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Heavy metal concentrations levels in groundwater and wastewater sources in parts of Trans-Amadi, Port Harcourt, Nigeria

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Abstract

This research assesses the concentration levels of heavy metals in parts of Trans-Amadi Layout, Port Harcourt, Nigeria. Standard sampling and analytical method were employed in the study. Geochemically significant concentrations of lead (Pb2+) and iron (Fe^2+ and Fe^3+) prevail in about 70% of the functioning domestic water supply wells in Trans Amadi, Port Harcourt, while traces of Mercury and Arsenic (with relatively high concentration of lead and Iron) characterize industrial effluent liquid wastes (usually discharged untreated into the environment). The major industries in Trans Amadi industrial layout area of Port Harcourt (in addition to breweries and mineral water industries) produce wide range of pharmaceuticals, cosmetics and textiles, with elevated potential to release chemical waste such as oxides of mercury, iron and titanium; silicates of magnesium and aluminum, phosphates; and sulphates (such as FeSO4 used as coagulates in water treatment) into the environment of common sight along the streets and waste sites are metallic cans from food items, old and worn out rubber, leather and machine parts, variable sizes of broken metallic, plastic and asbestos pipes and enamel wares, as well as a wide range of used textile materials. Enrichment of heavy metallic ions in urban waters in non-mineralized areas is controlled by chemical activities on these wastes. Liquid wastes from industrial and municipal sources are commonly discharged (untreated) along road sides and streets where they constitute shallow ponds, or flow at a very slow rate (depending on flow volume and slope) to a distant termination point (mostly the river and stream flow channels). The liquid wastes, with suspended gaseous wastes from automobiles and industrial and domestic machine engines, are linked to the groundwater zone through recharge by meteoric waters. This accounts for the worrisome concentration of lead (Pb) in the groundwater in the area, without geologically-proven mineralization of lead and base metals.

Keywords: Heavy Metals; Groundwater; Wastewater; Waste; Port Harcourt

1. Introduction

This study is designed to investigate the concentration of the heavy metal in groundwater and waste water sources in parts of Trans-Amadi, Port Harcourt, Rivers State, Nigeria. Heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include but not limited to mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), and lead (Pb). Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result from drinking-water concentration (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain.

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Metals also have a high affinity for humic acids, organic clays, and oxides coated with organic matter was reported earlier [1; 2].The solubility of the metals in soils and groundwater is predominantly controlled by pH as illustrated earlier in [3,4,5], amount of metal and cation exchange capacity [6], organic carbon content [1] and the oxidation state of mineral components as well as the redox potential of the system [2]. Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises of liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources. Water is one of the most essential needs of human beings and is the most abundant natural resources on the surface of the earth [7]. Although, water is an absolute necessity for life, there is an inherent health implication in the consumption of contaminated or polluted water. It can lead to many diseases and even death when contaminated with organic and/or chemical pollutants [8]. But, clean unpolluted water is necessary for the maintenance of human health as well as quality of the environment [9].Water that is safe for drinking, pleasant in taste, and suitable for domestic purposes is designated as potable water and must not contain any chemical or biological impurity [10].

Exposure to very low levels of elements such as lead, cadmium and mercury have been shown to have cumulative effects since there is no homeostatic mechanism which can operate to regulate the levels of these toxic substances. The major pollutants from industrial discharge have been shown to be lead, mercury, nickel, arsenic, zinc and copper. Lead intoxication has been reported to be associated with neurological problems, renal tubular dysfunction and anemia. [11] revealed that the soils in Port Harcourt are highly polluted, since the concentration of the metals in all the stations/waste dumpsites were above permissible limits.

Investigation of heavy metals is very essential since slight changes in their concentration above the acceptable levels, whether due to natural or anthropogenic factors, can result in serious environmental and subsequent health problems.

