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Physicochemical Characteristics and Heavy Metals Level in Groundwater and Leachate around Solid Waste Dumpsite at Mbodo, Rivers State Nigeria

***ONWUALU-JOHN, JN; UZOEGBU, MU**

Department of Geology, Faculty of Science, University of Port Harcourt, Port Harcourt, Nigeria.

**Corresponding Author Email: josephine.onwualu@uniport.edu.ng*
Co-Author Email: Uche.uzoegbu@uniport.edu.ng

ABSTRACT: The dump site at Mbodo study area is characterized by diverse kinds of waste, from municipal waste to industrial waste, agricultural waste, and solid waste. Hence, this study evaluated the physicochemical characteristics and heavy metals level in groundwater and leachate around solid waste dumpsite at Mbodo, Rivers State, Nigeria using standard methods after sample treatment. The physiochemical results of the underground waters were studied and the results range are pH (4.50-4.77); Total dissolved solid (7.0-8.0); Total hardness (2.40-4.04); Turbidity (0.4); Conductivity (14-17); chloride (4.6- 6.0), Nitrate (0.9). The physiochemical parameters are within the world health organization standard except for pH of the waters which indicates low pH (4.48-4.477). The low pH of the underground water could be due to surrounding factors like elemental compositions of the aquifer, the nature of the underground water, reactions of the elemental components in the water, reactions of metals at the subsurface, dissolution of confined CO_2 in the underground water. The leachates have average composition of (Cu= 0.015; Mn=5.565; Fe=15.01). The heavy metals in the underground water are within the permissible limit which can be tolerated by human beings as compared with the world health organization standard. The heavy metals concentrations range from (Ca =0.06-0.11; Mg= 0.05-0.2; Mn=0.02-0.03; Fe= 0.033; Ni=0.047) while Cd, Cr and Pb are not significant. The waste dump at Mbodo study area did not have any significant effect on the proxy underground water.

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The study of heavy elements in the environment has become paramount due to diverse hazards that occur in the environment. The need to have a sustainable environment is crucial in all the spheres of the environment which in one way or the other interferes with each other. The contaminant in the biosphere/ lithosphere has the tendency of extending to the hydrosphere and other areas. The existence of heavy elements in the environment should always be monitored in order to ensure that the tolerant level is not exceeded. The toxicity of elements in the environment is dependent on the level of concentration of such elements. Least concentrations of some heavy elements in the environment can pose a very high risk to the sustainability of such environment, excessive high concentration of some of the heavy elements can as well cause the environment to be toxic / hazardous. Nevertheless, there are some elements that are toxic to human (mercury, lead, aluminum, arsenic and cadmium), these toxic elements if enters human either through ingestion, contact or inhalation will result to a very serious health challenge and eventually death. Waste dumps sites host diverse types of waste which generates different types of heavy and toxic metals.

All these waste if not properly treated results to environmental deterioration. Besufekad *et al.* (2020) mentioned that open waste dump can lead to toxicity

**Corresponding Author Email: josephine.onwualu@uniport.edu.ng*

of the environment through accumulation of heavy metals in the soil. Most times the constant accumulation of the heavy metals in a waste dump increases the level of concentration of these metals. During erosional / flooding processes, some of the heavy elements are washed to nearby surface waters or percolate to the underground water thereby disrupting/altering the potability of the water bodies. These accumulations of toxic waste in the dumpsite affect the environmental sustainability. Reaction of the heavy elements with other component in the waste dump can make the elements to be very toxic (Ya -Jun Hong et al., 2020).

Hence, this study evaluated the physicochemical characteristics and heavy metals level in groundwater and leachate around solid waste dumpsite at Mbodo, Rivers State Nigeria.

MATERIALS AND METHODS

Geology of the study area: The study area is Mbodo which is within the Niger Delta basin. The Formation of Niger Delta started in the Jurassic and ended in the Cretaceous during the separation of South American plate and African plate when the south Atlantic began to open. It is formed as a result of failed rift; this rifting gave rise to several faults.

There was marine transgression and regression in the Niger Delta basin which is evidenced by the deposition of sands and shales (Kogbe, 1976). The Sediment infill in the Niger Delta is estimated to be 450,000km. The sediments in the Niger Delta are composed of Akata Formation, Agbada Formation and Benin Formation

The Benin Formation: Benin Formation ranges from Miocene to recent. Benin Formation is younger in age; it is poorly sorted. It is made up of intercalation of sandstones and shales. This Formation has a thickness of about 2500m thickness in some places. Benin Formation is underlain by the Agbada Formation.

