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Heavy Metal Assessment of Borehole Water Use in Oil Refinery Host Communities

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ABSTRACT: *The research was carried out to assess heavy metal presence in borehole water used in eleme Port Harcourt Refinery host communities in Rivers State. The physicochemical parameters determined include: Temperature, pH, turbidity, alkalinity, and total dissolved solid (TDS) using conventional equipment and standard laboratory procedures, also the concentration of of Pb, Hg, Fe, CD, SO4, SO3, CO3 and Cl-, were determined using Atomic Absorption Spectrophotometer(AAS), bacterial analysis were carried out and characterized using standard methods. The results showed that physical parameters such as pH, temperature and turbidity in some communities did not show any reason for concern. The chemical parameters measured are within the World Health Organisation (WHO) and National Standard for Drinking Water Quality (NSDWQ) standard except for cadmium which show a very high concentration with the range of 0.13-0.48mg/l as compared to approved 0.003mg/lof World Health Organisation and 0.05mg/l of National standard for Drinking Water Quality respectively. Also, the concentration of iron (Fe) was very high in all the communities sampled with the range of 0.19 -0.44mg/l as compared to approved 0.3mg/l of WHO and NSDWQ. The concentration of of Cadmium (Cd)detected was very high compared to the approved standard of World Health Organisation and National Standard for Drinking Water Quality as it ranges from 0.00-0.4750mg/l. The presence of Cadmium may be due to the leaching of petroleum and hydrocarbon compounds in the sampled area. Intervention of Government and Non- governmental Organisation is highly recommended.*

KEYWORDS: borehole, quality, water, community.

INTRODUCTION

Water accounts for about 70% or more of the weight of most organism. In human adults also, total body water account for about 70 % of the lean body mass (Ikeyi & Omeh 2015). Adult slim females have a low water content of about 46 - 60% whereas Infants can be in the range of 65 - 77% (Jain et'al 2013). The human body temperature of 37°c is maintained mainly because water is expelled by lungs and the skin. A loss of 10% of water in our body is serious while a loss of 20% is fatal in human. No order substance on earth is as abundant as water and it is present almost in air, clouds, oceans, Lakes, rivers, glaciers or Springs. In 5km layer below the sea level on earth water is 6 times as abundant as all other substances put together. And nọ other substance exist in three states of matter at the same time (Jain et al 2013). It is water that had conditioned our climates. The water in the oceans, season and the atmosphere (vapour) act as an accumulator of heat. In hot weather, it absorbs, heat and in cold, it gives up heat thereby making the planet warm. Without water our planet will be cold to zero temperature long ago and all forms of life would have perished. Water is the most important possession of humanity and keeping in view the relevance of the role of water in our planet NASA launched a satellite known as "Aqua" to study the effect of water in various forms on climate (Jain et al 2013). Water has the ability to dissolve substances more than any other known liquid hence it is known as universal solvent. Obi et al (2016) defined water as a liquid that boils at 100oC, has a pH of 7 and pressure of 760mmHg. Water as well serve as a very useful substance to mankind in many says, for instance: it serve as a means of transportation, serves as a sporting and recreation activity. Electricity is also generated from water, bathing, drinking, washing, cleaning as well as cooking activities are carried out with water (Obi,2016).

Water and its quality is a very serious and vital issue for mankind due to its link with human health and welfare. It is one of the most important, valuable and renewable essential resources. Water is one of the essential elements of human life as the body cannot survive longer than few days without adequate water (Alepu et al, 2016). The availability of adequate water supply both in quality and quantity is essential for human existence. There is abundance of it on the earth surface but the quality as well as the quantity to serve its intended purpose is where the problem lies. This because, water that may be good for tanning and dyeing of clothes may not be good for domestic purposes. Water can originate from various sources which include rain water, surface water and groundwater. But the most important one is the groundwater which originate as a result of rainfall infiltration into the ground through the pores of rock and soil thus meeting the water table. It is normally abstracted through domestic boreholes and is essentially used for human consumption. As such, the need to ensure that individuals get access to clean water cannot be ignored. However, improved access to safe water in Nigeria remains slow due to several issues related to corruption that pervades every sector of the economy and this has hindered establishment of legal acts to checkmate water usage in the country (Valipour, 2015). Nigeria is the most populous country in Africa with an estimated population of over 170 million, growing annually at a rate of 2 percent (Al-Zayer, 2020). According to the USAID (2021), the fast-growing population has not been accompanied by increase access to good water supply. The gap between the areas that have access to safe water supply and those without has grown wider.