2. Material and methods

2.1. Description of the Study Area

The study area lies within Longitudes $7^{0}01'00''$ and $7^{0}05'10''$ E; and between Latitudes $4^{0}48'20''$ and $4^{0}50'34''$ N of the Equator (Fig. 1). The study area lies within the mangrove freshwater swamps hydrogeological province underlain by the deltaic plains. Aquifers are encountered at varying depths within the study area with varying water qualities. The depth of the water table ranges from few meters to tens of meters within the study area. The high permeability, over-lying lateritic earth materials containing dense vegetation, the weathered top formations as well as the underlying shale strata provide the hydrologic conditions that favoured aquifers in the study area. Recharge is high in the study area resulting from heavy rainfall that is almost an-all year-round event.

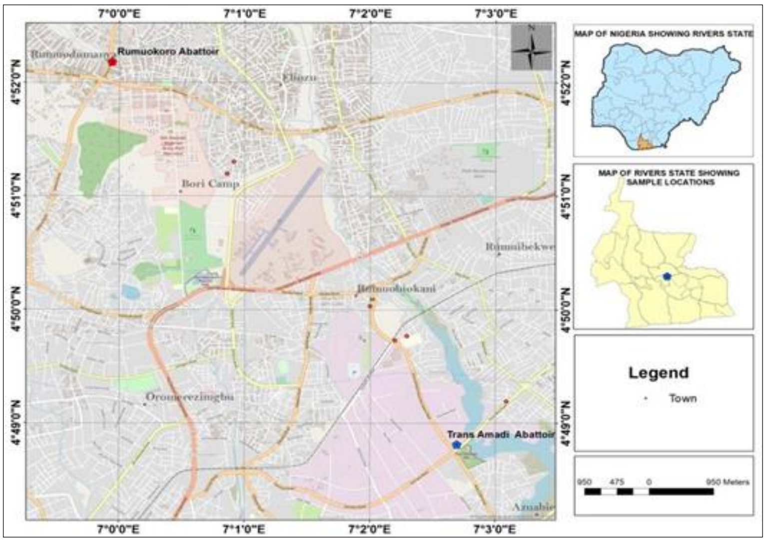

Figure 1 Map of the studied area

The Niger Delta consists of three diachronous units, namely Akata (oldest), Agbada and Benin (youngest) formations. The Benin Formation (Oligocene to Recent) is about 2100m thick at the basin centre and consists of medium to coarse grained sandstones, thin shales and gravels as reported earlier by [12]. The Niger Delta has spread across a number of ecological zones comprising sandy coastal barriers, brackish or saline mangrove, freshwater and seasonal swamp forests. The Niger Delta has two most important aquifers, Deltaic and Benin Formations. With a typically dendritic drainage network, this highly permeable sands of the Benin Formation allows easy infiltration of water to recharge the shallow aquifers. [13] described the aquifers in this area as a set of multiple aquifer systems stacked on each other with the unconfined upper aquifers occurring at the top [14]. Recharge to aquifers is direct from infiltration of rainfall, the annual total of which varies between 5000mm at the coast to about 2540mm landwards. Groundwater in the area occurs in shallow aquifers of predominantly continental deposits encountered at depths of between 45m and 60m. The lithology comprises a mixture of sand in a fining up sequence, gravel and clay. Well yield is excellent, with production rates of 20,000 litres /hour common and borehole success rate is usually high as reported by [15,16].

