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Sediment physicochemical properties of Maa-Dee-Tai River System in Sogho community, Ogoniland, Rivers State, Nigeria

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Abstract

River sediments act as pollutant sinks resulting in changes in physicochemical properties of the sediment which eventually impacts the quality of overlying waters. This study examined some physicochemical parameters in sediments from Maa-Dee-Tai River system in Sogho Community, Ogoniland, Rivers State, Nigeria using appropriate standard techniques. Data obtained revealed that the physicochemical parameters recorded given in range, mean and standard deviation were total organic carbon TOC [(3.88±0.10-4.13±0.04 (3.92±0.18) %], pH [4.99±0.015-5.39±0.042 (5.18±0.037)], conductivity ([174.8±2.81-79.25±45.8 (127.5±21.90) µS/cm], Cl^-[7.35±0.32-9.18±0.388 (8.28±0.42) mg/Kg], salinity ([12.2±0.46-15.18±0.917 (13.7±0.70) mg/Kg], NO_3^- [0.77±0.1-0.841±0.066 (0.81±0.08) mg/Kg] and PO_4^{3-} [7.12±0.05-7.96±0.33(7.44±0.21 mg/Kg)] respectively. Sediment particle size distribution indicate that the river bed has a higher proportion of clay [clay (82±1.12%) > silt (9.33%) > sand (6.58%)]. Considering the physicochemical characteristics of the River system, it was revealed that the River is acidic and has high level of phosphate which could be a pointer to increased growth of algae and large aquatic plants. This study is timely since the Maa-Dee-Tai River system in Sogho Community, Ogoniland, Rivers State, Nigeria has no published report on its environmental status. Hence, the present research is to provide baseline data for developing water and sediment quality index of the coastal zone in the Songo territorial waters. This River is not a recipient of any industrial and municipal wastes and therefore strict environmental policies should be enacted by the community leaders to maintain the natural state of the river system.

Keywords: River sediment; Pollutant sink; Physicochemical parameters; Baseline data

1. Introduction

The sediment at the bottom of a river play a significant role in the pollution scheme of such river system (Horsfall et al., 1994; Horsfall ad Spiff 2002). Aquatic sediments are a known source of pollutants, but their impact on the quality of overlying waters is not easily quantified. Sediments are generally considered to behave as a sink for pollutants such as heavy metals in the aquatic environment, frequently acting as a source for their presence in waters, with implications for catchment management (Ho-Sik *et al.,* 2012). River sediment typically acts a ‘sink’ or ‘source’ of phosphorus for the overlying water owing to the adsorption of phosphorous by the sediment or release of phosphorous to the water, respectively (Xiaolong et al., 2020). The physicochemical parameters of the sediments such as electrical conductivity, dissolved oxygen, pH, and total organic carbon can control the occurrence and abundance of species distributed in them (McLusky and Elliott, 1981). Sediments are sources and sinks of contaminants and play an important role in mediating pollutants across environmental compartments of terrestrial and aquatic ecosystems. In surface waters (lakes, slowly flowing or dammed rivers, estuaries, oceans), organic and inorganic contaminants are either dissolved or sorbed to suspended matter and sediment particles according to their chemical properties. In the case of strong sorption, settling of suspended particles and sediment formation scavenge contaminants out of the water phase, resulting in the accumulation of contaminants in the beds of rivers and lakes (Aurea *et al.,* 2022). Sediment is also the major site for

