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ORIGINAL RESEARCH

Heavy Metals and Physicochemical Characteristics of Soils from the Banks of Effluent Wastewater Retention Pits in the Niger Delta, Nigeria

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ABSTRACT
This study investigated some physicochemical and heavy metals concentration in soils from around the bank of waste retention pits receiving municipal and industrial waste water from the vicinity of oil and gas facilities in Rivers state, Nigeria. Soil samples were collected during the rainy season month of June 2010 from the bank of two waste dump pits with one control sample being established 100 meters away from the waste point sources. The soils were collected and analyzed following standard field and analytical protocols. Results revealed the following soil characteristics: 6.08 – 7.53 (pH), 140 - 490 μS/cm (conductivity), 26.4 – 887.8 mg/kg (oil and grease), 1.05 – 1.66 mg/kg (ammonium), 85 – 320 mg/kg (chloride), 0.039 – 2.240 mg/kg (nitrite), 40.6 - 564 mg/kg (nitrate), 1.40 – 5.2 mg/kg (phosphate), 1.4 – 5.2 mg/kg (sulphate), 72.31 – 240.85 mg/kg (sodium), 27.20 – 78.5 mg/kg (potassium), 17.12 – 210.83 mg/kg (calcium), 13.94 – 41.19 mg/kg (magnesium), <0.01 mg/kg (mercury), 572.7 – 1,858.8 mg/kg (iron), 0.57 – 2.87 mg/kg (chromium), 0.01 – 0.130 mg/kg (cadmium) and 0.94 – 5.28 mg/kg (zinc). The waste pits showed an apparent enrichment in their various physicochemical attributes especially in waste pit 2. Therefore, the municipal and industrial waste water discharged in these pits could be contributing to an alteration in soil physical and chemical characteristics of the receiving environment since soils rich in organic matter actively retains metallic elements while the significant levels of toxic heavy metals and hydrocarbon in the control soil when compared to waste pit 1 may have resulted from the tendency of soils to retain persistent toxicants in an acidic environment since metal solubility tends to increase at lower soil pH. The elevated concentrations of oil and grease in the soils of waste bank 2 and control locations as compared to DPR target values also suggests that runoff from rainfall may have resulted in the transportation of organic constituents of improperly disposed municipal and industrial wastes into nearby surface or open water bodies depending on the retention time of the micro pollutants in the soil matrix and the relative topography of the area.

KEY WORDS: *Dumpsite, Environmental contamination, Soil, Waste water, DPR*

INTRODUCTION

Environmental pollution is in the increasing trend, thereby confronting its sustainability (Izah *et al.*, 2017a) especially in cities (Akinro *et al.*, 2012). Pollution of the environmental components is majorly affected by human activities and to lesser extend natural effects (Seiyaboh and Izah, 2017a, b; Izah *et al.*, 2017b). Several activities resulting from manufacturing or processing operations generate wastes which are discharged into the environment (Izah *et al.*, 2017b). Other economic activities that generate waste streams include market, food processing, agricultural activities (Izah *et al.*, 2017a) and oil and gas facilities. For instance, in agricultural activities the remains of empty cans of pesticides could be detrimental to the aquatic ecosystem probably due to its toxicity (Ojesanmi *et al.*, 2017; Inyang *et al.*, 2017, 2016a, b).

Some food processing wastes is also detrimental to the environment. For instance, oil palm processing wastes such as palm oil mill effluents affects the characteristics of the receiving environment (Izah *et al.*, 2016a). Izah *et al.* (2017d) also reported that cassava waste water alters the characteristics of receiving environment as well. The waste generated by different economic activities is poorly discharged especially in developing countries. Some individuals especially those living along coastal water ways discharge most of the waste generated from household into the surface water (Agedah *et al.*, 2015; Seiyaboh and Izah, 2017a,b; Ogamba *et al.*, 2015a,b; Ben-Eledo *et al.*, 2017a,b). Municipal solid wastes are packaged and deposited in receptacle centers where appropriate government agency moves it to central dumpsites. Sometimes waste are discharged in several unapproved locations including uncompleted buildings, undeveloped plot of lands and some strategic locations in streets (Angaye *et al.*, 2015). Generally, this waste disposal system is carried out in an unsustainable manner in most regions of the world especially in developing nations (Izah *et al.*, 2017c). During rainfall, most waste materials are transported to close by surface water due to runoff. As such, surface waters, sediment and soil are the major recipient of waste generated from all sectors of any nation's economy.

