Evaluation of Heavy Metals Concentrations in Coastal Area of Mbo LGA, Akwa Ibom State

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ABSTRACT

The study assessed heavy metal concentrations in surface water samples from coastal regions of Mbo in Akwa Ibom State as a result of human activities posing health risks to aquatic organisms and people. Ten sampling sites were randomly selected across the region, with samples collected from streams and rivers during dry and wet seasons. GPS coordinates were recorded, and atomic absorption spectroscopy analyzed eight heavy metals. Results were compared with WHO permissible levels. Cadmium levels exceeded WHO limits, ranging from 0.58-0.96 (dry season) and 0.008-0.082 (wet season). Zinc ranged from 0.208-0.461 (dry) and 0.204-0.460 (wet). Lead was between >0.001-0.018 (dry) and >0.001-0.014 (wet). Manganese varied from >0.001-0.849 (dry) to >0.001-1.412 (wet). Iron ranged from 0.148-2.425 (dry) to 0.142-2.42 (wet) all in mg/dl. Cadmium, zinc, manganese, iron, and nickel levels surpassed WHO standards, with lead exceeding in two sampling points. Cobalt and copper were below WHO levels. Cadmium, manganese, zinc, iron, and nickel concentrations were elevated in coastal water samples, posing health risks to residents relying on these sources. Further research is needed to comprehensively assess water quality and mitigate pollution impact.

Keywords: Heavy metals, Surface water, Anthropogenic activities, Pollution, Lead

INTRODUCTION

The coastal areas of Mbo LGA of Akwa Ibom State had witnessed active ports activities, oil drilling, coastal fishery and agricultural activities, tourism-related projects, industrial activities, urbanization and other socioeconomic activities over the years. The effect of these activities impact negatively on the quality of water used for daily activities (UNEP, 2016). Our oceans had become the dumping ground of trash and refuse which accumulate on our shores to the point of saturation and becoming an eyesore (Bakari, 2014). These endanger marine life and also cause serious pollution in our water bodies (Ashiru et al., 2017).

Anthropogenic activities contaminate both surface and groundwater resources through discharge of pollutants related to the nature and degree of such activities. Where agricultural activities predominate, agro-chemical metabolites (such as pesticides, fertilizers etc.) and nutrients such as nitrates etc. are the major pollutants and contaminants (Akporido & Onianwa, 2015). 884 million of the world population without improved water supplies, Unsafe and insufficient water is a leading cause of all infectious diseases in the world and in Nigeria, >3.8 million deaths are recorded annually from pneumonia and diarrheal diseases which affecting children under the age of five in Nigeria (UNICEF, 2009), Hence this work studies the concentration of heavy metals on the coastal areas in Mbo, Akwa Ibom State, Nigeria.

The coastal community of Mbo LGA has several on-shores and offshore oil wells as well as numerous reports of oil spillages, gas flaring, gas leak, discharge of effluent, sewage, refuse and plastics into or close to freshwater bodies. These unwholesome activities results in the degradation of the aquatic environment, reducing the surface and underground water quality. Heavy metals are among the most toxic environmental contaminants because of their high toxicity, persistence and ability to bio accumulate (Zhong et al., 2018). They originate from municipal, agricultural, and industrial wastes discharged into aquatic environments (Fabio et al., 2015; Zhong et al., 2018, Cameron et al., 2018).

In the coastal area, increasing population growth and pollution of the environment have resulted to overexploitation of water resources, thereby degrading the environment (Choudri et al., 2015). These activities lead to the release of PAH, total petroleum hydrocarbon and heavy metals (Edokpayi et al., 2016, Denis et al., 2013). Effect of heavy metals quality on surface water resources of the coastal areas of Mbo LGA has not been fully investigated. Lack of awareness regarding the water quality causes a variety of health problems. Management of water resources is paramount in ensuring high quality of water. In view of this, this study was geared towards identifying different heavy metals that are found in surface and ground water in Mbo LGA.

Aim of study

To evaluate heavy metals concentrations during the dry and wet season and to determine the seasonal variations in Mbo LGA. This study is significant as it craves to determine the heavy metal found in surface water. Such information will provide useful information to the public, government and private bodies on the effects and danger of the pollution on the coastal regions, effect on lives and how it degrades the surface water quality.