2.2. Sampling

The investigation of heavy metal concentration in groundwater and waste water sources in parts of Trans-Amadi, Port Harcourt was conducted in August, 2011. A total of fourteen (14) samples were collected to assess the heavy metal concentration in the study area, ten (10) samples from boreholes and four (4) waste waters from industries. The study locations were; Nkpogu, Ordinance, Rivoc Road, GTC (By Zoo), Nwuke Street, Eastern By-Pass, Odili Road, Amadi-Ama, Abuloma, Oginigba, Waste water from breweries (WWBR), Waste water from ceramics (WWCM), Waste water from plastics (WWPE) and waste water from textiles (WWTX). Groundwater were collected in polyethylene container which were thoroughly cleaned with 1:1 HNO_3 rinsed several times with distilled water and dried in electric oven. Before sample collection, the wells were pumped continuously for at least five minutes in order to have representative samples from the aquifer. A global positioning system (GPS), Germin 76 model was used for recording the geographical co-ordinates of the sampling points. Samples were collected in clean 1.5 litre plastic containers. The samples were collected per borehole as close to the well head as possible in order not to sample water that has gone through overhead tanks or treatment units. After sampling, the containers containing the samples were corked immediately to avoid oxygen contamination and escape of dissolved gases. The containers containing the water sample were labeled to avoid sample mixed up during the practical analysis. The samples were transported in ice-packed coolers to the laboratory for analysis within 24 hours.

2.3. Analytical Procedure

The parameters tested are as follows: Lead (Pb), Total Iron (Fe), Mercury (Hg), Arsenic (As) and Cadmium (Cd). Flame Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer A3100) methods were used for the determination of the heavy metals. Resonance lines and hollow cathode lamps of respective metals were used and the instrument was optimized for maximum response. Air and Acetylene were used as oxidant and fuel respectively. The results were compared with reported values within the Niger Delta region and WHO (2004) standards for drinking water.

3. Results and discussion

The summary of the result analysis of heavy metal concentration in groundwater and waste water sources in the study area is shown in Table1. The evaluation of the heavy metal concentration in the study area involves a comparison of the results with the World Health Organization (W.H.O) Standard.

3.1. Lead (Pb)

Mean concentrations of lead (Pb) in the various locations range from <0.001mg/l-0.150mg/l. The level of lead (Pb) in the study area is generally high. The high concentration of lead in all the study area implies caution as lead is a very toxic element, which accumulates in the skeletal structure of man and animal. It is a widespread contaminant in soils. Lead poisoning is one of the most prevalent public health problems in many parts of the world. It was the first metal to be linked with failures in reproduction. It can cross the placenta easily. It also affects the brain, causing hyperactivity and deficiency in the fine motor functions, thus, it results in damage to the brain. The nervous systems of children are especially sensitive to lead (Pb) leading to retardation as earlier reported [17].

3.2. Iron (Fe)

Iron (Fe) content varies from <0.010mg/l to 26.741mg/l (Table 2.) The high concentration values of iron has the potential of staining laundry, metal pipes for reticulation and scaling in pipes. It may also give undesirable taste[18]. This explains the reddish brown colour stain commonly seen on most metal tanks and fence within the study area. Iron can be treated by encouraging the iron to precipitate when the water is exposed to the air [13]. The ferric hydroxide precipitate is then filtered out to have potable water. The primary source of the iron in the water is geologic. Iron is abundant in iron-bearing minerals; hence it could be derived from minerals like goethite, haematite, and limonite in the Benin Formation or from plant debris in the alluvial soils [19].

Table 1 Heavy metal concentration (mg/l) in groundwater and wastewater in the study area

Location	**Lead (Pb) mg/l**	**Total Iron (Fe) mg/l**	**Mercury (Hg) mg/l**	**Arsenic (AS) mg/l**	**Cadmium (Cd) mg/l**
Nkpogu	0.050	0.161	<0.001	<0.001	<0.002
Ordinance	<0.001	0.063	<0.001	<0.001	<0.002
Rivoc Road	0.150	0.160	<0.001	<0.001	<0.002
GTC (By Zoo)	<0.001	0.065	<0.001	<0.001	<0.002
Nwuke Street	0.050	0.226	<0.001	<0.001	<0.002
Eastern Bye-pass	0.100	<0.010	<0.001	<0.001	<0.002
Odili Road	0.100	0.065	<0.001	<0.001	<0.002
Amadi-Ama	0.050	<0.010	<0.001	<0.001	<0.002
Abuloma	<0.001	0.065	<0.001	<0.001	<0.002
Oginigba	0.075	<0.010	<0.001	<0.001	<0.002
1 WWBR	0.150	0.903	<0.001	<0.001	0.003
2 WWCM	0.075	26.741	<0.0025	<0.005	0.004
3 WWPE	0.150	1.226	<0.001	<0.013	0.003
4 WWTX	0.050	<0.010	<0.001	<0.001	0.003
WHO Permissible Limit	0.01	0.05	0.001	0.01	0.003