Agbada Formation ranges from Eocene- Pliocene. This Formation is characterized by also intercalation of sandstones and shales. The Agbada Formation hosts some fossils at its base. It is a hydrocarbon bearing Formation. It has a thickness of about 3500m.

The Akata Formation is Paleocene in age. It is beneath the Agbada Formation. It is made up of Sandy silty shales. The Akata Formation hosts some fossils. It has a thickness range of about 6500m-7000meters in some places. It is formed under dissolved oxygen depleted environment.

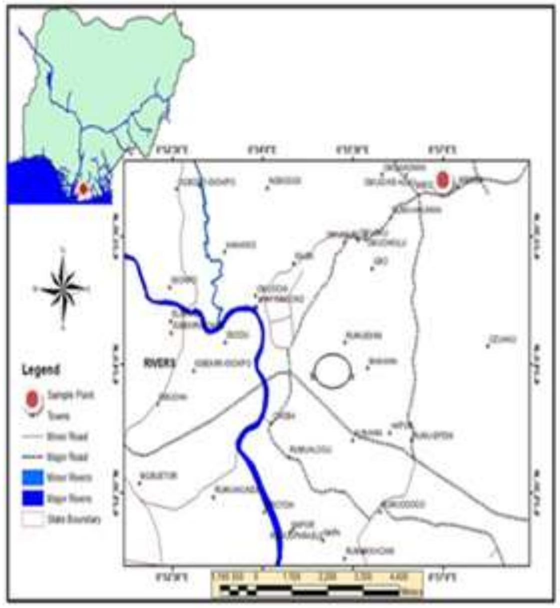

Fig 1: Map Showing the study area and the environs

Plate 1: Showing waste dump at the study area

Plate 2: Waste dump and leachates at the study area

Sampling Techniques: Eighteen parameters (eight physiochemical parameters and Ten heavy metals) were analyzed on the water samples collected at the dumpsite and environ. The ground water samples (G1, G2, G3, and G4) were collected from boreholes. The distance of G1, G2, G3, and G4 to the dumpsite is 80m, 130m, 200m and 40m respectively.

The groundwater water samples and the leachates were collected using plastic bottles; the plastic bottles were rinsed with a representative sample before the required water samples were filled in to the brim in order not to create vacuum for oxidation processes and corked properly. The samples were taken to the Laboratory for physiochemical (hydrogen ion potential (pH), Turbidity, Nitrate, Total Dissolved Solid (TDS), Total Hardness (TH), Sulphate, Chloride, and Conductivity) and heavy metals analysis. The leachates were subjected to heavy metal analysis. The results were compared to world Health Organization standard for potable water.

Sample Treatment: Prior to the heavy metals analysis, the water samples were acidified with Nitric acid and Atomic Absorption Spectrometry was used to determine the heavy metals in the samples. Uddin *et al* (2016) documented on the efficiency of Atomic absorption spectrometry in dictating heavy metal concentrations.

The pH of the water samples was determined using pH meter. This method involves dipping electrode inside the sample, then the measure button is turned on and allowed for some time for the reading to balance, hence the pH value is read from the meter. Buck et al. (2020) confirmed the use of electrodes and pH meter as a standard method of determining the pH of water.

The Turbidity of the water sample is determined by pouring the water sample in a test tube glass, cover it and insert into a Nephelometer. The Nephelometer measures the spread of rays of light with reference to the water samples, then the photo detector / readout gadget gives out the value. Nitrate in water sample is determined by colorimetric method (Spectrophotometric). Nerdy and Effendy (2018) documented that colorimetric method has been found as an effective method for determining nitrate and nitrites.

Gravimetric Method is used to determine total dissolved solids. This method involves evaporation of fluid from the samples, then the remnant mass is weighed.

The Sulphate constituent in water sample is determined by acidification of the water sample with hydrochloric acid, then barium chloride is also added to precipitate the sulphate via barium sulphate.

Chloride is determined by volumetric method. This method involves evaluating the analyte through measuring the volume of a concentrated solution (water sample).