Materials and Methods

Study area

The Mbo LGA of Akwa Ibom State is located on latitude 4° 39′ 0″N, longitude 8° 19′ 0″E with an area of 365 km², It is bbounded by Atlantic Ocean and Republic of Cameroon on the South, Urue Offong/Oruko LGA by the North, Esit Eket and Ibeno LGA on the West and Udung Uko LGA on the east. Mbo has a Population of 104,012 (55,395 males and 48,617 females) according to 2006 national Census figures. And has natural resources like salt, gravel, clay deposits, forest reserves, timber, fruits, and palm fruit. The area also has a rich water resource where oil exploitation and exploration is taking place. The area witnessed a lot of oil wells for drilling purposes. Their predominant occupation is marine-based, comprising fishing, marine transportation and subsistence farming. There are a lot of human and vehicular traffic with heavy earth-moving, oil drilling and pumping equipment for different oil exploitation activities between Nigeria and China Government.

Mbo LGA has dry season and wet season. The heaviest rainfall is between May and July while driest period ranges from November to February. Annual rainfall of 2000mm is experienced in the area. The people of Mbo speak Oron dialect with minor differences.

Sampling Site

Ten sampling sites were selected randomly across Mbo LGA. The surface water was chosen from streams and rivers along the different settlements. The coordinates of the locations were recorded using GPS.

Sampling of water

Water sample was collected every three months from April, 2021 to March, 2022 using (April to September for wet season, October to January for dry season) plastic containers. Water samples were collected according to the guidelines of the APHA (2012) method. Non-ionic detergents were used to wash the containers; distilled water was used for rinsing and soaked for one day in 10 % HNO_3. Sample water was used to rinse the containers just before sampling. Care was used to remove the cap to avoid contamination. The bottle was held at the bottom and dipped about 15 cm beneath the surface of the water to collect the sample. The container was capped immediately and put in the ice bag which was then taken to the laboratory. Three samples were obtained randomly in a particular sampling site within a radius of 10 m and mixed together after which a representative sample was taken for analysis (Gorleku and Carboo, 2014).

Analyses of Heavy Metals

Heavy metals contents including Pb, Zn, Cu, Mn, Fe, Co, Cd, Cu and Ni were analysed in the Laboratory unit, Ministry of Science and Technology, Uyo. 100 ml of the water sample was placed into a round-bottom flask,

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followed by the addition of 20 ml of concentrated nitric acid in the fume hood. Heat was applied for about 15-20 minutes in the electro-thermal heater to a little dryness for digestion to be completed. The flask was brought down and allowed to cool. 50 ml distilled water was measured into the flask, swirled, then filtered to 100 ml volumetric flask and distilled water added to mark. It was run then with a computerized Atomic Absorption Spectrometer (969 UNICAM Thermo Elemental AAS) for the presence of the different metals using their respective lamp and wavelengths. Standard solutions of the respective metals were used for calibration.

Statistical analysis

Statistical Package for Social Scientists (SPSS Version 21.0) followed by Duncan Multiple Range Test was used to analyse the data and values expressed as mean.

Results

The mean levels of heavy metals from 10 sites in the coastal region of Mbo LGA are presented in the tables.

Table 1: Mean levels of heavy metals in water sampled in 10 sites of coastal region of Mbo LGA during the dry season in mg/dl

	1	2	3	4	5	6	7	8	9	10	Range	WHO
Lead	0.012	<0.001	0.004	0.002	0.018	0.010	0.002	0.004	0.004	0.006	<0.001-0.018	0.01
Zinc	0.429	0.219	0.29	0.284	0.389	0.584	0.06	0.021	0.249	0.464	0.06-0.584	0.1
Copper	0.367	0.29	0.387	0.196	0.156	0.01	0.002	0.01	0.004	0.416	0.01-0.416	1
Manganese	0.418	1.109	0.818	0.678	<0.001	0.686	0.82	0.81	0.809	0.849	<0.001-0.849	0.4
Iron	0.439	0.622	0.148	0.626	2.425	0.816	0.917	0.299	0.827	0.386	0.148-0.917	0.3
Nickel	0.449	0.316	0.426	0.068	0.310	0.088	0.168	0.322	0.010	0.008	0.010-0.449	0.07
Cobalt	0.014	0.004	0.012	0.006	0.012	0.008	0.004	0.002	0.012	0.014	0.002-0.014	<2.0
Cadmium	0.58	0.89	0.62	0.69	0.58	0.87	0.89	0.69	0.87	0.96	0.58-0.96	0.003
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01

