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Analysis of sediment quality in the oil-reach Bayelsa state, Niger delta region of Nigeria

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Abstract

Sediments are a dire part of the aquatic ecosystems, and their contamination is a global concern. Therefore, this study evaluates sediment quality in the Niger Delta region of Nigeria based on heavy metal-contamination. To achieve this, three set of sediment samples were collected, two were sampled from areas with history of crude oil spills, and a control sample was collected from an area with no history of crude oil spills. Sediment sampling covered three different sites. For site 1, the mean concentrations of heavy metal were 0.49, 14.70, 7.35, 8.72, 13.92, and 38.06 mg/kg for cadmium, chromium, copper, nickel, lead, and zinc, respectively. These concentrations were below the threshold effect concentration, and probable effect concentration. These are both environment risk guidelines. Similarly, for site 2, the mean concentrations of heavy metals were 1.92, 30.61, 19.41, 20.05, 22.99, and 102.28 mg/kg for the heavy metal order above. The concentration of cadmium (1.92) is above the threshold effect concentration value (0.99 mg/kg), which implies adverse effect is expected to occur. The concentration values of the rest heavy metals were below both the threshold effect concentration and probable effect concentration guideline values. For site 3, the mean concentration values following the heavy metal order were 0.29, 36.45, 20.20, 16.25, 21.51, and 62.14 mg/kg, respectively. These values are all below the two specified guideline values. The control samples all had concentrations below the guideline values of the two specified guidelines, indicating that the high concentration values were due to crude oil spills in the area. However, since heavy metals are known for their bioaccumulation and biomagnifications potentials, and degradation resistance, there is need for sediment quality analysis in the region to safeguard our aquatic ecosystems.

Keywords: Crude Oil; Sediment; Heavy Metal; Environmental Pollution

1. Introduction

Sediments are a dire part of aquatic ecosystems. Sediment pollution is dangerous to aquatic ecosystems and has attracted global environmental concern [1, 2]. Thus, the need for developing cost-effective measures for sediment quality analysis and remediation.

Sediment contaminants are both organic and inorganic [2, 3]. The Niger Delta region of Nigeria is globally known for her blessings with oil and gas reserves; thus, the home of the oil and gas industry in the country. The presence of the oil and gas industry in the region has contributed immensely to the development of the Nigeria's economy. However, their operations and associated activities have impacted negatively on the environment (e.g., soil, sediments, water, and air). Petroleum hydrocarbons (crude oil), the primary product from the activities of the oil multinationals is a complex mixture of aromatic and aliphatic hydrocarbons amongst others. These contaminants pollute the environment (both soil and water resources) in various means- majorly crude oil spills (accidentally/equipment failure or through

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sabotage). Crude oil also contains heavy metals, HMs [4]. HMs are known for their degradation resistance, biomagnification and bioaccumulation potentials [5, 3, 6].

Sediment pollution due to HMs has been widely documented in the literature. For example, HMs concentrations in sediment samples from different countries across six continents were computed [7]. The authors reported that sediment pollution due to HMs is alarming. In another study, [8] also documented the content of HMs in sediment samples sampled from the main river systems, China. Results show that Cd and Hg contents have caused high ecological risks in Haihe and Pearl Rivers.

Literatures reported that maximum Cd levels in South Africa (Port Elizabeth harbor), in Greece (Keratsini Harbor) and East London harbor have reached 1000 mg/kg [9,10]. These levels exceeded the probable effect concentration (PEC) value for Cd (Table 1), which is likely to impact negatively on aquatic organisms [11]. In Southeastern China, sediments have been reported to be impacted by HMs due to industrial pollution and other factors. This is particular case of coastal sediments [12]. In another study, [11] reported that the maximum concentrations of most HMs exceeded the PEC and the grade III of marine sediment quality in China [13]. The elevated contamination of HMs where observed in both sediment and seawater along China's coastal environment, which is likely to increase the risk of human exposure to HMs [14]. Therefore, this current study is aimed at assessing sediment quality in the oil-reach Niger Delta Region of Nigeria, and make recommendations that will help safeguarding aquatic ecosystems in the region. To establish that, sediment samples were collected from areas with oil spill history. In addition, control sample was collected from an area of no crude oil spill history, and the two group of sediment samples were analyzed for HMs to know the cause of sediment pollution in the study area.

2. Materials and Method

2.1. Study Area and Sampling

The study area is located in Bayelsa State, Southern Nigeria. The area is selected because of its history of crude oil spills and environmental contamination. Sediment sampling covered three different sites. Three (n = 3) set of sediments samples were collected, two samples were collected from sites with history of crude oil spills, and a control sample was collected from an area with no history of crude oil spills.

2.2. Heavy Metal Analysis

This study used Inductively Coupled Plasma (ICP, AQ300, Vancouver, Canada) for the HMs analysis in the sediment samples. Chemical analysis strictly followed the procedure in [15].