With the exponential increase in population, access to improved water remains an important pre-condition for sustaining human life, maintaining ecosystems and for achieving sustainable development (Waziri et al, 2022). Accessibility and availability of fresh clean water is a key to

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sustainable development and an essential element in health, food production and poverty reduction (Adekunle et al., 2014). A water resource such as rain, river, groundwater and sea is one of the major components of environmental resources that are under serious threat from over exploitation or pollution from anthropogenic activities (Olowoyo, 2012). Fresh water resource deterioration is now a global problem and is increasing at a faster rate (Mahananda et al., 2015). Discharge of toxic chemicals, over pumping of aquifers and contamination of water bodies with substances that promote algae growth are some of the major causes of water quality deterioration (Awoyemi et al., 2014). Today there are traces of contamination not only of surface water but also of groundwater, which are susceptible to leaching from waste dumps, mine tailings and industrial production sites (Mahananda et al., 2005). Groundwater is an increasingly important resource all over the world. The term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formation that are fully saturated (Uzomah & Scholz, 2021). Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies (Zaman 2021). Importantly, groundwater can also be contaminated by naturally occurring sources.

Groundwater is generally very difficult to remediate, except in small defined areas and therefore the emphasis is on preventing contamination (Mahananda et al., 2015). Water quality reflects the composition of water as affected by natural cause and man's cultural activities expressed in terms of measurable quantities and related to intended water use (Kumar, 2017). One way of determining quality of water is to evaluate its physical and chemical properties (World Health Organization WHO 2021). Boreholes serve as a major source of drinking water in Nigeria, hence there is a growing concerned about the quality of water from this source (Mustafa et al., 2021).

Borehole water has become the most used source of water dating back to ancient China (202BC-220AD), the Han dynasty used deep boreholes, reaching as deep as 600m (2000ft) (Loewe, 2018). This borehole water fills the spaces between the rocks and soils making an aquifer (Driscoll, 2016). Ground water depth and quality varies from place to place and this affects the quality of water obtained. Also, the various kinds of rocks and soils which it moves through affect it too. Water moving through underground rocks and soils may pick up natural contaminants, even with no human activity or pollution in the area (Beltaoset al., 2016). In addition to nature's influence, water is also polluted by human activities, such as defecation, dumping garbage, poor agricultural practices and chemical spills at industrial sites (Coe, 2017). Even though water may be clear, it does not necessarily mean that it is safe for drinking. It is very important to judge the safety of water with respect to its physical, chemical and bacteriological property. With little or no municipal water supply, no rivers or nearby streams and the urgent need for safe water, residents in Southern Nigeria including Rivers State faced the only source which is underground borehole water. As much as underground borehole water seemed to be a remedy, several factors affect its usage. Distance between the site of the borehole and septic/ soak away tank, distance between borehole and refuse dump unit, depth of the borehole and the distance between borehole and neighbours' septic tank are all factors to be solely considered prior to drilling borehole due to limited plot allocation. However, according to World Health Organization standard and guidelines, borehole water should be sunk 150ft below the ground level. It should be situated far and opposite from refuse disposal and sewage disposal unit. However, in most parts of Nigeria, these standards by default are not met (Dibal & Odiana, 2021). The increasing rate of sinking of borehole in these areas could likely result into environmental hazard if not checked.