Source: Author's work, 2024

Table 1 depicts dry season results. Lead (Pb) concentration ranges from <0.001 - 0.018 mg/l. Lead concentrations exceed the WHO recommended limit of (0.01 mg/l) at two sites (Site 5 (0.012) and Site 1(0.018)). Zinc (Zn) concentration was between 0.06 - 0.584. Most sites have zinc concentrations exceeding the WHO limit (0.1 mg/l), Site 6 had the concentration of 0.584 mg/l which was the highest. All sites are within the World Health Organization's threshold of 1 mg/L for Copper (Cu) concentration which ranges from 0.01 - 0.416. The highest concentration of 0.416 was observed for copper. Manganese (Mn) had the mean concentration ranges from <0.001 - 0.849. Several locations go beyond the WHO recommended limit of 0.4, with Site 2 having the highest concentration of 0.949 mg/L. The average concentration of Iron ranges from 0.148 - 2.425. Most sites exceed the WHO limit of 0.3, with Site 5 showing a particularly high concentration of 2.425. Nickel (Ni) concentration ranges from 0.010 - 0.449. Concentrations at several sites exceed the WHO limit og 0.07, with Site 1 having the highest concentration of 0.449. Cobalt (Co) recorded the mean level between 0.002 - 0.014. All sites are well within the WHO limit of < 2.0 mg/l. Cadmium (Cd) concentrations range from 0.58 - 0.96. All sites far exceed the WHO limit of 0.003mg/L, With Site 10 showing the highest value of 0.96 mg/l. Mercury (Hg) had the mean values of <0.001 which are below the WHO detectable limit of 0.01.

Table 2: Mean levels of heavy metals in water sampled in 10 sites of coastal region of Mbo LGA during the wet season in mg/dl

	1	2	3	4	5	6	7	8	9	10	Range	WHO
Lead	0.008	<0.001	<0.001	<0.001	0.014	0.001	0.001	<0.001	<0.001	<0.001	<0.001-0.014	0.01
Zinc	0.426	0.217	0.287	0.280	0.386	0.580	0.058	0.204	0.246	0.460	0.058-0.580	0.1
Copper	0.362	0.287	0.384	0.192	0.152	<0.001	<0.001	<0.001	<0.001	0.412	<0.001-0.384	1
Manganese	1.412	1.104	0.814	0.672	<0.001	0.682	0.816	0.804	0.804	0.846	<0.001-1.412	0.4
Iron	0.437	0.618	0.142	0.622	2.420	0.812	0.91	0.296	0.824	0.382	0.437-2.420	0.3
Nickel	0.446	0.312	0.422	0.064	0.304	0.082	0.164	0.318	<0.001	0.004	<0.001-0.446	0.07
Cobalt	0.012	0.010	0.012	0.004	0.010	0.004	0.002	0.010	0.040	0.012	0.002-0.012	<2.0
Cadmium	0.048	0.082	0.074	0.076	0.024	0.062	0.024	0.046	0.034	0.008	0.008-0.082	0.003
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01

Source: Author's work, 2024

Table 2 depicts the average concentrations during wet season, Pb had the values range from less than 0.001 to 0.014 with only Site 5 (0.014 mg/l) exceeds the WHO. Zn values recorded between 0.058 - 0.580. Comparable to the dry season, most sites exceed the WHO limit, with Site 6 having the highest concentration. Copper values range from less than 0.001 to 0.384. All sites are within the WHO limit. Mn recorded values of <0.001 - 1.412. Several sites exceed the WHO limit, Site 1 exhibited the highest concentration, measuring 1.412 mg/L. Fe shown levels ranging from 0.437 - 2.420 mg/l, most sites exceed the WHO limit, with Site 5 showing the highest concentration of 2.420 mg/l.