3. Results and Discussion

3.1. Heavy Metal

The chemical analysis for HMs in the sediment samples are summarized and presented in Table 1 below. The study analyzed HM contents in sediments collected from areas with crude oil spill history and from areas with no crude oil spill history. Results show that site 2 is more contaminated followed by site 3. However, site 1 is more contaminated than site 3 in the case of Cd only. These results were all below the concentration values of HMs in the control sediment samples. The results were further compared with both the threshold effect concentration (TEC), and probable effect concentration PEC values. Concentrations below the TEC, which means adverse effects are not expected to occur, whereas concentrations above PEC, indicates adverse effects are expected to occur more often than not [11]. The concentrations of HMs across the study sites were below the TEC guideline values, except Cd concentration level in site 2. This implies that, adverse effects are expected to occur in the case of Cd contamination. However, the HMs concentration values across the three sites were still below the PEC guideline value. This indicates that no adverse effects are expected to occur more often than not [11].

Table 1 Summary of heavy metals concentration in sediment samples in the current study. The results are compared with environment guideline values (TEC and PEC).

Sample Type	**Heavy metal**	**Concentration [mg/kg]**		**Mean conc. [mg/kg]**	**Control conc. (Cc) [mg/kg]**	**TCE [mg/kg]**	**PCE [mg/kg]**
	SITE 1						
Sediment	TM	C_1	C_2	(C_1+ C_2)/(2)	Cc		
	As	<0.001	<0.001	<0.001	<0.001	9.79	33
	Cd	0.48	0.49	0.485	0.12	0.99	4.98
	Cr	14.68	14.71	14.695	2.09	43.4	111
	Cu	7.35	7.34	7.345	0.43	31.6	149
	Hg	<0.001	<0.001	<0.001	<0.001	0.18	1.06
	Ni	8.72	8.72	8.72	0.37	22.7	48.6
	Pb	13.92	13.91	13.915	1.95	35.8	128
	Zn	38.06	38.05	38.05	18.91	121	459
SITE 2							
Sediment	As	<0.001	<0.001	<0.001	<0.001	9.79	33
	Cd	1.95	1.88	1.915	0.12	0.99	4.98
	Cr	30.20	31.01	30.605	2.09	43.4	111
	Cu	19.40	19.42	19.41	0.43	31.6	149
	Hg	<0.001	<0.001	<0.001	<0.001	0.18	1.06
	Ni	20.12	19.98	20.05	0.37	22.7	48.6
	Pb	22.92	23.06	22.99	1.95	35.8	128
	Zn	102.7	101.86	102.28	18.91	121	459
SITE 3							
Sediment	As	<0.001	<0.001	<0.001	<0.001	9.79	33
	Cd	0.28	0.29	0.285	0.12	0.99	4.98
	Cr	38.40	38.49	36.45	2.09	43.4	111
	Cu	20.19	20.20	20.195	0.43	31.6	149
	Hg	<0.001	<0.001	<0.001	<0.001	0.18	1.06
	Ni	16.25	16.25	16.25	0.37	22.7	48.6
	Pb	21.50	21.52	21.51	1.95	35.8	128
	Zn	62.15	62.13	52.14	18.91	121	459

TM= target metals; TEC= threshold effect concentration; PEC= probable effect concentration

Cadmium (Cd) concentration values were compared with results of other studies in the literature. For example, [16] measured Cd in sediment samples from Hwasun wharf in Incheon North Port, Korea. The authors reported that Cd concentration value was 0.8 mg/kg. This value is below that of the most contaminated site (i.e., site 2) in the current study, as presented in Table 1 ~~2~~ above; while it is above the values obtained in site 1 and 3. The Cd concentration values in the current are below the value (4.7 mg/g) reported in [17] after analyzing the Cd contents in a marine sediment

collected from Dongting Lake, Hunan Province, China. Similarly, the Cd concentration value from a marine sediment reported by [18] was higher than the Cd results from the current study.

4. Conclusion

Crude oil spill is known to contaminate and/or pollute both soil and water resources, causing environmental pollution and degradation in diverse ways. The challenges underscores the assessment of sediment contamination, and recommendations for environment friendly remediation schemes. Therefore, this study evaluated the contents of HMs in sediment samples collected from three different sites with history of crude oil spills. To know the cause of HMs pollution in the sediments, control sample from site of no crude oil spill history was collected and analyzed. Results of HMs concentrations across the sampling sites were all below both the TEC and PEC environmental guideline values, except that of Cd (1.92 mg/kg) which exceeds the TEC value (0.99 mg/kg). This implies adverse effect is expected to occur in terms of Cd pollution. Though the concentrations are below both the TEC and PEC, except the case of Cd; the elevated concentrations relative to HMs concentrations in the control sample may be attributed crude oil spills in the area. Since sediment pollution is dangerous to aquatic ecosystems and has attracted global environmental concern, and HMs are known for their bioaccumulation and biomagnification potentials, and degradation resistance, the following recommendation are made to better safeguard our environment:

- Oil multinationals should guide against any activity and/or operations that will cause oil spill in their operational fields.
- The regulators should make sure that environmental laws are strictly enforced to the later.
- There is need for sediment quality analysis in the oil-rich Niger Delta Region of Nigeria to safeguard our aquatic ecosystems.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest was disclosed by the authors.

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