Table 2 Range in values of the heavy metals (mg/l) in the study area

Parameter	**Units**	**Min**	**Max**	**Mean**	**Desirable Limit**
Lead (Pb)	mg/l	<0.001	0.150	0.071	0.01
Total Iron (Fe)	mg/l	<0.010	26.741	2.120	0.05
Mercury (Hg)	mg/l	<0.001	<0.0025	0.000	0.001
Arsenic (As)	mg/l	<0.001	0.013	0.001	0.01
Cadmium (Cd)	mg/l	<0.002	0.004	0.001	0.003

3.3. Mercury (Hg)

Mercury (Hg) ranges between <0.001 mg/l to <0.0025 mg/l (Table 2). Mercury is toxic even at low concentrations to a wide range of organisms including humans. The organic form of mercury can be particularly toxic, and the methyl- and ethyl-forms have been the cause of several major epidemics of poisoning in humans resulting from the ingestion of contaminated food, e.g. fish as reported [20].

3.4. Arsenic (As)

Arsenic (As) levels ranges from <0.001mg/l to 0.013 mg/l (Table 2). Arsenic is well-known as a poison and a carcinogen. It has an average concentration in the soil of 5 to 6mg/kg. Its amount in the soil is related to rock type and industrial activity as reported [20].

3.5. Cadmium (Cd)

Cadmium concentration ranges from <0.002mg/l to 0.004 mg/l (Table 2). Its toxicity is linked with reproduction problem because it affects sperm and reduces birth weight. It is a potential carcinogen and seems to be a causal factor in cardiovascular diseases and hypertension. Large concentrations of cadmium (Cd) in the soil are associated with parent material (black slates) and most are manmade (burning of fossil fuels, application of fertilizers, sewage sludge, and plastics waste [17].

4. Conclusion

The results of the study revealed that heavy metal concentration in the groundwater and waste water sources in the area is high in some locations. Significantly, higher concentrations of lead occurring in all locations in Trans Amadi strongly indicate the presence of heavy metal pollution (lead) from those highly industrialized areas. This calls for serious concern, as the levels of contamination needs remediation. To remediate the effects of the polluted water on the health of the inhabitants, the authorities concerned should designate a properly engineered landfill in the area, putting into consideration the groundwater and its flow directions. There is need to also establish functional waste disposal mechanisms in the area with sanitation inspectors recruited with enactment of sanitary bye-laws. Mass awareness and information should be disseminated on the effects of heavy metals on water quality and human health.

It is recommended that industries in the area should set up effluents treatment plants and should remain effectively operational in order to safe guard the groundwater in the area. Conscientious efforts to control/regulate and educate the populace on the consequence of poor waste disposal practices should be carried out. More importantly, systematic study of the heavy metals concentrations in groundwater and waste water sources in the area should be carried out regularly. This is important since the inhabitants in the area depend on groundwater for drinking purposes.

Compliance with ethical standards

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Disclosure of conflict of interest

The Authors declares that there is no conflict of interest.

References

[1] Elliot HA, Liberali MR, Huang CP. Competitive Adsorption of Heavy Metals by soil. J. Environ. Qual. 1986; (15):15 – 214.

[2] Connell DW and Miller GJ. Chemistry and Ecotoxicology of pollution, John Wiley & Sons, 1984; NY 444

[3] Baker AJM and Walker PL. Heavy metal tolerance in plants. In: Shaw, A.J Evolution aspects (ed). Boca Raton: CRC Press, 1990 ; 155 – 177.

