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Effects of sand mining activities on water quality of Okoro Nsit stream, Nsit Atai local government area, Akwa Ibom state, Nigeria

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Abstract

The physicochemical parameters of water samples collected from upstream and downstream of OkoroNsit stream were assessed. The physicochemical parameter like, pH, temperature, turbidity, dissolved oxygen (DO_2), biological oxygen demand (BOD), sulphate, nitrate, phosphate, total dissolved solid (TDS), total suspended solid (TSS), total alkaline, total hardness, calcium, magnesium and oil and grease (O/G) was determined.The result of the physicochemical analysis were obtained in the following range; pH (5.99 – 6.22), temperature (28.2 – 28.3^{o}C), EC (420.0 – 630.1µS/cm), Turbidity (20.1 – 24.4 NTU), DO_2 (5.2 – 6.2 mg/l), BOD_5 (1.4 – 3.2 mg/l), Sulphate (15.0 – 15.5mg/l), Nitrate (10.7 – 12.4), Phosphate (2.5 – 3.6 mg/l), TDS (281.4 – 422.2 mg/l), TSS (8.4 – 10.2 mg/l), Total Alkaline (240.5 – 420.0 mg/l), Total Hardness (55.2 – 68.8 mg/l), Calcium (40.0 – 65.2 mg/l), Magnesium (3.6 – 15.2 mg/l) and Oil and Grease (4.5 – 6.3 mg/l). Heavy metal content, like iron (Fe), lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), nickel (Ni), chromium (Cr), manganese (Mn) and vanadium (Vn) was analyzed. The results were compared with standards prescribed by WHO (2008). It was found that the water samples collected from OkoroNsit stream was contaminated as a result of sand mining activities at IsoEsuk River, IkotAkpaEkpu. The results of some of the parameters analyzed were within the recommended limit, while some of the physicochemical parameters and heavy metal content were found to be above the approved water quality limits. The water quality of the stream studied is therefore unsafe for portability and other human uses that can affect health.

Keywords: Sand Mining; Water Quality; Rivers; Okoro Nsit Stream; Nigeria

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1. Introduction

Sand mining describes the removal of sand from where they are deposited naturally. Sand is needed in every aspect of construction, be it road or land restoration. Upon its enormous usefulness, it causes some environmental problems when it is over-mined (Ashraf et al., 2011). Several adverse effects of sand mining on the immediate and extended environment have been widely reported in literature.

According to Rinaldi et al. (2005), mining and dredging operations have the tendency to lessen downstream water quality and may adversely affect aquatic life. Rabie et al. (1994) reported that sand mining processes have the capability to interrupt and or alter natural balance within an ecosystem.

Ashraf et al. (2011) reported that In-channel or Near-channel sand-and-gravel mining can affect the quantity of sediment, and this may bring about significant change in the water course. Their report further indicated that reductions of sediment owing to In-channel mining can adversely impact benthic organisms and that debris deposited by running water is a function of geological structure. The report asserted that a good knowledge of the nature of response of the water channel being mined to mining disruptions is required to be able to be able to checkmate the negative effects of sand-and-gravel mining.

Byrnes and Hiland (1995) and Saviour (2012) chronicled some of the various effects of sand mining in an aquatic environment thus; River bed degradation can undermine bridge supports, pipe lines or other structures. Degradation may change the morphology of the river bed, which constitutes one aspect of the aquatic habitat. Mining in close proximity to public infrastructure (bridges, pipelines, and utility lines) can damage them. Mining can displace or deplete aquatic biota or their food chain. Lowering of the water table can destroy riparian vegetation, cause erosion, pollute water sources and reduce the diversity of animals supported by these woodlands habitats.

Lawson (2011) definition of water quality implies there are key parameters that defines the quality of a given water. They specified such parameters to include the chemical, metabolic activities, growth, feeding, and reproduction, physical and biological contents of water. Despite the preceding assertion, Chitmanat and Traichaiyaporn (2010) reported that seasonal variability and physical features of earth surface can alter water quality despite it's pollution status. The importance of water to life on earth cannot be over emphasized. In buttressing the importance of water Kataria et al. (2011) reported that water is the most essential commodity for all living creatures. In biotic organisms, water is made up of 78% of the total body fluid. Therefore if man fails to take required quantity of water he becomes dehydrated. Water is needed for domestic, industrial as well as aqua-cultural purposes. Hydro-powered electricity is not left out in many of its uses. Water supports transportation. Therefore, it is important that water is readily available when needed, not just in the right quantity, but also in the right quality devoid of pollutants to meet the various needs for which it is naturally or artificially applied.