Furthermore, the high level of industrialization, unlawful waste management practices in urban areas, indiscriminate and improper disposal of both solid wastes and waste water, boreholes are contaminated which make it unfit for human consumption (Singh et al., 2017). In the industrial areas such as the refinery area of Port Harcourt in Rivers State Nigeria, there have been reported cases of oil and gas pollution which could also impact the quality of borehole water available to the residents (Emuedo et al, 2014). Also water demand has increased due to population increase, urbanization, industrial as well as agricultural activities, etc. Thus, the quest for alternative sources to satisfy water demand has led to the indiscriminate construction of boreholes by individuals as coping strategy without any concern on the quality of water abstracted. Hence, the necessity to check for the quality of borehole water in these regions is paramount, considering the rise of water borne diseases which is as a result of the alteration of some physiochemical and biological quality of the water.

Lack of accurate data makes it difficult to determine whether Nigeria is making progress to meet its Sustainable developmental goals relating to water infrastructure (APHA, 2019). Water infrastructure in Nigeria has suffered from many years of poor operation. Inefficient institutions and unsustainable public sector spending have contributed to poor access to good water. State water agencies (SWAs) are responsible for the supply of urban water while the local government authorities are responsible for the establishment and maintenance of rural water supply. Most rural areas depend on boreholes or hand-dug wells for the water system (WaterAid, 2017). However, there is no guarantee about the hygiene condition of this kind of water supply. Many people in the rural areas suffer from several kinds of diseases due to poor hygiene conditions of their water supply. It is against this background that this study is embarked on to assess heavy metal presence in borehole water used in Refinery activity area in Rivers State.

Aim and Objectives of the Study

The aim of this study is to assess the heavy metal presence in borehole water used in Refinery host communities of Port Harcourt Oil Refinery:
The specific objectives of the study include to assess:

1. The physical characteristics of borehole water used in Port Harcourt Oil Refinery host communities.

2. The heavy metals and chemical (mineral ions) properties of borehole water used in Port Harcourt Oil Refinery host communities.

Hypotheses

The following hypotheses will be tested at 0.05 level of significance:

1. The physicochemical characteristics of borehole water used in host communities of Port Harcourt Oil Refinery host communities do not significantly differ from the World Health Organization's parameter for safe drinking water.
2. The heavy metals properties of borehole water used in host communities of Port Harcourt Oil Refinery host communities do not significantly differ from the World Health Organization's parameter for safe drinking water.

METHODOLOGY

This study is a descriptive cross sectional survey of borehole waters in activity area in Rivers State. In using the research design, borehole water samples were selected across the Refinery activity area of Rivers State. This study was carried out in the six selected host communities of Eleme Port Harcourt Refinery in Rivers State. The selected host communities are: Abam, Darka, Ekereakana, Okochiri, Ogan, and Alesa respectively. The sampling location coordinates are given in the table below:

Table 1: Coordinates of the Sampled Communities.

Sample Location	Latitude	Longitude
ABAM	45.760^0N	5.708^0E
ALESA	46.191^0N	6.158^0E
DARKA	45.006^0N	5.959^0E
EKEREAKANA	45.108^0N	6.175^0E
OGAN	45.288^0N	5.829^0E
OKOROCHIRI	44.968^0N	6.453^0E

Two water samples were collected from each of the host communities for physical, chemical and biological analysis. The water samples were collected from the various boreholes using sterilized plastic water bottles (1000ml). The tap was allowed to run 2-3 minutes and an ample air space of 2.5cm was left in the water bottles to create space for oxygen so that organisms in the water samples will not die before testing and also to facilitate mixing before shaking before testing. The water samples were collected from various communities and were labeled accordingly. The water samples were immediately sent to the laboratory in an insulated bag to prevent external factor like temperature from changing some of the parameters. Analysis commenced within 12 hours of sampling (APHA 1998). The physico-chemical parameters like temperature, PH, total Dissolved Oxygen (TDS), conductivity, Turbidity were measured. This was done using pH meter. The electrode was first standardized and calibrated using the three set of buffer solution at pH 4.00, 7.0 and 9.0, the electrode was rinsed thoroughly with distilled water and immersed in distilled water. The electrode was then dipped into the sample to determine the pH. This method is adopted by (APHA 1989). This was done by pouring 25ml of distilled water into the cuvette and set at zero in the HACH spectrophotometer and read at 45nm, then 25ml of sample was poured into another cuvette and read in the meter. This method is adopted by (APHA 1989). Calculation Turbidity (NT) =Instrument Turbidity x Slope Reciprocal.