Conductivity of water sample is carried out using conductivity meter, in this process, electrodes are placed in samples and current is passed through them. The current is measured using conductivity meter. Kur et al. (2019) used electro–chemical parameters to determine the conductivity and quality of water.

The Heavy metal concentrations in the leachates were determine by acidification of the leachates with hydrochloric acid after which flame emission spectrometer is used to measure the heavy metals in the samples

RESULTS AND DISCUSSION

The physiochemical results show that the groundwater has average concentrations of Turbidity 0.90NTU; pH 4.60; Total dissolved solids 7.33; Total hardness 3.50; Nitrate 0.36; sulphate 0.69; conductivity 16.0, Chloride 4.70 (Table 1). The average concentrations of heavy metals in the underground water are Ca 0.077, Mg 0.0128; Mn 0.023, Fe, Pb, and Zinc are absent in sampls UGW 1-3 while Cd, Cr, and Pb are insignificant in sample UGW 4. The leachates have average heavy metal concentration of Mn 5.543; Cr 0.0075; Fe 15.01, Cd, Cu, Ni, Pb are insignificant. The average heavy metals concentrations in the leachates are Mn 5.565; Fe 15.01, Cr 0.0.0075 while Cd, Cu, Ni, and Pb are insignificant (Table 3).

Table 1. The physiochemical results of the underground water

Physiochemical parameters	UGW 1	UGW 2	UGW 3	Average	WHO standard
pH	4.77	4.50	4.48	4.60	6.5-7.5
Total Dissolve Solids	7.0	7.0	8.0	7.33	Less than 300ppm
Total Hardness	2.40	4.04	4.04	3.50	200ppm
Turbidity	0.4	0.4	0.4	0.4	Not more than 5 NTU
Sulphate	0.69	0.69	0.69	0.69	250ppm
Conductivity	17	16	14	16.0	1000
Chloride	4.0	4.0	6.0	4.70	250
Nitrate	0.09	0.09	0.09	0.09	10ppm

Table 2 The heavy metals concentrations in the underground water

Samples	Ca	Mg	Mn	Fe	Zn	Cd	Cu	Ni	Cr	Pb
UGW 1	0.114	0.050	0.03	-	-	-	-	-	-	-
UGW 2	0.057	0.219	0.02	-	-	-	-	-	-	-
UGW 3	0.060	0.117	0.02	-		-	-	-	-	-
UGW 4	-	-	-	0.033		-0.016	0.000	0.047	-0.038	-0.252
Average	0.077	0.128	0.023	0.033		-0.016	0.000	0.047	-0.038	-0.252
WHO standard	7.5	5.0	0.1	0.3						0.01

Table 3. Heavy metal concentrations in the leachates

Samples	Mn	Fe	Cd	Cu	Ni	Cr	Pb
L1	8.50	21.176	-0.03	-0.003	-01.9	0.004	-0.138
L2	2.63	8.845	-0.0061	-0.003	-0.046	0.011	-0.353
Average	5.565	15.01	-0.01805	-0.003	-0.973	0.0.0075	-0.245

The physiochemical features of the underground water indicate that the average turbidity, total dissolve solids, total hardness, sulphate, conductivity, chloride are within the acceptable rate for potable water (Table 1). The average pH of the underground water shows that the water at the study area is acidic (Low pH). The low pH of the underground water at Mbodo study area is similar to the low pH of underground water at another part of the Niger Delta Basin as recorded by Offodile and Onwualu-John, 2022. The inability of the waste dump to affect the physiochemical features of the underground water could be due to the deep levels of the water table. The solubility of the chemical components of the waste also played some roles in the assimilation and infiltration processes of the heavy elements into the underground water. This implies that either the waste is dominated with insoluble elements or that exothermic reactions took place and there was not enough time for the elements to migrate or assimilate into the underground water. The clay lining of the soil may have prevented the underground water from having some alterations from the waste dump especially when the clay lining is devoid of cracks. The thickness of the sediments probably has played vital roles in limiting the intrusion of foreign particles in the underground water. Proper sorting of the waste by scavengers would have reduced the rate of reactions of the waste thereby hindering the alteration of the underground water. In most cases, waste is not sorted from the source before its being deposited at the open dump site but at the dump sites the scavengers directly or indirectly sort these wastes thereby reducing the velocity and rate of chemical reactions that would have taken place, this sorting activities helps to reduce the impact of solid waste disposal on man and environment. Municipal waste consists of waste from homes, industries and agricultures which are not sorted (Bekun et al, 2005).