Another source of wastes in the Niger Delta is oil and gas activities. Waste is generated in oil and gas activities at various stages of processing beginning from exploration to marketing of petroleum products. There are regulations regarding the discharge of wastes resulting from oil and gas activities. This waste requires treatment before disposal. Industrial wastewater discharge is a major source of wastes stream from oil and gas facilities. At times, aqueous effluents are discharged in waste water receptacles in the form of waste pits within a company's facility to serve as an intermediate holding point prior to treatment.

Typically, soil is a distinctive habitat for lives as such it is a vital component of the environment (Izah *et al.*, 2017d). The soil is also known to play essential economic, social and ecological lives (Izah *et al.*, 2017d). Therefore, alteration in the characteristics of the soil due to human interferences could cause major change in the role of such soil. Several human activities take place in the soil to cause alteration in soil properties that could affect the water quality of the area depending on the depth of the aquifer and soil characteristics. Akinbile and Yusoff (2011) reported that leachate from dumpsite affects some characteristics of groundwater. Furthermore, soil is the platform through which vegetation are cultivated. Most plant has the tendency to bioaccumulate toxic substances such as heavy metals in their tissues. Most of these plants are an important source of food to humans. Therefore, it could indirectly cause adverse health effect on human that consume vegetation cultivated in contaminated sites.

Studies have been severally carried out on the impacts of waste on soil characteristics and its role on soil, water and air quality (Angaye and Abowei, 2017). According to the authors, waste are known to emit particulates and some pollutant gases, increase the density and diversity of microbes in the environment and alter soil physicochemical and heavy metal properties. Hence there is need to frequently study dump site with regard to different pollution indicating soil properties.

Several studies have been carried out with regard to dumpsite in Nigeria. Some of these studies were carried out in the Yenagoa metropolis, Bayelsa state (Amos-Tautua *et al.*, 2014), Owerri, Imo state (Eneje and Lemoha, 2012), Karu, Nasarawa state (Butu *et al.*, 2013), Uyo metropolis, Akwa-Ibom state (Ukpong *et al.*, 2013), Bauchi metropolis, Bauchi state (Buteh *et al.*, 2013). But, there is dearth of information on the characteristics of waste retention pits receiving industrial effluent water. Hence, this study is aimed at assessing the heavy metal and physicochemical characteristics of soils collected from the bank of waste pits receiving industrial waste water around oil and gas facilities in the Niger Delta, Nigeria.

RESULTS AND DISCUSSION

Table 1 presents the result of physicochemical and heavy metal composition of soils collected from the bank of two waste retention pits receiving industrial wastewater from within and around oil and gas installations. The pH was apparently low (more acidic) in the control (4.79) when compared to the waste retention pits (6.08 – 7.53). The acidic condition of the control soil reflected in the high iron concentration in the environment. Furthermore, the apparent higher (more alkaline) condition of soils from the waste retention pits may have been due to neutralization of the natural acidic nature of the environment probably emanating from the constituent of the waste and its associated leachates. pH result obtained from this present study is contrary to previously reported trend where pH values for soils collected from control and waste dumpsites depicted alkaline and acidic environments respectively as reported by Amos-Tautua *et al* (2014). The variation could be due to varying characteristics of the waste streams as well as the prevailing season of study.