The results obtained showed that the sampled water is contaminated with cadmium and Iron hence they exceeded the WHO standard as well as NSDWQ standard. Although portable water is expected to contain dissolved mineral ion but it has to be to a limit (WHO 2011). This is to reduce the rate of contamination of such water since most of the metals are disastrous to human health on excessive consumption. The presence of heavy metals in drinking water higher than a certain concentration can be destructive to human fitness. Cadmium occurs certainly in rocks and soils and enters water when there is contact with soft groundwater or surface water. Moreover, it could be added via paints, pigments, plastic stabilizers, mining and smelting operations, and other industrial operations such as electroplating and fossil fuel, fertilizer, and sewage sludge disposal. The level of cadmium in sample Abam was 0.048mg/l which was above the 0.003 ppm WHO permissible level and may pose health risk. This high concentration may be attributed to the industrial activities nature of the study area. Sample Alesa was 0.013mg/l which was above the world Health Organisation standard. Data was be analyzed using Statistical Package for Social Sciences (SPSS) version 25. Descriptive statistics (mean and standard deviation) was used to answer the research questions and one-way analysis of variance (ANOVA) was used to test for the hypotheses at 0.05 confidential level.

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RESULTS AND DISCUSSIONS

Research and Analysis

Table 4.1: mean and standard deviation of the physical characteristics of borehole water used in Port Harcourt Oil Refinery host communities.

			Physical Characteristics/parameters				
Sampled communities		**PH**	**Turbidity**	**Conductivity**	**Temperature**	**Alkalinity**	**TDS**
ABAM	Mean	5.25000	3.15000	11.50000	26.00000	1.00000	6.00000
	N	2	2	2	2	2	2
	Std. Deviation	.070711	.212132	.707107	1.414214	.000000	.000000
ALESA	Mean	5.75000	3.50000	15.00000	25.00000	2.00000	11.00000
	N	2	2	2	2	2	2
	Std. Deviation	.353553	.707107	1.414214	1.414214	.000000	4.242641
DARKAAMA	Mean	5.30000	3.00000	26.50000	27.75000	3.50000	15.50000
	N	2	2	2	2	2	2
	Std. Deviation	.707107	.000000	.707107	1.060660	.707107	.707107
EKEREKANA	Mean	5.30000	2.50000	31.00000	26.20000	6.50000	17.00000
	N	2	2	2	2	2	2
	Std. Deviation	1.697056	.707107	.000000	1.697056	2.121320	.000000
OGAN	Mean	4.65000	1.00000	15.50000	26.00000	3.00000	8.50000
	N	2	2	2	2	2	2
	Std. Deviation	.070711	1.414214	2.121320	.000000	1.414214	.707107
OKOROCHIRI	Mean	6.80000	.00000	25.50000	27.00000	3.00000	14.00000
	N	2	2	2	2	2	2
	Std. Deviation	.000000	.000000	.707107	.000000	.000000	.000000
Reference	**WHO 2011**	6.5 – 8.5	5	900	-	2.00	600
Points	**NSDWQ 2016**	6.5 – 8.5	5	1000	20 - 32	20 - 200	500

Table 4.1 shows the physical characteristics of borehole water used in host communities of Eleme Port Harcourt Oil Refinery host communities. The average pH of the borehole water in the sampled Communities; ABAM, ALESA, DARKAAMA, EKEREKAN , OGAN and OKOROCHIRI were 5.25, 5.75, 5.30, 5.30 , 4.65, 6.80 respectively with a range of 5.25 to 6.80. All pH level are below (WHO, 2008; NSDWQ, 2016) except in OKOROCHIRI community. Turbidity average of the borehole water in the communities were ABAM, ALESA, DARKAAMA, EKEREKAN , OGAN and OKOROCHIRI were 3.15, 3.50, 3.00, 2.50, 1.00 and 0.00 respectively which are the reference point of WHO (2008) and NSDWQ (2016). Conductivity in the sampled communities varied widely, from 11.50 to 31.00 s/cm on average which is also below the reference point of which are the reference point of WHO (2008) and NSDWQ (2016). The tempereature and alkalinity average of the borehole water in the sampled communities were 26 – 27^{0}C and 1- 6.5mg/L. This indicates the temperature falls within reference point of WHO (2008) and NSDWQ (2016). And the Alkalinity far below the reference point of WHO (2008) and NSDWQ (2016). Average TDS concentration of the sampled communities was 6.00 – 17.00 mg/l which also below reference point of WHO (2008) and NSDWQ