Ashraf et al. (2011) reported that In-stream sand mining activities causes water to be turbid, thereby interfering with the penetration of sunlight for benthic organisms. Oil spills or leakage from mining machinery into water hamper free circulation of air into water for survival of aerobic organisms. Constant coastal erosion raises suspended solids in the water at the mining site and downstream. Suspended solids may narrow the river channel as well as making it shoal. The impact is felt more downstream of the site especially if the abstraction of water is for domestic use. Cost of water treatment can be compounded by suspended solids as a direct consequence of sand mining.

Wholesome water quality is essential for preventing infections and sustaining life processes. Hardly any water source without impurities and these may arise as a result of discharging wastewater effluent into water body. Naturally, impurities may come in contact with aquatic ecosystem through surface run-off, precipitation and from man-made source. Heavy metals are bio-accumulated by aquatic organisms that are finally consumed by human beings (Adefemi and Awokunmi, 2010).

Sand mining activities involving both manual and mechanical sand dredging equipment takes place in IsoEsuk River, which is the main source of water feeding OkoroNsit Stream, which constitutes the areas were the samples for this study were collected. Consequently, this study aims to determine the further effects of sand mining activities in a river channel (IsoEsuk River) on the water quality of a stream (OkoroNsit stream) farther downstream of the river. This is justified by the fact that this stream is a source of various domestic water uses for various local community members in the area. Also, adverse changes in water quality of the stream that may be occasioned by the sand mining activities constitutes serious sources of threat to the flora and fauna (including fish) depletion from the stream farther downstream, which gets it is major source of water supply form the river.

1.1. Geographical setting of the study area

The study area is in equatorial West Africa, which comprises the region lying between latitude 4 44' 0'' 4 54' 30'' North of the equator, and between longitude 8 0'30''8 4' 0''E on the Atlantic Coast of Africa. The study area is characterized by high solar radiation, cloud cover, heavy precipitation, light winds and low atmospheric pressure. It is located in the rain forest belt that is associated with the heavy rainfall (Udosen, 2006). The temperatures are influenced by the cloud cover and damp air. The lowest temperatures are recorded in the rainy season months of June to September ranging between 22^{o}C – 27^{o}C while the highest temperatures (27.0C - 33.50C) are recorded in February and March. Rain falls throughout the year with a short dry spell in the months of January to March in some parts. Dry season is always dusty as well as high temperatures. Dry season spans through three to four months (November to February). The wet season lasts from March to October and it may extend to early November and beyond, during which there may occasional rainfalls.

Nsit-Atai is located in the south east of Nigeria and is a Local Government Area of AkwaIbom State. NsitAtai local Government Area is situated in the south–Eastern part of AkwaIbom State and is the component unit of Uyosenatorial district with latitude 4 44' 0'' 4 54' 30''N 'and longitude 8 0'30''8 4' 0''E , and is approximately 50 kilometres from Uyo. It is bound in the North by Uruan, in the East by Okobo, in the West by IbesikpoAsutan Local Government Area covers about 17,00km shown in the map above. It has a population of over 74,595 people as confirmed by National population Commission with a major occupation of farming and trading due it abundant land and water resources. Figures 1 and 2 show the study area within AkwaIbom state and Nsit-Atai Local Government area respectively.