Table 1: Physicochemical and heavy metal composition of soils collected from the bank of waste retention pits receiving industrial wastewater around oil and gas installations

Parameter(s)	Soil Control (0-15cm) 100m from waste pit	Soil Sample (0-15cm) Bank of waste pit 1	Soil Sample (0-15cm) Bank of waste pit 2
pH	4.79	6.08	7.53
Conductivity (μS/cm)	240	140	490
Oil & Grease (mg/kg)	120.2	26.4	887.8
Ammonium (mg/kg)	0.86	1.05	1.66
Chloride (mg/kg)	155	85	320
Nitrite (mg/kg)	<0.001	0.039	2.240
Nitrate (mg/kg)	21.4	40.6	564
Phosphate (mg/kg)	5.8	3.1	13.2
Sulphate (mg/kg)	2.2	1.4	5.2
Organic matter (%)	0.877	0.944	2.022
Sodium (mg/kg)	20.75	72.31	240.85
Potassium (mg/kg)	48.87	27.20	78.53
Calcium (mg/kg)	22.72	17.12	210.83
Magnesium (mg/kg)	29.57	13.94	41.19
Iron (mg/kg)	615.7	572.7	1,858.8
Mercury (mg/kg)	<0.01	<0.01	<0.01
Cadmium (mg/kg)	0.090	0.010	0.130
Chromium (mg/kg)	0.89	0.57	2.87
Zinc (mg/kg)	1.29	0.94	5.28

Conductivity concentration in waste pit 2 (490 μS/cm) was apparently higher than the control (240 μS/cm) unlike waste pit 1 (140 μS/cm) that was lower than the control. The trend in conductivity level is peculiar to several parameters such as chloride, sulphate, oil and grease, Zinc, chromium, iron, magnesium, calcium, potassium. This trend suggests a variation in soil characteristics in both waste retention pits and the uncontaminated soil (control). The trend of some soil parameters having higher concentration compared to control is comparable to the findings of Izah *et al* (2017d) that reported elevated heavy metal concentrations in soils that received cassava mill effluents from cassava processors in a rural community within the Niger Delta region of Nigeria.

Consequently, the concentration of the nutrition related parameters in the waste pit were 1.05 – 1.66 mg/kg (ammonium), 85 – 320 mg/kg (chloride), 0.039 – 2.240 mg/kg (nitrite), 40.6 - 564 mg/kg (nitrate), 1.40 – 5.2 mg/kg (phosphate), 1.4 – 5.2 mg/kg (sulphate), 72.31 – 240.85 mg/kg (sodium), 27.20 – 78.5 mg/kg (potassium), 17.12 – 210.83 mg/kg (calcium), 13.94 – 41.19 mg/kg (magnesium), 572.7 – 1,858.8 mg/kg (iron), 0.57 – 2.87 mg/kg (chromium) and 0.94 – 5.28 mg/kg (zinc). These parameters play an essential role in the agricultural productivity of soil. When compared to the control, the study showed that the waste retention pit portends significant impacts on the receiving soil physical and chemical characteristics. The trend of organic matter concentration in this study also supports the nutrient composition of the waste pit. The high nutrient composition of the waste pit could encourage the growth of plants without fertilizer. Furthermore, Eneje and Lemoha (2012) attributed higher concentration of soil physicochemical parameters in waste dump contaminated soil compare the control to the decomposition and mineralization of the biodegradable solid wastes, thereby leading to release of minerals and cations.

An evaluation of heavy metal levels obtained from this study against target values for soil micro pollutants as stipulated by the Department of Petroleum Resources depicted chromium, cadmium, mercury and zinc concentrations to be below the target limit of 100 mg/kg, 0.8 mg/kg, 0.3 mg/kg and 140 mg/kg respectively. Furthermore, the oil and grease value for soil around the bank of waste pit 2 and control locations were higher than the target value of 50 mg/kg as specified by DPR (2002). The variation suggests that there may be other possible sources of soil pollution in the area apart from the oil and gas facilities. Typically, soil is contaminated from several human activities. Runoff resulting from rainfall is a major medium through which soil is contaminated. Runoff can transport constituents of improperly disposed municipal wastes into nearby surface water/water bodies depending on the retention time of the micro pollutants in the soil matrix and the relative topography of the area. This may have contributed to the variation in the physicochemical characteristics of soil obtained by the banks of the recipient medium.

