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Assessment of Heavy Metals Concentration of Crude Oil Polluted Soil and Water in Some Coastal Communities of Akwa Ibom State, Nigeria

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Abstract: The level of heavy metals concentrations of crude oil polluted soil and water was assessed in some coastal communities (Eket, Ibeno, EsitEket and Onna) of Akwa Ibom State, Nigeria using Atomic Absorption Spectrophotometer. The mean values of the heavy metals determined were: Cr(0.1544±0.01), Cd(0.0137±0.00), Pb(0.0340±0.04), Ca(64.9360±1.55), Ni(0.0112±0.02), Cu(0.0164±0.00), Co(0.00), Mn(1.0067±1.54), Fe(0.6526±0.13), Zn(0.1175±0.04) for water samples and Cr(0.5595±0.12), Cd(0.2139±0.17), Pb(0.1559±0.03), Ca(1.7940±0.62), Ni(0.1685±0.02), Cu(0.1398±0.04), Co(0.0180±0.01), Mn(5.7187±1.34), Fe(9.5787±0.89), Zn(0.2626±0.22) for soil samples. The results showed that calcium was very high in water Ca(64.9360±1.55) samples compared to the soil Ca(1.7940±0.62) samples which suggest that the water is hard, though these values were within the WHO standards. Also, cobalt was not detected in water samples. All other heavy metals determined were above the WHO permissible limits for water and soil samples except zinc and copper which were within the acceptable limits. In all, the concentration of heavy metals in the soil samples was observed to be higher than the water samples which might be due to leaching and bioaccumulation. Thus, a further comprehensive study is recommended and also, intervention strategies like remediation, to better the life of the people.

Keywords: Crude Oil, Soil, Water, Akwa Ibom State, Heavy Metals

1. Introduction

Soil and water are among others the most renewable natural resources which are vital for achieving sustained socio-economic and general well-being of humanity on earth. Over the years, the frequent crude oil spillage arising from commercial exploration and exploitation activities have impacted negatively on terrestrial and aquatic resources of southern Nigerian states. Contamination of environment in the Niger Delta region of Nigeria by crude oil spill has increasingly become an issue of serious environmental concern. Subsistence farming and fishing are the mainstay of the people, out of which 75% rely on natural endowments for a living [1]. Before now, Nigeria was Africa's largest oil producer [1, 2]. With the development of oil industry, its oil-producing Niger Delta region has become extremely vulnerable to damaging effects of oil pollution occasioned by multi-national oil companies.

Crude oil and refined fuel spills have damaged natural ecosystems in Alaska, the Gulf of Mexico, the Galapagos Islands, France, the Niger Delta region in Nigeria and many other places worldwide [3]. Spills may occur of crude oil (unrefined oil) from oil rigs and platforms, oil wells, during the transport of the refined petroleum product in vessels and tankers as well as operational or maintenance faults by the oil companies. Illegal dumping of waste oil into oceans by organizations who do not want to invest in the cost of degrading their waste oils also contributes to increasing oil spills [4]. In a country like Nigeria where there is illegal oil bunkering by militants, oil spills occur quite frequently which pose a major environmental challenge. Statistics have shown that in the last 30 years, more than 400,000 tons of oil had spilled into the creeks and soils, thereby, devastating the environment of the fertile Niger Delta in Nigeria [5, 6, 7].

When crude oil spills into a residential neighborhood, the most immediate health concerns are those caused by volatile chemicals. But crude oil also contains certain amounts of heavy metals that rarely evaporate into the air. Instead, they stay with the oil as it spills onto the ground and into waterways [8, 10]. Environmental hazards derived from heavy metals concentration and bioaccumulation in soils, uptake by plants, and contaminations of water bodies have received much attention because of their toxic effect. Heavy metals are non-biodegradable and are toxic under certain conditions. Industrial accidents involving oil spillage which accompany long lasting pollutants such as heavy metals have the most serious effects [12]. When in contact with living tissues, they become concentrated since organisms have no means of excreting them. They accumulate and are passed on at successively greater concentrations to predators higher up the food chain. Heavy metals also occur naturally, but rarely at toxic levels [13]. These compounds, which include mercury, manganese, nickel, chromium, etc., are toxic at high doses, and some, like arsenic and lead, can damage the nervous system even at relatively low doses [14]. Yet little is known about the level of accumulation of these heavy metals and the potential risks associated with people who live near oil spill sites. One key demographic characteristic of the focus areas is that over 80% of its populace still live in the rural areas across the creeks which are seriously contaminated by oil spillage. In addition, various developmental efforts are difficult to measure because of lack of established baseline information to form benchmark for growth and development progress in the communities over time. Thus, the aim of this research was to assess the level of heavy metals concentrations of crude oil polluted soil and water in some coastal communities (Eket, Ibeno, EsitEket and Onna) in Akwa Ibom State, Nigeria.