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(2016). Therefore, there is no health-based limit for TDS in drinking water (WHO, 2008). The Borehole water in the sample communities was fresh water.

Table 4.2: mean and standard deviation of the heavy metals and chemical (mineral ions) properties of borehole water used in Port Harcourt Oil Refinery host communities.

Sampled Communities		Heavy metals properties heavy/parameters				
		Lead	**Cadmium**	**Nickel**	**Mercury**	**Iron**
ABAM	Mean	.00100	.04750	.01050	.00100	.10500
	N	2	2	2	2	2
	Std. Deviation	.000000	.000707	.013435	.000000	.120208
ALESA	Mean	.00100	.01350	.01500	.00100	.42500
	N	2	2	2	2	2
	Std. Deviation	.000000	.000707	.021213	.000000	.035355
DARKAAMA	Mean	.00150	.03300	.00100	.00150	.19000
	N	2	2	2	2	2
	Std. Deviation	.000707	.001414	.000000	.000707	.000000
EKEREKANA	Mean	.00100	.02350	.00100	.00150	.40500
	N	2	2	2	2	2
	Std. Deviation	.000000	.000707	.000000	.000707	.007071
OGAN	Mean	.00100	.00400	.00100	.00150	.24000
	N	2	2	2	2	2
	Std. Deviation	.000000	.000000	.000000	.000707	.014142
OKOROCHIRI	Mean	.00100	.00100	.00100	.00100	.44000
	N	2	2	2	2	2
	Std. Deviation	.000000	.000000	.000000	.000000	.000000
Reference Points	**WHO 2011**	0.01	0.003	0.07	0.001	0.3
	NSDWQ 2016	0.01	0.05	0.02	0.001	0.3

Table 4.2 shows the heavy metals properties of borehole water used in host communities of Eleme Port Harcourt Oil Refinery host communities. The average properties of heavy metals such lead, cadmium, Nickel, Mercury and iron in sampled communities ; ABAM, ALESA, DARKAAMA, EKEREKAN , OGAN and OKOROCHIRI have the range of 0.000 – 0.001,mg/L, 0.01350– 0.04750mg/L, 0.001 -0.21213mg/L, 0.001 – 0.0015mg/L and 0.105 -0.440mg/L. The following heavy metals properties of borehole water like lead, Nickel, Mercury in the sample communities falls below and within the reference point when compared reference point of WHO (2008) and NSDWQ (2016). The presence of cadmium in the Borehole water in the sample communities was actually far above the reference point of WHO (2008) and NSDWQ (2016),this is similar to the work of Bamigboye *et`at* (2018). Also heavy metals

properties of borehole water such iron was also below the reference point when compared reference point of WHO (2008) and NSDWQ (2016) except for communities like ALESA, EKEREKANA and OKOROCHIRI

Table 4: ANOVA analysis of the physicochemical characteristics of borehole water used in Port Harcourt Oil Refinery host communities

	Sum of Squares	Df	Mean Square	F	Sig.(p-value)	Decision
Between Groups	1993.267	5	398.653	21.105	.001	Reject H0
Within Groups	113.335	6	18.889			
Total	2106.602	11				

Table 4 indicate that physicochemical characteristics of borehole water used in host communities of Port Harcourt Oil Refinery host communities do not significantly differ from the World Health Organization's parameter for safe drinking water, $F(2,6) = 21.105$, $p = 0.001$. Therefore reject the null Hypothesis ($p < 0.05$)

Table 5: ANOVA analysis of the heavy metals properties of borehole water used in Port Harcourt Oil Refinery host communities