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organic matter decomposition which is largely carried out by bacteria. Important macro-nutrients are continuously being interchanged between sediment and over-lying water (Abowei, and Sikoki, 2005). Furthermore, sediments have an impact on ecological quality because of their quality, or their quantity, or both (Stronkhorst *et al.,* 2004). It is observed that continuous accumulation of pollutants due to biological and geochemical mechanisms, and cause toxic effect on sediment dwelling organisms and fish, resulting in decrease survival, reduced growth, or impaired reproduction and lowered species diversity (Mucha *et al.,* 2003; Praveena *et al.,* 2007). Sediments are sources and sinks of contaminants and play an important role in mediating pollutants across environmental compartments of terrestrial and aquatic ecosystems. Physicochemical changes represent the presence of contaminants that can enter rivers through the disposal of these effluents. Evaluating the physicochemical properties of water and sediments can provide valuable insights into the extent of pollution and its potential impacts on the rivers' ecosystems. Physicochemical parameter such as the pH of water is a critical indicator of its quality, influencing water solubility and nutrient content (Amadi *et al.*, 2010; Ching *et al*., 2015). Electrical conductivity, another important parameter, depends on the presence, concentration, and mobility of ions, as well as temperature (Saxena and Sharma, 2017). Turbidity, the measure of water clarity, indicates the presence of suspended particles. Excessive turbidity can impair light penetration, affecting aquatic life and ecosystem dynamics (Onoyima *et al.*, 2022). Several studies have been carried out on the some physicochemical characteristics of surface sediments in China (Gao et al., 2016; Wang et al., 2020; Liu et al., 2020, Kang et al., 2014; Fan et al., 2017; Zhang et al., 2020, Guo et al., 2001, while in Nigeria numerous Rivers has been investigated for physicochemical parameters (Edori *et al.,* 2019; Keremah *et al.,* 2014; Togue *et al.,* 2017; Daka and Moslen, 2013; Daka *et al.,* 2007; Kaizer and Osakwe, 2010; Ilechukwu *et al.,* 2020; Inyinbor *et al.,* 2018; Jonah *et al.,* 2014; Olorode *et al.,* 2015; Onyegeme-Okerenta and Ogunka (2015). Ologbosere *et al.,* 2016, Muduli and Panda, 2010). However, the Maa-Dee-Tai River System in Sogho Community, Ogoniland, Rivers State, Nigeria has very little known from the physicochemical characteristics stand point. Hence, the objective of this paper is to evaluate some physicochemical parameters in sediments from Maa-Dee-Tai River in Sogho Community, Ogoniland, Rivers State, Nigeria

2. Materials and methods

2.1. Study area

This River is situated in Sogho community, Ogoniland, Niger Delta Region, Nigeria (Figure 1). The river has tributaries with Imo and Bori rivers and served as a source of water for cassava fermentation, drinking and washing of fabric materials.

Figure 1 Maa-Dee-Tai River in Sogho Community, Ogboni land

= Sampling Stations

Also, fishing activities is commonly carried out by the people residing within the community. The town is reportedly known for farming activities that use fertilizers and pesticides on their farmland. Although there is no industrial activities within the town but it is close to Afam power and Korokoro Flow Stations in Oyigbo and Tai Local Government Areas respectively (Fig 1).

2.2. Sample collection and Analysis

Sediment samples were collected at the peak of the rainy season in June at three sampling stations (Tai: (S1), Werri: (S2) and Barawansah: (S3) established during the reconnaissance visits. Replicate grabs samples were collected for particle size analysis and physicochemical analysis of the sediment. These were transported to the laboratory in ice-cooled boxes.

Samples of the bed sediments were collected at four core depths that is four samples per site and 8m away from the flowing water using an Ekman grab (15 cm by 15 cm) and were kept in clean glass containers. Apart from in-situ measurement after the sediment samples were mixed in a ratio of 1:1 with distilled water in a beaker before inserting the probes and appropriate readings taken after allowing the instrument to stabilize, readings were taken for conductivity and pH, using hand held electronic pH meter; Hannah DI-4337 and hand held electronic pH meter; Hannah DI-4337; the other parameters such as Total Organic Carbon (TOC%), anion and particle size were analyzed using Walkley Black-T method (Walkley and Black, 1934), Hach 3900DR Spectrophotometer and Hydrometry method respectively. Nitrate (NO3) levels in sediment were determined following the Brucine Method (APHA (1998)), while available phosphorus in sediment was determined by Bray and Kurt method (Bray and Kurtz, 1945).

2.3. Determination of Phosphorus in Sediment

The determination of Phosphorous in the soil sample was done using Olsen's Method. (ASTM, 2007). Exactly 2.00 g of air-dried soil sample (passed in a 2 mm sieve) was weighed into a 125 mL Erlenmeyer flask and 5.00 mL of 18.0 M of sulphuric acid was added with 0.400 g of ammonium persulfate and boiled until a final volume of about 10.0 mL was reached. The solution was filtered and made up with distilled water to 40.0 mL. And 5.00 mL of Antimony Molybdate was added to the solution, followed by the addition of 2.00 mL of ascorbic acid. The blank and standard solutions were subjected to the same treatment as above. After about 10-20 minutes, the absorbance of the sample, standard and blank solutions were measured with Ultra violet spectrophotometer at a wavelength of 680nm. The calibration curve (Figure 1) was obtained for a standard solution of 2.00, 4.00, 6.00, 8.00, 9.00 and 10.00 ppm phosphate and the concentration of the samples were obtained from the calibration curve using the absorbance of the samples.