[4] McNeil KR and Warring S. Contaminated lead treatment technologies. In: Rees, J.F (ed) Society of Chemical Industry, Elsvier Applied Sciences, London, 1992; 143 -159.

[5] Henry JR. An overview of photoremediation of lead and mercury, NNEMS Report, Washington, D.C. 2000; 3 – 9.

[6] Martinez CE and Motto HL. Solubility of lead, zinc and copper added to mineral soils. Environmental Pollution, 2000; 107:153 – 158.

[7] Oyinloye AO, Jegede GO. Geophysical Survey, Geochemical and Microbiology Investigation of ground well water in Ado–Ekiti, North, South Western Nigeria. Global J. Geol. Sci., 2004; 2(2): 235-242.

[8] Bartran J and Balance R. Water Quality Monitoring: A practical guide to the design and implementation of fresh water quality studies and monitoring programmes. E and F. N. Spoon, London.1996

[9] United Nations Environmental Programme (UNEP). International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management. International Environmental Technology Centre Technical Publication Series (6). United Nations Environmental Programme.1996

[10] Horsfall M and Spiff AI. Principles of environmental Chemistry. Metrol Prints Ltd, Nigeria, 1998; 107–118.#

[11] Ogbonna DN, Benjamin IKII and Patrick OY. Some physico-chemical and heavy metal levels in soils of waste dumpsites in Port Harcourt Municipality and Environs. J. Appl. Sci. Environ. Manage. 2009; 13(4) 65 – 70

[12] Weber KJ and Daukoru EM. Petroleum geology of the Niger delta: *9th World Petroleum Congress Proceedings*.1975; 2:209-221

[13] Nwankwoala HO, Amadi AN, Oborie and E, Ushie FA. Hydrochemical Factors and Correlation Analysis in Groundwater Quality in Yenagoa, Bayelsa State, Nigeria *Journal of Applied Ecology and Environmental Sciences. 2013;* 2(4):100-105 Available online ahttp://pubs.sciepub.com/aees/2/4/3

[14] Ngerebara OD and Nwankwoala HO. Groundwater potentials in the offshore Niger Delta environment, Nigeria. *Electronic Journal of Environmental Hydrology*. 2008; 16:28. Avalaible online @ www.academicjournals.org

[15] Etu-Efeotor JO. and Odigi MI. Water supply problems in the eastern Niger Delta. J. Mining Geol.1983; 20(12), 183-193.

[16] Amadi AN, Olasehinde PI, Yisa J, Okosun EA Nwankwoala HO and Alkali YB. Geostatistical Assessment of Groundwater Quality from Coastal Aquifers of Eastern Niger Delta, Nigeria. *Journal of Geosciences. 2012;* 2(3): 51-59

[17] Osayande AD and Nwokedi AV. Assessment of Some Heavy metals and Physico-Chemical Properties of Soils Within the Vicinity of University of Port Harcourt Teaching Hospital Medical Dumpsite,PortHarcourt,Rivers State,Nigeria. Scientia Africana 2019; 18(3)61-74

[18] Nwankwoala HO and Udom GJ. Major ion chemistry and hydro geochemical processes of groundwater in Port Harcourt City, Southern Nigeria. Journal of Spatial Hydrology 2011; Vol.11, No.1.

[19] Okojie ME and Osayande AD. Geochemical Evaluation of Soils and Groundwater around Upper Ekehuan Dumpsite,Ekehuan road,Benin City Nigeria. Scientia Africana 2018; 17(1) 132-154

[20] Mahipal SS, Mayuri K, Manisha N, Rajeev K, Prashant A. Heavy Metals Contamination in Water and their Hazardous Effect on Human Health-A Review. *Int.J.Curr.Microbiol.App.Sci.2016;* 5(10): 759-766.