	Sum of Squares	Df	Mean Square	F	Sig.(p-value)	Decision
Between Groups	.168	5	.034	11.119	.005	Reject H0
Within Groups	.018	6	.003			
Total	.186	11				

Table 5 indicate that heavy metals properties of borehole water used in host communities of Eleme Port Harcourt Oil Refinery host communities significantly differ from the World Health Organization's parameter for safe drinking water, $F(2,6) = 11.119$, $p = 0.005$. Hence reject the null hypothesis ($p < 0.05$)

DISCUSSION OF FINDINGS

Table 4.1 showed that physicochemical characteristics of borehole water used in host communities of Eleme Port Harcourt Oil Refinery host communities differ from the World Health Organization's parameter for safe drinking water. The average pH of the borehole water in ABAM, ALESA, DARKAAMA, EKEREKAN and OGAN were 5.25, 5.75, 5.30, 5.30 and 4.65 respectively. Table 4.5 confirmed that the difference was significant. The findings of this agrees with Maseke and Vegi (2019) who reported there is significant difference of the parameters pH and Ni2+ between hot spring and borehole waters. This shows that most of the physical parameters that were assesed in the borehole were found to deviate from the normal range of World Health Organisation (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ) except for Okochiri with the pH level of 6.8. The pH levels between 6.5 and 8.5 according to WHO (2008) and NSDWQ (2016) are considered optimal for drinking water. The pH values of the borehole water are safe for human consumption. Acidity levels below 6.5 are considered low for human consumption and have been linked to acidosis and other health issues. This implies that the sampled communities whose pH level is below the reference of WHO and NSDWQ is clear evidence that those communities used for boreholes are under great influence based on the quality of the water. Also the acidity of the borehole water in the communities whose pH is below 6.5 could be as a result of increase in temperature, high concentration of carbon dioxide in water due to global warming and acid rain. Consumption of acidic water is dangerous to human health because it makes the blood acidic by forming carbonic acid in the body system. Therefore, borehole water from those communities should be treated before consumption. The finding of this study agrees with Gana et al (2021) in their study hydrochemistry and quality assessment of groundwater from constituency water projects, Pategi Local Government Area found that boreholes were mainly acidic which could be of natural origin such as mineral dissolution. Turbidity ranged from average of 0.000 3.1500. The range indicates wide distribution of turbidity in water of Borehole in the sampled communities. High turbidity in water has both esthetic and health effect. Thus, it is essential to eliminate the turbidity of water in order to effectively disinfect it for drinking purposes. This finding of this study is consonance with Edori and Nna (2018) who reported that colour, odour, pH, turbidity, DO, BOD, COD, and Cl- do not meet the WHO standard for portable water, therefore the water is polluted.

The conductivity in water samples ranged from 11.50 to 31.00 s/cm on average. The range indicates wide distribution of conductivity of water samples in dry season. The range of 11.50 to 31.00 µs/cm is relatively low compare to World Health Organisation (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ) because water of good quality for domestic use should have conductivity of 1500 µs /cm3 and above. The temperatures recorded in the six sampling communities, of the study area, were well within the WHO recommended limits (20 -32) for drinking water quality. Changes in temperature, as noted earlier, affect living organisms. The rates of biological and chemical reactions depend to a large extent on temperature. Total Dissolved Solids (TDS) varied from community to community with a mean range of 6.00 17.00 mg/l. The concentration of TDS is within the regulatory standard for drinking purpose. Thus, all values are below 500 Mg/l limit set by WHO (2008). This may not have negative effects on the consumers of the borehole water in the sampled communities since it is a higher TDS level that affects water quality. High level of TDS may cause an objectionable taste, odour and colours to the water. However there is no health-based limit for TDS in drinking water (WHO, 2011). According to the TDS categorization, all of the groundwater samples were fresh water.