We also evaluated the Sandel Sensitivity Index as follow

Sandell's index or sensitivity is the lowest concentration in ppm (μg/cm3) which results in absorbance of 0.001 in a 1 cm path length. Can be calculated as follows:

$$Ss = \frac{(0.001)x(1.0cm)}{slope\ (cm^3/\mu g)}$$

2.4. Calibration Graph

Under the optimum condition, a good linear relationship Figure 2 was found to exist between the absorbance of the system and concentration of phosphate 0.3-12.24 ppm with a straight line having slope 0.0991(Cal.) and intercept 0.0.021. Molar absotptivity, correlation coefficient, and Sandell's sensitivity values were calculated and were found to be $6.103x10^3$ mol-1cm,-1 0.997 and 0.0112 mg cm^{-2} respectively. The precision and accuracy of the method were studied by analyzing a series of solution containing known amount of phosphate (0.3, 3.0 and 10.7 ppm) by using recommended volumes and concentration of the reagents. The precision of the method as expressed by relative standard deviation was less than 3.7% whereas the accuracy expressed by the calculated relative error was 3.4%.

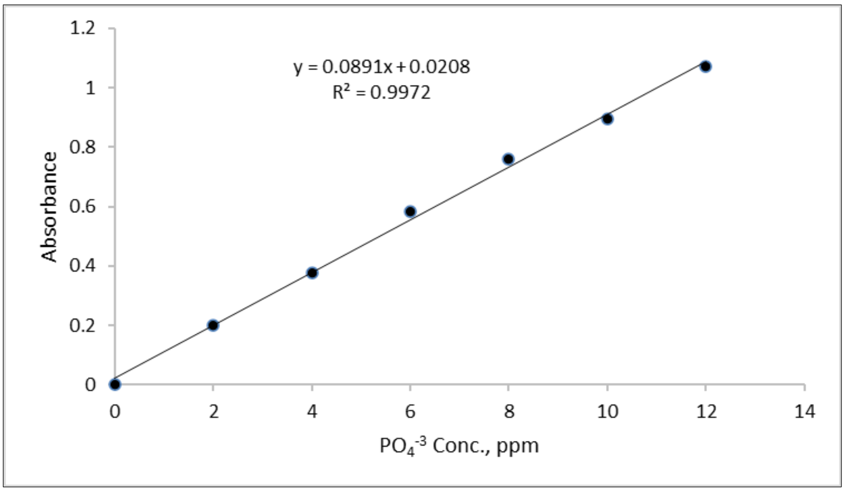

Figure 2 Calibration graph for the determination phosphate under optimized experimental condition

2.5. Data Analysis

Experimental data obtained for analysis of each sediment variable were validated using the mean, standard deviation, One-way ANOVA and correlation analyses.

3. Results and discussion

Sediments are complex environments, with varying physicochemical characteristics, such as composition and type of organic matter, particle size distribution, and pH. Contaminated sediment is a significant environmental problem affecting many marine, estuarine and freshwater environments throughout the world. Sediment is important in the formation of beaches, spits, sand bars and estuaries and provides substrates for aquatic plants and animals. Sediment also provides nutrients and minerals vital to the health of downstream ecosystems. River sediments are incredibly important for marine wildlife, as they provide a home for a diverse array of marine invertebrates and fish, as well as providing a rich foraging ground for larger predators to feed on. The physicochemical parameters of the sediments such as electrical conductivity, dissolved oxygen, pH, and total organic carbon can control the occurrence and abundance of species distributed in them (McLusky and Elliott, 1981).