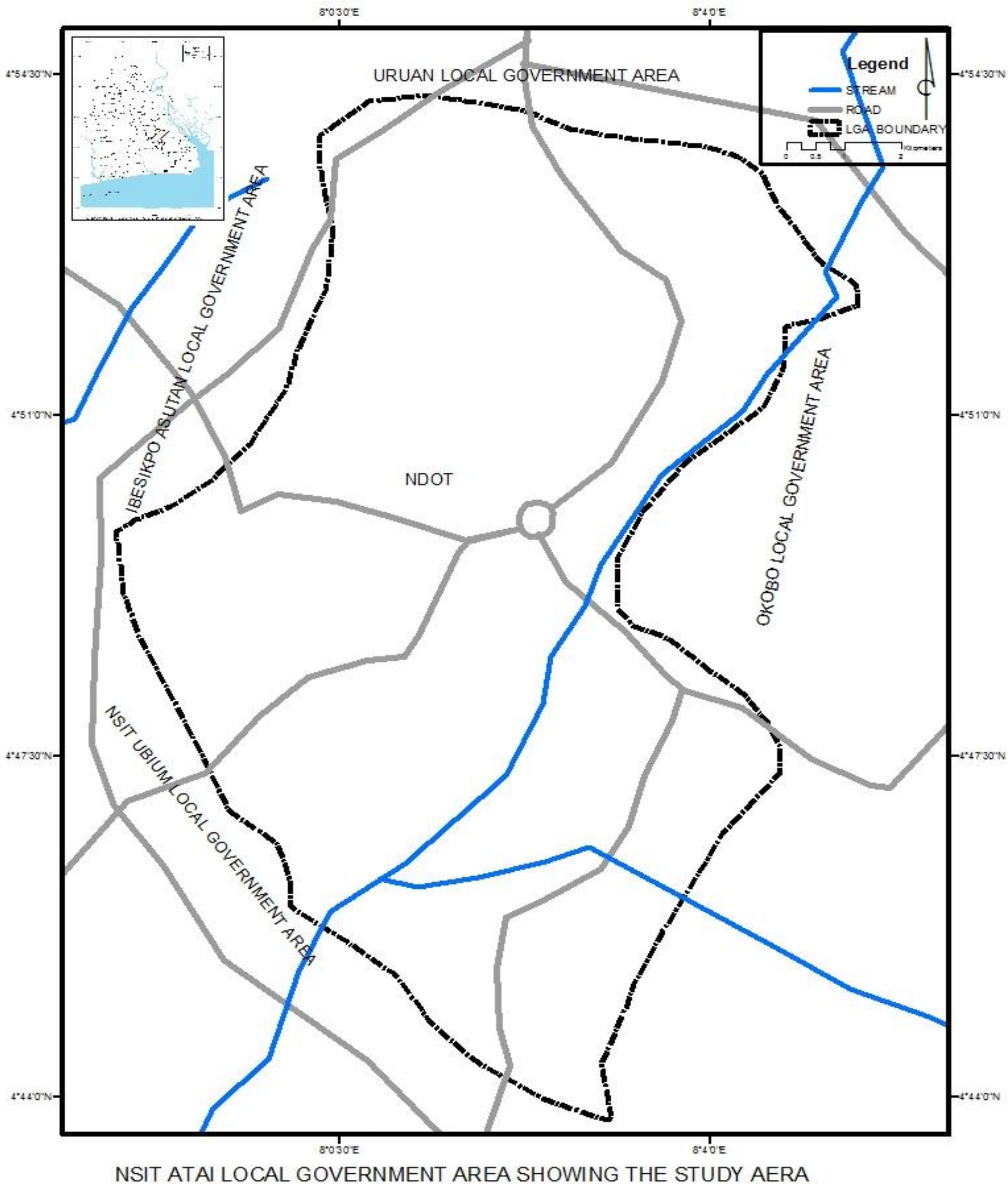

Figure 1. Map of NsitAtai Local Government Area showing the Study area

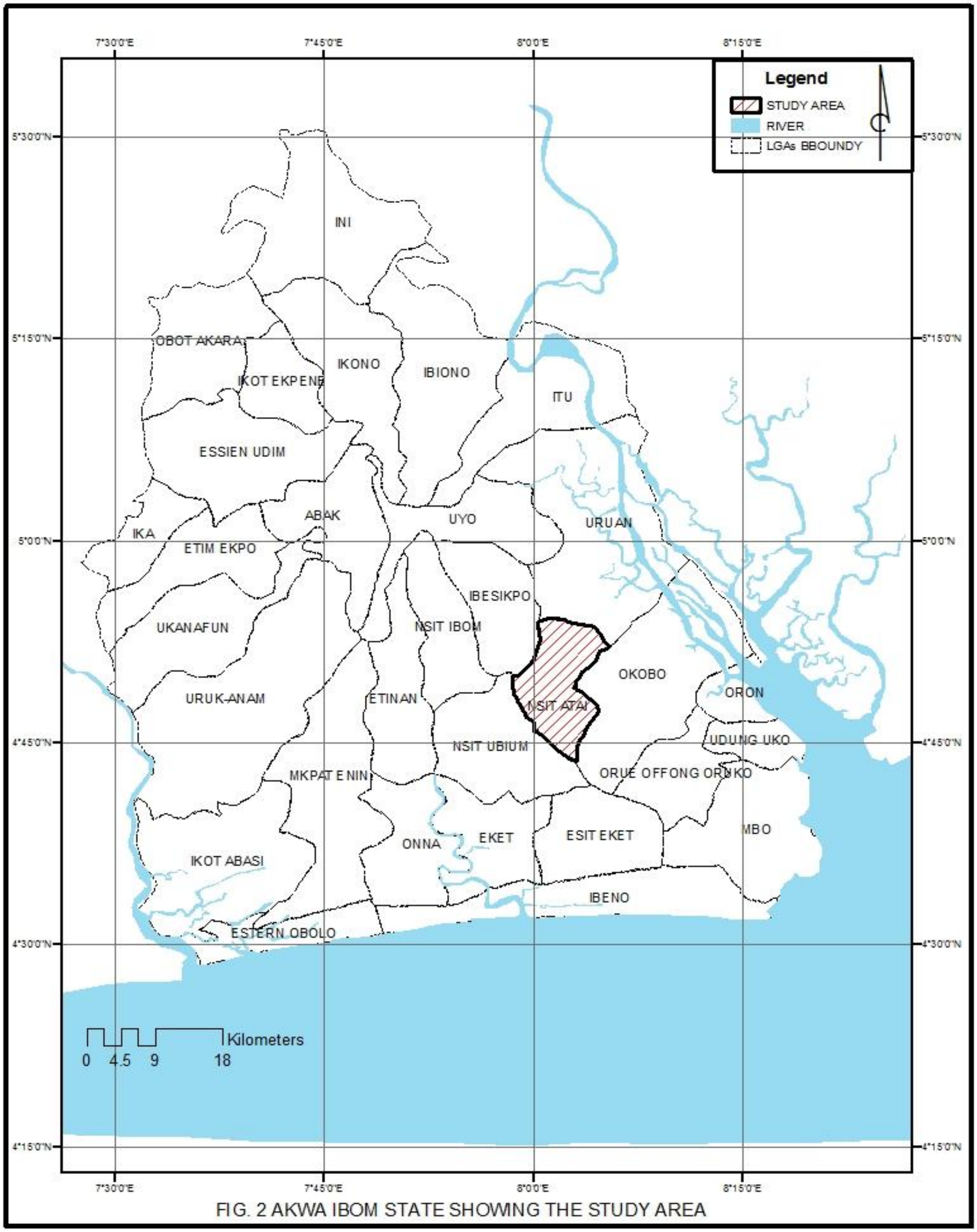

Figure 2. Map of Akwa Ibom state showing the Study area

2. Materials and methods

The different procedures through which data used for this study were collected and analyzed are explained as follows:

2.1. Sample collection

A total of samples four (4) samples were collected from two (2) locations from OkoroNsit stream. Two (2) samples each in the upstream and downstream of the were collected from OkoroNsit stream, using plastic sampling bottles of 1liter by dipping the bottles 15cm below the water level at designated sampling stations and capped under water to avoid air bubbles. Prior to sample collection, all the plastic bottles were thoroughly washed with phosphate-free detergent and dried. Before collection, the plastic bottles were rinsed twice with the same water to be collected.

Samples for biological oxygen demand (BOD) were collected in dark glass bottles for incubation to forestall photosynthetic reaction. Glass bottles were used for collection of samples for the determination of oil and grease. These samples were acidified or stabilized with nitric acid. The fast-changing parameters like pH, temperature, dissolved oxygen (DO) and electrical conductivity (EC) were measured right there in the field using portable meters.

2.1.1. Physicochemical analysis

Samples were analyzed according to standard method of American Public Health Association (APHA) (1988) and AOAC (2005). Physicochemical parameters analyzed were pH, Temperature, conductivity, Turbidity, Dissolved Oxygen, Biological Oxygen Demand, Sulphate, Nitrate, Total Hardness, Total Dissolved Solids, Total suspended Solids, Total Alkalinity, Calcium, Magnesium and Potassium, Oil and Grease and Phosphate.

2.1.2. Heavy metal content

Heavy metals were determined in water samples using a UniCam model 969 Atomic Absorption spectrophotometer. The method used for the determination of physicochemical parameters was described by A.O.A.C. (2005). Iron (Fe), Lead (Pb), Zinc (Zn), Copper (Cu), Cadmium (Cd), Nickel (Ni), Chromium (Cr), Manganese (Mn) and Vanadium (Vn) are the heavy metals to be analyzed in the samples collected.

3. Data and analysis

The physicochemical and heavy metal content data are presented in Tables 1 and 2.