The low pH of the underground water could be due to interaction with acid rain. Acid rain would have been triggered by emission of gasses which occurred during decomposition and reactions of waste components at the waste dump. These gasses dissolved in the rain water and percolate down to the underground water. Carbondioxide (CO_2) released by subsurface organisms during respirations can be dissolved inside the underground water and this can make carbonic acid ($H_2CO_3HCO_3$) to be formed in the water. The elemental / mineral components of the surface and subsurface geology of the study have the tendency of affecting the pH of the underground water. Water with low pH can be corrosive or toxic and this corrosive nature can result to production of more elements inside the water through reaction processes with the lithology of the study area.

Heavy metals present in the leachates (Fe, Mg) can low the pH of the underground water. The reactions of the leachates and components of waste with high solubility contents have the tendency to low the pH of the underground water. The underground water can react with other minerals in the aquifer thereby making the pH of the water to be low. Water with low pH has the tendency to dissolve rocks faster as well as disintegrating the metallic bonds in a soil thereby making the underground water to be acidified. Presence of iron (Fe) in the underlying rock can decrease the pH of the underground water. Temperature increase at depth can increase the chemical reactions of underlying rocks thereby making the pH of the underground water to be low. The nature of the underlying soil can low the pH of underground.

Underground waters get mineralized through reactions with lithology, through equilibrium reactions among the constituent minerals, assimilations of foreign particles into the water, biodegradations, and the mineral composition of the source. The mineral chemistry has shown that some elements are required by the body but it becomes hazardous when the permissible limit is exceeded. Long term exposure to heavy elements can cause Alzheimer's disease and muscular dystrophy (Monisha et al, 2014), whereas exposure to heavy metals below the recommend limit does not pose any problem to humans. Calcium (Ca) Magnesium (Mg), manganese (Mn) and iron (Fe) are below the world health organization recommended standard (Table 2). This implies that the waste dump did not have a significant effect or interaction with the underground water. The phenomena could be that the waste is properly treated, or that there is a good recycling process. The heavy metal concentrations in the underground water would have contributed to the physiochemical parameters of the water thereby making the underground water to be potable for drinking. If the Ca, Mg, Mn and Fe concentrations have exceeded the recommended values, the adverse effects would have been seen on the turbidity, total dissolved solids, total hardness and the water conductivity. Most cases, open waste dumps constitute nuisance / pollution to the environment and the underground water, but this is not the case for the dumpsite and underground water at the study area. Bayene and Banerjee (2011) stated that open disposal of waste can cause environmental degradation through introduction of different toxic heavy metals in the soil and water. Yarlagadda et al, (1995) stated that the disposal of solid waste represents the source of metals release into the environment. Heavy metals in the leachates depend on the nature of the solid waste and the chemical reaction (Tamru and Chakma, 2015). The inability of the waste to pollute the underground water at the study area could be due to deep water table and the aquifer seals. Table 3 shows the concentrations of heavy metals in the leachate. The leachate is enriched with Manganese (Mn), iron (Fe), Chromium (Cr). The concentrations of manganese and chromium in the leachate are not reflected in the underground water, the physiochemical nature of the underground water did not indicate that iron concentrations have any negative effect. The world health organization recommends that iron content in drinking water should not be more than 0.3mg/l. The high concentration of iron in the leachate would have been used in other chemical reaction, leachate migration to surface waters and soil can make the iron concentration not to affect the underground water though leachate migrations can bring dissolution of more chemical compounds. Ayoola et al 2021, documented that among the natural occurring elements, about (30) thirty metals and metalloids are potentially toxic to human, of which Cr, and Mn are among them. Population increase, infrastructural development, urbanization and industrialization are key factors responsible for production of waste of diverse forms which generates heavy metals in the environment. Ziadat and Moth, (2005) mentioned that increasing consumption of resources results to large amount of solid waste from industrial and domestic activities.

Conclusion: The Waste dump at Mbodo study area does not have any adverse effect on the underground water of the study area. It is imperative to note that the physiochemical parameters of the underground water at the study area met the required standard for a potable water except for the low pH of the water which signifies acidity and can be corrected through proper water treatment. Proper sorting of the waste minimized the rate of chemical reactions which would have given rise to much toxic elements in the water.

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