The sediment particle size analysis (Table 1) of the Maa-Dee-Tai River in Sogho Community, Ogoniland, Rivers State, Nigeria were dominated by clay particles, which ranged from 85.5±1.12-82±1.12% indicating that the sediments are loamy in nature. While the sand and silt portions in the sediments ranged from 7.25±0.83-6±1.80% and 12±1.22-8±0.71% respectively. This is contrary to the investigation of Bodo Creek that is dominated by sand particles Vincent-Akpu *et al.,* (2015) but it's in agreement with reports of Nwaja Creek (Adesuyi *et al.,* 2016). Consideration of the individual sampling stations revealed that the Werri Sample Station had a higher silt components (12±1.22 %) than Dee-Tai (8±0.71 %) and Barawansah (8±0.71 %) sampling stations. The percentage sand content was higher in Dee-Tai (7.25±0.83 %) sampling station than Werri (6±1.80) and Barawansah (6.5±0.5) stations respectively, while clay content in the sampling stations were Dee-Tai (84.75±0.43 %), Barawansah (85.5±1.12 %) and Werri (82±1.12 %) respectively. The overall textural class of sediment particle in the study area is loamy sandy, which could been responsible for the over 80% clay in the study area.

Apart from particle size analysis, some sediment physicochemical properties in the Maa-Dee-Tai River system in Sogho Community of Ogoniland in Rivers State, Nigeria were evaluated in Dee-Tai, (Figure 3), Barawansah (Figure 4) and Werri (Figure 5) respectively. According to Ogbeide and Edene (2023), sediments are indispensable to the wellbeing status of water bodies as they are basins for pollutants and nutrients which crosses threshold into the water bodies. They have the potential to capture and release these pollutants or nutrients back into the water column depending on factors such as pH, temperature and other conditions within the aquatic ecosystem. Also, river organisms can take up these substances directly from sediments (Pereira *et al.,* 2021). Data obtained reveal that sediment physicochemical properties in the Maa-Dee-Tai River system in Sogho Community of Ogoniland in Rivers State, Nigeria were much lower than those recorded in previous studies. In a study by Nnaji *et al.* (2010), the mean values recorded for pH, conductivity and organic matter were 5.99, 197.7µS/cm and 3.781%, respectively. In another study by Edori *et al.* (2019), the mean values recorded for pH, conductivity, organic carbon and organic matter were 7.20, 1.67E4µS/cm, 2.37% and 4.09%, respectively. There was a decreasing trend in the values of pH, nitrogen, phosphorus, total organic carbon and silt in sediments as the study progressed from Dee-Tai to Werri along the River. The changes observed are attributed to the reduced inputs from anthropogenic sources (Shehu, 2019).

Table 1 Mean (%) of some physicochemical properties of sediment samples from Maa-Dee-Tai River in Sogho Community, Ogoniland, Rivers State, Nigeria

Parameter	Dee-Tai	Barawansah	Werri	AMCS	DPR
pH	4.99±0.015	5.39±0.042	5.17±0.055	5.18±0.037	6.5-8.5
Electrical conductivity(µS/cm)	79.25±45.8	128.5±17.1	174.8±2.81	127.5±21.90	2000
%Total Organic Carbon	4.13±0.04	3.88±0.10	3.75±0.13	3.92±0.18	
Salinity (mg/Kg)	15.18±0.917	13.8±0.73	12.2±0.46	13.7±0.70	2000
Chloride (mg/Kg)	9.18±0.388	8.30±0.54	7.35±0.32	8.28±0.42	
Nitrate, NO_3^- (mg/Kg)	0.841±0.066	0.82±0.059	0.77±0.1	0.81±0.08	10
Phosphate PO_4^{3-} (mg/Kg)	7.96±0.33	7.23±0.26	7.12±0.05	7.44±0.21	5
Silt, %	8±0.71	8±0.71	12±1.22	9.33	
Sand, %	7.25±0.83	6.5±0.5	6±1.80	6.58	
Clay, %	84.75±0.43	85.5±1.12	82±1.12	84.1	
Textural class				Loamy sand	

Note (n=12), values are mean ± SD. AMCS-Average Means Concentration for the sampling stations. DPR-Department of Petroleum Resources (2002) values for material discharged into water for domestic utilization in Nigeria

3.1. pH

In this study, the sediment pH ranged from 4.99±0.015-5.39±0.42 (Figures 3 and 4) indicating mild acidity when compared with the allowable limit proposed by Department of Petroleum Resources (DPR), Nigeria. This range of values is more acidic when related with those of Sombreiro River sediments (6.61±0.175 – 7.16±0.03) Wokoma and Friday, (2017); and Bodo creek sediments (8.8±0.1-8.9±0.1) Vincent-Akpu *et al.,* (2015) respectively but the value are considerably similar to those reported by Umesi (1999) who posited a range of 2.7±0.10 – 5.5±0.31 in Rumueme creek sediment and almost in agreement with sediment from Sombreiro River which varied from 5.06 – 5.85 (Ezekiel, 2011). The mild acidity values of the sediment observed is related to mainly anthropogenic sources such as acid rain and runoff within the locality.