Ni ranges from <0.001 - 0.446 mg/l. Several sites exceed the WHO limit, with Site 1 having the highest concentration. Co values were between 0.002 - 0.012 mg/l. All sites are well within the WHO limit. Cd had the concentrations between 0.008 - 0.082 mg/l. All sites exceed the WHO limit. Mercury concentrations were below detectable limits.

Seasonal Comparison and Significance

Higher concentrations of lead are observed in the dry season. Only Site 5 was more than the concentrations in the wet season, indicating a possible dilution effect during the wet season. Zinc consistently exceeds the WHO limit in both seasons, suggesting persistent sources of contamination. Slightly higher values are noted in the dry season. Copper had similar concentrations in both seasons, with all values within safe limits. Higher values of manganese are observed in the wet season, especially at Site 1, which significantly exceeds the WHO limit. Elevated levels of iron are seen in both seasons with no significant seasonal variation. Nickel demonstrated similar patterns in both seasons, with multiple exceedances of the WHO limit. Cobalt values are consistently low and within safe limits in both seasons. During the dry season, cadmium concentrations were notably elevated, with all sites exceeding the WHO limit in both seasons. Mercury levels in both seasons were undetected, indicating compliance with safety standards.

DISCUSSION

The levels of Pb, Ni, Mn, and Cd surpass WHO limits, compromising water quality and making it inappropriate for drinking and household use (Magaji and Adakayi, 2021). High concentrations of lead, zinc, manganese, iron, and cadmium identified in some sites during both seasons, surpassing WHO limits, whereas mercury was undetectable. Heavy metals like nickel, manganese, iron, and zinc are necessary at trace levels for enzymatic activities as catalysts. Their presence in surface water can result from rock weathering and leaching. Despite the low concentrations of most heavy metals, zinc levels exceeded WHO standards for surface water, indicating significant contamination (Udidiong et al., 2021). Cadmium concentrations also surpassed WHO limits, posing danger to human health and aquatic ecosystems (Olasoji et al., 2019).

Hazardous metal pollution arises from both anthropogenic and natural sources. Natural sources include rock weathering, fire outbreaks, and volcanic emissions, which release metals into the environment (Agnieszka & Marek, 2015; Spark et al., 2017). Anthropogenic sources include transportation, industrial activities, agriculture, and mining waste disposal, leading to metal release into the environment. Metals dissolve in water, forming either free radicals or complex ions. Humans and other organisms risk metal ingestion through drinking water, consuming aquatic animals, or engaging in water activities, with potential acute or chronic health effects (Jackson et al., 2013).

Excessive iron concentrations in water can cause hemochromatosis, leading to fatigue, cardiovascular and liver disorders and diabetes (Nwachukwu et al., 2014). Iron can also cause allergic reactions, breathing difficulties, chest tightness, severe vomiting, and stomach pain. Nickel concentrations are affected by soil type, pH, and sampling depth, with elevated levels observed near chemical, industrial, or mining facilities. In this study, nickel concentrations surpassed the recommended limit of 0.07. Cadmium, which can cause symptoms such as lung, kidney, gastrointestinal issues and bone disorder, was found to exceed the maximum allowable level of 0.003 mg/L, posing risks of premature birth and cancer (Parui et al., 2024)

Lead, a cumulative poison, damages the brain, deposits in bones, and is carcinogenic, affecting reproduction, liver, and thyroid function. Although zinc is beneficial at low levels, high concentrations can be toxic. Cadmium is highly toxic at low concentrations and bioaccumulates in ecosystems and organisms, leading to kidney failure with long-term exposure (Malan et al., 2015; Ehi-Eromosele and Okei, 2012). Cd affects calcium metabolism, resulting in poor bone formation. Exposure occurs through skin contact, ingestion, and inhalation (Su et al., 2014).