2. Materials and Methods

The Study Area

Akwa Ibom is one of the 36 states in Nigeria named after the Qua Iboe River. It is located in the coastal South-Southern part of the country, lying between latitudes 4°321 and 5°331 North, and longitudes 7°251 and 8°251 East. The State is bordered on the east by Cross River State, on the west by Rivers State and Abia State, and on the South by the Atlantic Ocean and the southernmost tip of Cross River State. Akwa Ibom has a population of over 5 million people and more than 10 million people in Diaspora. It was created in 1987 from the former Cross River State. It has 31 Local Government Areas and is currently the highest oil and gas producing state in the country. Onna, Eket, EsitEket and Ibeno are amongst the "oil-rich" Local Government Areas of Akwa Ibom State. The areas are the thriving hub of oil and gas business, with more than 250 companies providing support services [15].

3. Sample Collection, Preparation and Preservation

Sixteen soil samples were randomly collected using soil auger from the four selected oil-impacted areas; Esuk Odio in Eket LGA, Ukpenekang in Ibeno LGA, Okorokit in EsitEket LGA and Ikot Akpatek in Onna LGA of Akwa Ibom State, Nigeria. The samples were collected at random from four chosen points in each site, stored in sealed polythene bags properly labeled and transported to the laboratory for pre-treatment and analyses. At the laboratory, the soil samples were air-dried for two weeks, rolled manually, mixed and sieved with 2 mm mesh to remove stones and debris. Samples from the four points in each impacted site were mixed together to obtain homogeneous sample. [16]. Sixteen water samples were also collected in the said areas in well-labeled polyethylene sterile bottles. The samples were transported to the laboratory in a lightproof insulated box containing ice-packs with water. Uncontaminated samples were used as control. They were further preserved in the refrigerator prior to analyses [17].

4. Heavy Metals Analyses

2 g of each soil sample was digested using aqua regia digestion method (USEPA 3050) [9]. After filtration, the filtrate was collected into a 100 ml well-labeled polyethylene bottle prior to analysis. All digestions were carried out in triplicate for each sample and the amounts of trace metals recorded as mean value. The extracts were analyzed for heavy metals (Cr, Cd, Pb, Ca, Ni, Cu, Co, Mn, Fe and Zn) using atomic absorption spectrophotometer (AAS) iCE 3000 Series.

500 ml of each water sample was evaporated to about 100 ml, then, 10 ml of conc. HNO_3 was added and the solution was placed on a heating mantle at low heat for 30 min. After cooling, it was filtered and made up to 100 ml with deionized-distilled water. The heavy metals (Cr, Cd, Pb, Ca, Ni, Cu, Co, Mn, Fe and Zn) were determined with the aid of Atomic Absorption Spectrophotometer (AAS) iCE 3000 at their respective wavelength (357.9, 228.8,283.3, 422.7, 232.0,324.8, 240.7, 279.5,248.3 and 213.9 nm) according to APHA method [18, 19].

5. Statistical Analysis

All the determinations were conducted in triplicates and data generated were analyzed statistically by one-way analysis of variance (ANOVA) technique using (SPSS) 16.0.

6. Quality Assurance

To ensure that the results were accurate, reliable and reproducible, strict adherence to the standard operating procedures and precautions were ensured at all levels.