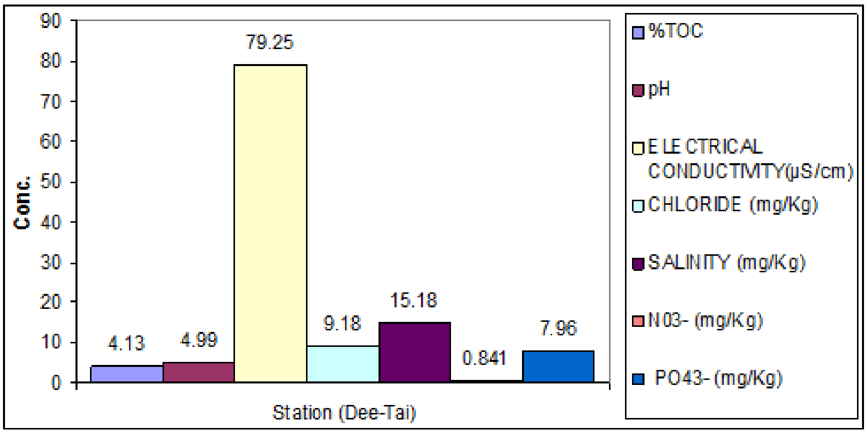

Figure 3 Evaluation of physicochemical parameters in sediment from Dee-Tai station

3.2. Conductivity

Electrical conductivity is the measure of water capacity to convey electric current. Electrical conductivity of water is directly proportional to its dissolved mineral matter content (Adeloye, 2004). The source of conductivity may be an abundance of dissolved salts due to addition of table salt in food materials, actual salt present in pure water, and other mineral discharges. The sediment conductivity values are found to be 79.25±45.8 μS·cm^{-3} for Dee-Tai, 128.5±17.1 μS·cm^{-3} for Barawansah, and 174.8±2.81 μS·cm^{-3} for 5.17±0.055 (Table 1). The electrical conductivity and salinity mean concentration values ranged from 79.25±45.8-174.8±2.81μS/cm and 12.2±0.46-15.18±0.917mg/Kg respectively. They are lower than standard limit values for drinking water approved by Department of Petroleum Resources (DPR). Lower values were obtained for conductivity and salinity at Dee-Tai and Werri respectively. In this work, the conductivity and salinity when compared with previous findings showed that they are lower than those reported by (Seiyaboh *et al.,* 2016; Adesuyi *et al.,* 2016). The measurements of conductivity are mainly applied in the process of monitoring the quality of water available and chemical oceanography for the determination of salinity (Horsfall and Spiff, 2013).

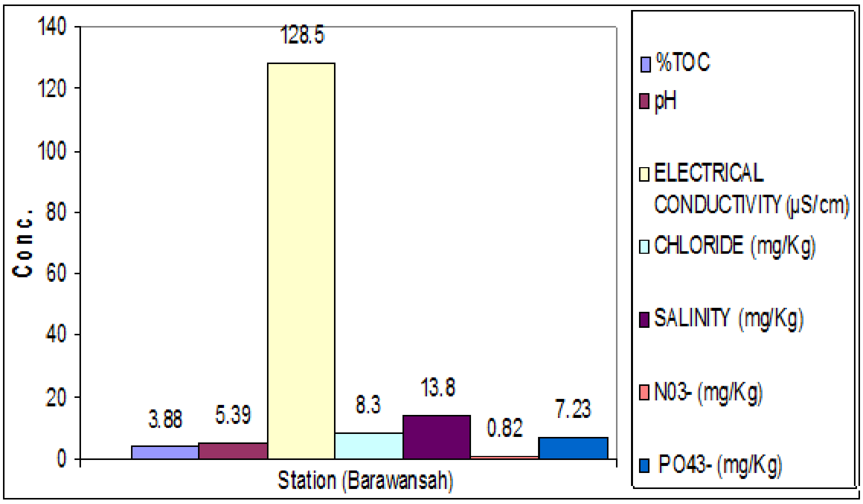

Figure 4 Evaluation of physicochemical parameters in sediment from Barawansah station