3.1. Physicochemical analysis

Table 1. Physicochemical Characteristics of Water Samples from Impacted Dredging Site at Okoro Nsit Stream

Site	pH	T(°C)	EC µS/cm	Turb NTU	DO mg/l	BOD mg/l	SO_4^{-2} mg/l	NO_3^- mg/l	PO_4^{3-} mg/l	TDS mg/l	TSS mg/l	T. Alk. mg/l	T. Hdns mg/l	Ca^{+2} mg/l	Mg^{+2} mg/l	O/G mg/l
OkoroNsit Stream																
US	5.99	28.2	630.1	20.1	5.2	3.2	15.5	12.4	3.6	422.2	8.4	420.0	68.8	65.2	3.6	6.3
DS	6.22	28.3	420.0	24.4	6.2	1.4	15.0	10.7	2.5	281.4	10.2	240.5	55.2	40.0	15.2	4.5
WHO	7-8.5	-	1400	5.0	-	-	250	5.0	-	1000	-	120	500	100	150	-

US = Upstream, DS = Downstream, T. = Total, T = Temperature, T. hdns = Total Hardness

3.2. Heavy metal content

Table 2. Heavy Metal Concentrations in Water Samples from Impacted Dredging Site) at OkoroNsit Stream

Site	Fe (mg/l)	Pb (mg/l)	Zn (mg/ /)	Cu (mg/l)	Cd (mg/l)	Ni (mg/l)	Cr (mg/l)	Mn (mg/l)	Vn (mg/l)
OkoroNsit Stream									
US	3.4120	0.0001	4.1200	0.9457	<0.0001	0.0001	<0.0001	3.1200	0.0001
DS	3.0024	0.0001	3.8602	0.7213	<0.0001	0.0001	<0.0001	3.0510	0.0001
WHO (2008)	0.50	0.01	3.00	2.00	0.003	0.07	0.05	0.4	0.01

US = Upstream DS = Downstream

The physicochemical parameters and heavy metal content of the OkoroNsit Stream have been given in the Tables 1 and 2. The physicochemical features of Okoro Nsit Stream water were influenced due to the discharge of dredging activities at Iso Esuk River. Khan et al. (2012) reported that water temperature is important because it affects the rates of biological and chemical processes Water temperature has an inverse relationship with dissolved oxygen as the ability of water to contain dissolved oxygen decreases as water temperature rises. The temperatures of water recorded were 28.2 ^{o}C to 28.3 ^{o}C.

3.2.1. pH

pH determines the acidity or alkalinity of water samples. pH strikes a balance between hydrogen ions (H+) and hydroxide ions (OH) in water. The pH is also a useful indicator of the chemical balance in water. A high or low pH will adversely affect the availability of certain chemicals or nutrients in the water for use by plants.

The pH were acidic values ranges between 5.99 and 6.22. The maximum pH value (6.22) was recorded in the downstream and minimum (5.99) in the upstream of OkoroNsit stream. The recorded values of pH did not comply with the WHO standard of 6.5 – 9.0. The factors like air temperature bring about changes in the pH values of water. The pH plays an important role in all chemical reactions associated with formation, alteration and de-solution of minerals in water. The mining or dredging activities at IsoEsuk River thus produced significant negative impact on OkoroNsit Stream.

3.2.2. Electrical conductivity (EC) in μS/cm

This is a measure of the ability of water to conduct an electrical current and it varies with temperature. Magnitude of electrical conductivity depends on concentration, kind, and degree of ionization of dissolved constituents. It can be used to determine the approximate concentration of dissolved solids (Murhekar, 2011). EC values were in the range from 420.0 μS/cm to 630.1 μS/cm. These high EC values is an indication that the quantity of dissolved ionized dissolved organic substances in the upstream and downstream of OkoroNsit Stream are seemingly high.

3.2.3. Turbidity in NTU

Turbidity indicates how far light can travel through water and is caused by fine dispersed and colloidal particles in water. The turbidity values varied between 20.1 and 24.4 NTU and were found to be above the limits prescribed by the WHO.

3.2.4. Dissolved oxygen (DO) in mg/l

Dissolved oxygen is a critical water quality parameter that constitutes the oxygen reserviour for aquatic organisms that utilize it for respiration. Most aquatic organisms depend on dissolved oxygen for their survival. Dissolved oxygen recording from the study varied between 5.2mg/l and 6.2mg/l. This relatively high level of oxygen recorded in the water can be attributed in part to the turbulence created in water by the sand mining activities. Turbulence positively affects dissolved oxygen in water, due to the trapping of atmospheric oxygen by exposed water molecules during turbulence.