Iron is prevalent in the Earth's crust and occurs in trace amounts in water, existing in both ferrous (+2) and ferric (+3) forms. Copper, although widely distributed and insoluble, is required for enzyme function and chlorophyll biosynthesis, but high levels are toxic. Chronic exposure to cadmium at 1 mg/kg can cause organ damage, including prostatic lesions, bone fractures, lung cancer, kidney failure, respiratory disorders, nervous system dysfunction, and reproductive issues. Lead exposure, even in minute quantities, has detrimental effects on humans and aquatic organisms, affecting the nervous and skeletal systems, causing mental retardation, skeletal disorders, and potentially death (Saha et al., 2016).

Dietary chromium is important for lipid metabolism and insulin activation but is carcinogenic (Hossain and Hasan, 2014; Ahmed et al., 2015; Varol, 2017). Copper and nickel act as cofactors in hemoglobin synthesis, but copper toxicity can cause nausea, fever, diarrhea, and bowel pain (Rajeshkumar and Li, 2018). Aquatic organisms bioaccumulate pollutants, making humans susceptible to high heavy metal levels (Ali and Khan, 2018). The behavior of heavy metals in aquatic systems is intricate and influenced by biogeochemical processes. studying metal levels in water bodies is crucial for assessing pollution and its sources in coastal areas (El-Metwally et al., 2019).

Coastal areas are significant due to the interaction between land and sea environments and are impacted by renewable and non-renewable resource discharge, anthropogenic activities, and urbanization. These activities affect the physio-chemical properties of coastal water, leading to pollution that impacts marine life and humans. Assessing these properties provides information on water quality and pollution sources. Rapid urbanization and industrialization cause coastal water pollution, leading to socio-economic problems and environmental stress in coastal communities (James et al., 2015).

CONCLUSION

There is significant seasonal variation for certain heavy metals like Lead, Manganese, and Cadmium, with generally higher concentrations during dry season, likely because of lower water volumes besides less dilution. Persistent exceedances of the WHO limits for Zinc, Iron, Nickel, and Cadmium indicate chronic pollution issues that need to be addressed, regardless of the season. Copper and Cobalt levels are consistently within safe limits, showing no significant seasonal variation. Mercury remains undetectable in both seasons, indicating no significant contamination. Overall, the data suggest that while some heavy metals show seasonal variation, the levels of contamination for many metals remain a concern throughout the year. Elevated concentrations are likely linked to oil spills and leakages (cadmium, lead, nickel, manganese), agricultural runoff with fertilizers and pesticides (cadmium, zinc, manganese), and artisanal fishing or domestic effluents (iron, zinc). Cobalt and copper remained within safe thresholds. Cadmium and lead toxicity, which can bioaccumulate and impair kidney, liver, and neurological functions in humans. Manganese and iron overload, potentially disrupting aquatic ecosystems and human health through waterborne exposure. Cumulative metal burden, increasing ecological stress and threatening food safety for residents dependent on fish and water from these sources. The findings underscore the urgent need for pollution control, stricter monitoring, and community health

Recommendation: Government should conduct comprehensive studies to identify specific sources of heavy metal contamination. Enforce strict regulations on industrial discharges and agricultural runoff. Develop and enforce environmental policies that limit the discharge of heavy metals into the surrounding environment. Also collaborate with local and national authorities to ensure compliance with WHO standards. Educating the community about the risks associated with heavy metal contamination will be very helpful. Promote the use of water filters and provide safe drinking water alternatives. Establish a continuous monitoring program to track level of heavy metals in water bodies and utilize advanced monitoring technologies to detect early signs of contamination.

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Appendix 1: Map of Mbo LGA of Akwa Ibom State, Nigeria

Appendix 2: Sampling Points Coordinate

SAMPLING POINT	CO-ORDINATE
1.	N05° 01' 36.3 " E007° 52' 51.6 "
2.	N04° 42' 46.4 "
3.	N4° 40' 41.3 " E008° 13' 57.2 "
4.	N 04° 38' 07.0 " E008° 15' 49.7 "
5.	N04° 39' 07.4 " E008° 18' 46.9 "
6.	N04° 39' 09.4 " E008° 13' 30.5 "
7.	N 04° 39' 18.6 " E 008° 11' 47.1 "
8.	N 04° 39' 23.9 " E008° 10' 90.0 "
9.	N04° 38' 34.5 " E008° 11' 09.1 "
10.	N04° 43' 17.8 " E 008° 11' 44.3 "