3.3. Total Organic Carbon (TOC)

TOC, is the amount of organic carbon present in a source rock expressed as a weight percent. It is a proxy for the total amount of organic matter present in the sediment (Ronov, 1958) and used as an indicator of source richness with respect to how much hydrocarbon the sediment may generate. Total Organic Carbon (TOC) is a measure of the total amount of carbon in organic compounds in pure water and aqueous systems. The average values for total organic carbon (TOC) content in the location assess in Maa-Dee-Tai River varied between (3.75±0.13-4.13±0.04) %. This signified high organic carbon content which is in agreement with the statement that "sediments with values of organic carbon content exceeding 1% are said to have high organic carbon content" (Wokoma and Friday, 2017). This value partially agreed with those obtained in sediment from Nwaja creek (0.98 - 4.58) % by (Adesuyi *et al.,* 2016) but above the concentration recorded by (Daka and Moslen, 2013).

3.4. Chloride

Chloride is a naturally occurring ion that is present in both fresh and salt water. Chloride is most commonly derived from dissolved salts such as sodium chloride or magnesium chloride. Chloride is essential in small amounts for normal cellular function in plants and animals. Chloride is prob- ably the most mobile component in the sediment-water system, and it represents a nonreactive element, useful for studying diffusional processes in sediments. Chloride is a serious threat to in-land freshwater lakes and streams. Since, the Maa-Dee-Tai River is a fresh water emptying into the brackish water of the Imo River, an assessment of its chloride content is very necessary. The mean values of chloride (Cl^-) varied within 7.35±0.32-9.18±0.388mg/Kg. These values are considerably higher than those observed in sediments from Epie creek (Izonfuo and Bariweni, 2001).

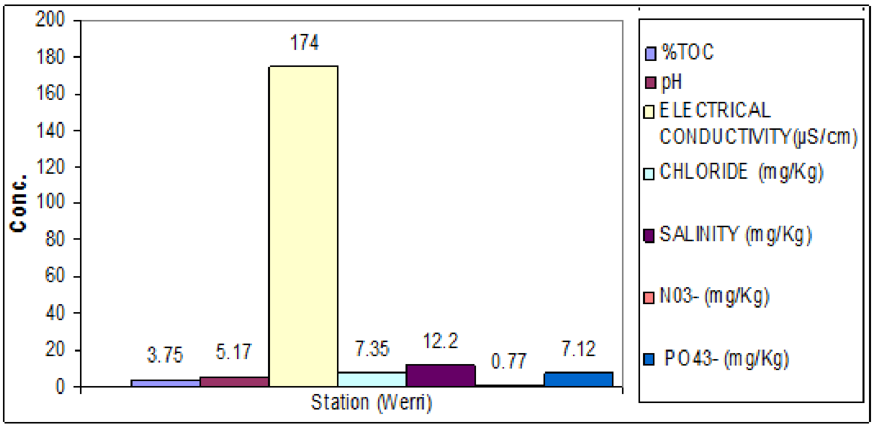

Figure 5 Evaluation of physicochemical parameters in sediment from werri station

3.5. Nitrate, and Phosphate

Nitrate, a compound of nitric acid, is the most highly oxidized form of nitrogen found in aquatic environment [Devi and Rajaram, 2018; Fadiran *et al.,* 2008; Flkresilasie, 2011). It is an essential nutrient for many photosynthetic autotrophs and in some instances, functions as a growth-limiting nutrient. It is used by algae and other aquatic plants to form plant protein which, in turn, can be used by animals to form animal protein. Nitrate is a major ingredient of farm fertilizers and is necessary for plant uptake and is essential for plant growth (Praveena *et al*., 2007). Nitrates are the indirect source of food for fish. This may increase the fish population. Polyphosphates are detrimental in that they interfere with coagulation, flocculation, and lime soda treatment of water. The levels of nitrate may give rise to methaemoglobinemia (Wokoma and Friday, 2017) in infants; also, the levels of nitrate reported in this study in addition to phosphate levels can cause eutrophication and may pose a problem for other uses. Phosphates are mostly from fertilizers, pesticides, industry, and cleaning compounds. Natural sources include phosphate-containing rocks and solid or liquid wastes. The element phosphorus is necessary for plant and animal growth. Nearly all fertilizers contain phosphates. Phosphates enhance the growth of plankton and water plants that serve as food for fish and aquatic life which results in increase of fish population that improves the quality of aquatic life. If excess phosphate is present, it may result in eutrophication. Many fish and aquatic organisms may not survive Hashemi *et al.,* 2016]. The huge agricultural activities coupled with the use of fertilizers, pesticides and other agrochemicals within the study area might have been responsible for the levels of phosphate in the water samples. In water, phosphorus is often biologically unavailable as it binds readily to particles. Soluble phosphorus which is available for uptake is called phosphate. Phosphates are not harmful to people or animals unless they are present in very high concentrations. The levels of phosphate in all the points exceeded the WHO maximum permissible limit of 5 mg/L (Paytan and McLaughlin, 2011).