3.2.5. Biological oxygen demand (BOD)

BOD is a measure of the rate by which oxygen is used by microorganisms in aerobic degradation of organic matter in water over a given period of time. The BOD values varied between 1.4 and 3.2 mg/l. The recorded BOD values of the sand mining site are considered high. This can be explained by the fact that the sand mining activity had considerably enhanced the circulation and concentration of organic matters in the water.

3.2.6. Sulphate (SO_4^{2-}) in mg/l

The sulphateconcentration varied between 15.0 mg/l and 15.5 mg/l and found to be below the WHO limit. Since sulphate in water naturally occurs as naturally occurring leachate form gypsum, it can be assumed that the gypsum content of the underlying rocks of the water is low.

3.2.7. Phosphate (PO_4^{3-}) in mg/l

The phosphate content in the study area was found in the upstream and downstream of the water sample and it varied between 2.5mg/l and 3.6mg/l.

3.2.8. Nitrate (NO^{3-}) in mg/l

The nitrate content in the contaminated area varied in the range 10.7 mg/l to 12.4 mg/l and found above the WHO prescribed limit.

3.2.9. Total dissolved solids (TDS)

The TDS ranges between 281.4mg/l and 422.2mg/l and, which were within the WHO limit.

3.2.10. Total suspended solids (TSS)

Turbidity is directly proportional to TSS. The recorded values of TSS ranged between 8.4mg/l and 10.2mg/l, which were well below the limits prescribed by WHO.

3.2.11. Total Alkalinity (TA) in mg/l

Alkalinity of any water is a measure of its capacity to neutralize acids. Although many materials may contribute to the alkalinity of water, most of the alkalinity in natural water is caused by the presence of hydroxides, carbonates, and bicarbonates (Murhekar, 2011). Total alkalinity values recorded during this study varied between 240.5mg/l and 420.0mg/l.

3.2.12. Total hardness (TH) in mg/l

Hardness is the property which makes water form an insoluble curd with soap and is primarily due to the presence of Calcium and Magnesium. The hardness values ranged from 55.2mg/l to 68.8 mg/l. The values were lower than the WHO prescribed limit.

3.2.13. Calcium (Ca^{2+}) in mg/l

Calcium concentration varied between 40.0 mg/l and 65.2 mg/l, which were within the permissible limit of WHO.

3.2.14. Magnesium (Mg^{2+}) in mg/l

Magnesium values ranged from 3.6 mg/l to 15.2 mg/l which were above WHO limit.

3.2.15. Oil and Grease (O/G) in mg/l

O/G concentrations ranged between 4.5 mg/l and 6.3 mg/l, which were below the permissible limit of WHO.

3.2.16. Heavy metals content

The results of the Heavy metal analysis of this study showed that cadmium and chromium were not detected in any of the samples. Values obtained for lead (Pb) were within the WHO recommended limits. The concentration of iron in the samples analyzed ranged from 3.4120 – 3.0024mg/l. Iron concentrations in all samples were higher than the WHO recommended limit of 0.05mg/l (WHO, 2004). The copper content of the two samples was lower than the WHO recommended limit for drinking water. Zinc concentration ranged between 3.8602 and 4.1200mg/l. The concentration of zinc in the samples were above the WHO (2004) recommended limit for drinking water. The nickel and vanadium contents of the two samples were within the WHO recommended limit for drinking water. Manganese concentration ranged between 3.0510 and 3.1200mg/l. The concentration of manganese in the samples were above the WHO (2004) recommended limit for drinking water.

4. Conclusion

Generally, the result showed that there were significant variations in some of the physicochemical parameters and heavy metal concentrations in the water quality of the stream. Some of the parameters analyzed were found to be well beyond the approved limits based on WHO standards. This therefore indicates that the water quality of the OkoroNsit stream water is reasonably impacted adversely by the sand dredging activities from the upstream River (IsoEsuk River). Amongst the heavy metals assessed, iron, zinc and manganese were found to be higher than WHO (2004) recommended limits for drinking water, while others were below the limits in all of the samples. It is recommended that OkoroNsit stream should be periodically monitored to ascertain its portability for drinking cum domestic and recreational purposes, such as swimming. Also further studies should be conducted to investigate and ascertain the level of metals deposits in fish tissues, organs and fluids from the stream, to ascertain if there is a significant correlation between the trends in the pollutants levels found in the water and fish biota, due to bio-accumulation and bio-magnification processes.

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