7. Results and Discussion

A total of ten heavy metals were analyzed for, namely: chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), manganese (Mn) and iron (Fe), nickel (Ni), calcium (Ca), cobalt (Co) and copper (Cu). All the samples collected from the four sites contained detectable amounts of the metals studied except Co which was absent in the water samples. Varying concentrations of the heavy metals were recorded in all the impacted sites with some sites reporting very high concentrations while other samples recorded relatively lower concentrations of the elements. Level of concentrations of metals analyzed in both the impacted sites and control sites are recorded in Tables 1 and 2. From the results obtained (Table 1 and 2), the heavy metal levels from all the crude oil impacted sites were significantly higher than their corresponding levels at the control sites. This signified that samples from the oil impacted sites have some levels of heavy metal enrichments.

The average concentration of chromium in the water samples was 0.1544±0.01 mg/l while that of the soil samples was 0.5595±0.12 mg/l which was above the permissible limit. Chromium is used in metal alloys and pigments for paints, cement, paper, rubber, and other materials. Low-level exposure can irritate the skin and cause ulceration. Long-term exposure can cause kidney and liver damage, and damage to circulatory and nerve tissues. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium [3].

Cadmium had the mean concentrations of 0.0137±0.00 mg/l and 0.2139±0.17 mg/l in water and soil samples respectively which was below the recommended limit. It can be found in soils and waters because of insecticides, fungicides, sludge, and commercial exploitation of crude oil that contains cadmium. Cadmium may be found in reservoirs containing shellfish. Lesser-known sources of exposure are dental alloys, electroplating, motor oil, and exhaust. Inhalation accounts for 15-50% of absorption through the respiratory system; 2-7% of ingested cadmium is absorbed in the gastrointestinal system. Cadmium targets the liver, placenta, kidneys, lungs, brain, and bones [4].

The average concentration of lead in the water samples as recorded was 0.0340±0.04 mg/l while that of the soil samples was 0.1559±0.03 mg/l which was above the acceptable limits recommended by WHO [20]. Lead accounts for most cases of pediatric heavy metal poisoning (Roberts 1999). It is a very soft metal and was used in pipes, drains, and soldering materials for many years. Every year, industry produces about 2.5 million tons of lead throughout the world. Chronic exposure to lead may result in birth defects, mental retardation, autism, psychosis, allergies, dyslexia, hyperactivity, weight loss, shaky hands, muscular weakness, and paralysis. Lead poisoning, which is so severe as to cause evident illness, is now very rampant indeed. At intermediate concentrations, however, there is persuasive evidence that lead can have small, subtle, subclinical effects, particularly on neuropsychological developments in children [21].

From table 1, Calcium had the highest concentrations in all the sites with an average value of 64.9360±1.55 mg/l in the water sample. In the soil sample, it was minimal with a mean value of 1.7940±0.62 mg/l (table 2). Calcium is one of the metals that are nutritionally essential for a healthy life. The concentrations of calcium as obtained here were within the acceptable limits recommended by WHO. As trace elements, some other heavy metals (e.g. iron, copper, manganese, and zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Nickel was present with a mean concentration of 0.0112±0.02 mg/l in the water samples and 0.1685±0.02 mg/l in the soil samples which was within the acceptable limit. Small amounts of Nickel are needed by the human body to produce red blood cells, however, in excessive amounts, can become mildly toxic. Short-term overexposure to nickel is not known to cause any health problems, but long-term exposure can cause decreased body weight, heart and liver damage, and skin irritation. Nickel can accumulate in aquatic life, but its presence is not magnified along food chains [22].

The average values of copper were0.0164±0.00 mg/l and 0.1398±0.04 mg/l in the water and soil samples respectively. These were below the WHO recommended standards. Copper is an essential substance to human life, but in high doses it can cause anemia, liver and kidney damage, and stomach and intestinal irritation. People with Wilson's disease are at greater risk for health effects from overexposure to copper [22].

Manganese was the third most abundant metal in the soil with a mean value of 5.7187±1.34 mg/l and 1.0067±1.54 mg/l in the water samples which were above the WHO permissible limits. Manganese is an essential element for all species and a very common compound that can be found everywhere on earth. It is not only necessary for humans to survive, but it is also toxic when too high concentrations are present in a human body. When people do not live up to the recommended daily allowances their health will decrease. But when the uptake is too high health problems will also occur. Manganese effects occur mainly in the respiratory tract and in the brains. Symptoms of manganese poisoning are hallucinations, forgetfulness and nerve damage. Manganese can also cause Parkinson, lung embolism and bronchitis. When men are exposed to manganese for a longer period of time they may become impotent. Iron was the second most abundant element in the soil with an average value of 9.5787±0.89 mg/l and 0.6526±0.13 mg/l in water samples which also exceeded the acceptable limits recommended by WHO [20].