Phosphorus is an important biogenic substance in aquatic ecosystems. Its migration, transformation, and transportation in river systems are of ecological significance (Paytan and McLaughlin, 2011; Hashemi *et al.,* 2016). In natural river systems, phosphorus typically exists in sediments, water, and aquatic organisms (Withers and Jarvie, 2008; Chen *et al.,* 2018). Desorption of phosphorus from sediments to the overlying water is called release, which is a type of phosphorus transformation in aquatic ecosystems. Because of the ecological significance of phosphorus, researchers have been studying its release from sediments to the overlying water. Nitrate (NO_3^-) and phosphate (PO_4^{3-}) average concentration values varied from 0.77±0.1-0.841±0.066mg/Kg and 7.12±0.05-7.96±0.33mg/Kg. The value for Nitrate is extremely lower compared to DPR approved limit while Phosphate value is moderately higher. They are higher than the finding of Epie creek (Izonfuo and Bariweni, 2001) but lower than those of Nwaja creek (Adesuyi *et al.,* 2016).

Correlation analysis of the physicochemical properties of the sediment samples collected from Maa-Dee-Tai River system sediments indicated that there was negative of no correlation with pH and all the parameters investigated (p<0.05). However, significant positive correlations (p<0.05) exists between total organic carbon and chloride; nitrate (NO_3^-); and phosphate (PO_4^{3-}) respectively. There were no significant differences (p<0.05) between the mean values of the electrical conductivity of the sediment samples and other parameters. This result suggest that the industrial and agricultural activities done in the studied riverine region did not cause major alterations in sediment physicochemical properties, however continuous environmental monitoring is necessary to maintain the water quality.

Table 2 Correlation Matrix of the physiochemical parameters in Table 1

	pH	**EC**	**TOC**	**Cl**	**NO**	**PO**
pH	1					
EC	0.465103	1				
TOC	-0.60221	-0.98682	1			
CL	-0.4108	-0.99818	0.975252	1		
NO	-0.42942	-0.9992	0.979583	0.99979	1	
PO	-0.2322	-0.96906	0.91635	0.982194	0.978134	1

EC = electrical conductivity; TOC = total organic conductivity; Cl = chloride; NO = nitrate (NO_3^-); PO = phosphate (PO_4^{3-})

Table 3 One-way Analysis of Variance (ANOVA) without replication of the sediment physicochemical properties

Source of Variation	**SS**	**df**	**MS**	**F-experimental**	**P-value**	**F-critical**
Between Groups	37912.98	6	6318.83	19.34456	4.95E-06	2.847726
Within Groups	4573.05	14	326.6464			
Total	42486.03	20				

One-way Analysis of Variance (ANOVA) without replication of the sediment physicochemical properties was evaluated as results presented in Table 3. In application of the One-Way Analysis of variance, experimental-F values are compared with critical-F values at the desired confidence level and degree of freedom. If $F_{exp} > F_{crit}$ at the desired level of significance, then there is a significant difference between the sets of data or the method. However, if $F_{exp} \leq F_{crit}$, then there is no significant difference between the sets of data or the methods. The data obtained show that the F_{exp} (19.35) > F_{crit} (2.85), are indicative of no immediate potential environmental contamination risk in the area studied.

4. Conclusion

Conclusively, the sediment physicochemical properties of the Maa-Dee-Tai River system in Sogho Community of Ogoniland in Rivers State, Nigeria indicate low pollution potential at the moment.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to disclosed.

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