prolong the impacts.

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