Table 5 showed that there is difference of heavy metals properties of borehole water used in host communities of Eleme Port Harcourt Oil Refinery host communities. Table 4.6 confirmed the difference of heavy metals properties of borehole water used in host communities of Eleme Port Harcourt Oil Refinery host communities was significant. The difference in heavy metal properties in the sampled communities could be attributed to the differences in individual metals solubility, pH, leaching by acid rain during the wet season and topography of the communities. The concentrations of heavy metals were generally low but some samples fall short of regulatory standards for drinking purpose. The concentration of Iron (Fe) was higher in communities like ALESA, EKEREKANA and OKOROCHIRI with the average heavy metal properties of 0 .42500, 0.40500 and 0.44000 respectively which were above the WHO permissible limit of 0.3 mg/L for human use while other communities average were below. High concentration of Fe in these communities may be due to natural existence iron rivers, lakes and underground water. Iron may also be released to water from natural deposits, industrial wastes, refining of iron ores and corrosion of iron containing metals. When the borehole water with higher concentration of iron is abstracted, it quickly oxidizes to ferric state in the form of insoluble ferric hydroxide, a brown substance. More so, effect of iron overload on some organs such as skin, is trivial, compare to hemosiderotic harm to other organs, like the liver and kidney, which can be fatal. The lead (Pb) content (mg/l) of the borehole water samples average range from 0.000 0.001mg/L, which is also within the limit of WHO (0.01mg/l) (WHO, 2008). The cadmium levels (mg/l) of the borehole water samples assayed from 0.01350 0.04750mg/L in 5 borehole water in the sampled, while it was not detected in the borehole water in OKOROCHIRI. This shows that the Cd levels are very high compared to the limit of 0.003mg/l prescribed by WHO. This high Cd levels could be as a result of the activities going on around the boreholes. Some of the boreholes were surrounded by beer parlour where there is high level of cigarette smoking. Cigarette has been attributed to high level of Cd which could pollute the environment (WHO, 2011). The results also showed that the concentration of Nickel and Mercury is slightly lower than the permissible standard. No health impairment is associated with consumption of water with low Nickel and Mercury. The finding of this agrees with Maseke and Vegi (2019) who reported that some of the parameters are at higher levels than permissible values for both hot spring and borehole waters.

CONCLUSION

The building of borehole requires underground pipe laying which supposedly need to meet up with its minimum requirement of Health and Safety rules; also, periodic maintenance, dumpsites, pit latrines, suck-away and drainages ought to be far from borehole water pipes to avoid cross contamination, this was likely not the case in some of these areas thus, making the quality of borehole water and its portability in-doubt. Consequently, both the water for home use and the commercially sold water quality was not guaranteed. In the midst of the increasing demand for water in Diobu area due to the high number of people and its commercial activities, the people look out for availability of water only, irrespective of the quality. This proves the fact that access to water may not guarantee water portability for consumption and use. Nonetheless, this is a strong side-line of Public Health concern, because consumption of an unsafe water could lead to water borne diseases thereby, increasing the burden of disease epidemic outbreak specially among the vulnerable ones, like the children in our Communities. However, the collective result from this study showed a strong need for prompt and regular risk evaluation of microbial contamination of borehole water since citizens residing and those doing all kind of businesses in this area make use of this water ignorantly, not knowing the health implication it could pose in their health. Also, this study reveals that safety of borehole water in the host communities of Port Harcourt Refinery cannot be guaranteed. The activities of the Refinery could be the major source of contamination of borehole water in the sampled area.

Recommendation

With the view of having safe borehole water for consumption and other purposes, the following are highly recommended:

1. Government at all levels should establish effective water control monitoring system.
2. Crude oil spillage and other industrial activities should be regulated by both the government and the Refinery.
3. The Refinery Company should check out for leaching pipes that causes contamination of water with iron.
4. Households should site their borehole far away from industrial pipes, suck-away and sewage dumps.
5. It is highly recommended that borehole water in the host communities of Eleme Port Harcourt Refinery be properly and routinely investigated as well as other water parameters checked.
6. Nigerian government in partnership with Non-governmental organization should conduct water security mapping to help identify vulnerable areas(communities) where there is high water stress such that the areas are given priority in borehole allocation.
7. Environmental awareness associations should regularly organize a program in order to educate members of the communities on the proper disposal of waste, management and Protection of their water resources. These would drastically reduce acute problem of water pollutants and water related diseases that are endemic to the health of man.

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