The earth's core is believed to consist largely of a metallic iron-nickel alloy. Iron is essential to almost all living things, from micro-organisms to humans. A more common problem for humans is iron deficiency, which leads to anaemia. A man needs an average daily intake of 7 mg of iron and a woman 11 mg; a normal diet will generally provided all that is needed. Ingestion accounts for most of the toxic effects of iron because iron is absorbed rapidly in the gastrointestinal tract. The corrosive nature of iron seems to further increase the absorption. Iron may cause conjunctivitis, choroiditis, and retinitis if it contacts and remains in the tissues. Chronic inhalation of excessive concentrations of iron oxide fumes or dusts may result in development of a benign pneumoconiosis, called siderosis, which is observable as an x-ray change [23]. Zinc had the mean concentration of 0.1175±0.04 mg/l in water and 0.2626±0.22 mg/l in soil samples which was within the acceptable limits. This difference in the pattern of heavy metals distribution between water and soil samples might be a result of their difference in many factors such as habitats and the rate of movement [24]. Generally, the concentration of heavy metals in the soil samples was observed to be higher than the water samples which might be due to leaching and bioaccumulation.

Table 1. *Result of the heavy metals concentrations of the water samples (mg/l).*

SITES	Cr	Cd	Pb	Ca	Ni	Cu	Co	Mn	Fe	Zn
EKET	0.1539	0.0137	0.0187	65.7320	0.0028	0.0159	ND	0.2968	0.8371	0.1385
IBENO	0.1578	0.0125	0.0073	62.6320	0.0024	0.0154	ND	0.1392	0.6350	0.0890
ESIT EKET	0.1402	0.0142	0.0232	65.4710	0.0046	0.0174	ND	0.2730	0.6142	0.0862
ONNA	0.1656	0.0144	0.0867	65.9087	0.0351	0.0168	ND	3.3176	0.5240	0.1561
MEAN±S.D	0.1544±0.01	0.0137±0.00	0.0340±0.04	64.9360±1.55	0.0112±0.02	0.0164±0.00	-	1.0067±1.54	0.6526±0.13	0.1175±0.04
CONTROL	0.0526	0.0101	0.0025	43.8741	0.0020	0.0128	ND	0.1423	0.3731	0.0075

ND = Not detected

Table 2. *Result of the heavy metals concentrations of the soil samples (mg/l).*

SITES	Cr	Cd	Pb	Ca	Ni	Cu	Co	Mn	Fe	Zn
EKET	0.5831	0.1912	0.1843	1.8195	0.1462	0.1843	0.0176	5.6638	10.4217	0.0915
IBENO	0.6417	0.2415	0.1108	1.1458	0.1562	0.1351	0.0326	6.8760	10.2635	0.3164
ONNA	0.3859	0.0037	0.1712	2.6184	0.1948	0.0837	0.0125	6.4724	8.7352	0.5527
ESIT EKET	0.6272	0.4193	0.1573	1.5923	0.1768	0.1562	0.0092	3.8627	8.8944	0.0897
ONNA	0.3859	0.0037	0.1712	2.6184	0.1948	0.0837	0.0125	6.4724	8.7352	0.5527
MEAN±S.D	0.5595±0.12	0.2139±0.17	0.1559±0.03	1.7940±0.62	0.1685±0.02	0.1398±0.04	0.0180±0.01	5.7187±1.34	9.5787±0.89	0.2626±0.22
CONTROL	0.2638	0.0166	0.0491	0.7215	0.0492	0.0271	0.0042	1.5825	5.1364	0.0375

8. Conclusion

This research has demonstrated that crude oil contamination can lead to gradual heavy metal build-up in water and bioaccumulation in soils. The study area is considered to be contaminated which may pose serious adverse effect to humans and the environment. Therefore, precaution measures need to be taken in order to prevent future heavy metal pollution. Also, there is urgent need for remediation strategies and management of the contaminated sites.

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