Unlike mercury that was observed below measurable detection limit of the instrument (<0.01) in the waste pits and control, the concentration of cadmium ranged between 0.01 – 0.13 mg/kg. Cadmium is one of the non-essential heavy metal that is not required by the body for growth and productivity. In fact, it is known to induce toxicity in human on exposure. Some of the pathological effects associated with cadmium have been documented by Izah *et al.* (2016b). Furthermore, the occurrence in the control suggests the natural occurrence of cadmium in the environment under study. Therefore, its distribution may not have been associated with industrial wastewater being discharged.

CONCLUSION

This study evaluated the physicochemical and heavy metal constituents of soils collected from the bank of industrial wastewater retention pits receiving industrial effluents from oil and gas facilities in the Niger Delta region of Nigeria. The study revealed an apparent elevation in concentration of toxic heavy metals especially in waste dump pit 2. The increase in these toxic heavy metals may have been due to the presence of biodegradable wastes which play host to indigenous microbes associated with a typical environment. This could be contributing to the alteration in soil physical and chemical characteristics of the receiving environment since soils rich in organic matter actively retain metallic elements. However, the relative increase in toxic heavy metal loading and the significant levels of hydrocarbon contamination in the control soil when compared to waste pit 1 may have resulted from the tendency of soils to retain persistent toxicants in an acidic environment since metal solubility tends to increase at lower pH. The elevated concentrations of oil and grease in the soils of waste bank 2 and control locations as compared to DPR target values also suggests that runoff from rainfall may have resulted in the transportation of organic constituents of improperly disposed municipal wastes into nearby surface or open water bodies depending on the retention time of the micro pollutants in the soil matrix and the relative topography of the area.

MATERIALS AND METHODS

Study Area

Ebocha is located in Ogba/Egbema/Ndoni Local Government Area of River state, Nigeria. Several oil and gas infrastructures are found in the area. The waste pit is located within oil and gas installations at Ebocha. The waste dump pits are the major recipient medium for aqueous municipal and industrial wastewater obtained from within the vicinity. Sampling was carried out during the rainy season month of June 2010. The climatic condition of the area is typical of the Niger Delta region. The climatic conditions of the Niger Delta region have been widely reported by authors (Seiyaboh *et al.*, 2016a,b, 2017a,b; Agedah *et al.*, 2015; Aigberua et al., 2017a; Ogamba *et al.*, 2015a,b; Ben-Eledo *et al.*, 2017a,b).

Soil Sampling

The samples were collected using a soil auger to scoop soils at the depth of 0 – 15 cm from the bank of the wastewater retention pit in June 2010. The soil was packaged in Ziploc bags and stored in an ice chest before being transported to the laboratory for analysis.

Sample Preparation for heavy metal analysis

The soil samples were air-dried at room temperature. The samples were pulverized and sieved through a 2 mm mesh size sieve to remove debris and gravels larger than 2 mm in diameter (Aigberua et al., 2016a,b; 2017a; Izah *et al*., 2017d). The pulverized soil was transferred into respective reaction vessels for heavy metals and physicochemical analysis. The prepared soil samples were digested with 2.0 ml of concentrated HNO_3 (sp. gr 1.42) and 6.0 ml of concentrated HCl (sp. gr 1.19) respectively. The acid mixture was added to 5 g of the air-dried soil and digested by heating on a corning PC-351 hotplate at medium heat until the solution remained about 10 ml. Thereafter, the solution was allowed to cool and the acid extract was filtered, rinsed and diluted to mark in a 50 ml volumetric flask with distilled water.

Physical and Chemical analysis of the soil

Standard analytical protocol was adopted for the soil physical and chemical characteristics. For methods previously described was adopted for each of the parameters including pH (IITA, 1979), conductivity (Aigberua *et al*., 2016a), calcium, magnesium, potassium and calcium (as described in Nwakaudu *et al*., 2012), nitrite, nitrates, phosphates and sulphates (as described in Dewis and Freitas, 1970), ammonium (APHA, 1998), oil and grease (Aigberua et al., 2016b) and organic carbon analysis (IITA, 1979). The heavy metals were analyzed via a flame atomic absorption spectrometer (GBC Avanta PM A6600 model).

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