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Physicochemical and Heavy Metal Contents of Groundwater in Okrika Mainland, Rivers State

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ABSTRACT:
The study focused primarily on the assessment of physicochemical and heavy metals contents of ground water in Okrika mainland. Ground water samples were randomly collected from 10 sampling locations (2 hand-dug wells and 8 boreholes) in six different communities in Okrika mainland, Okrika Local Government Area of Rivers State. These communities include Abonrin-dendemie Ama, Daka Ama, Ekerekana Community, Okochiri Community, Oko Ama and Okoro Ama. Sampling was carried out in the month of June, 2015. Standard analytical techniques were employed in the investigation. Physicochemical parameters and heavy metal contents were measured in the water samples in order to determine the present status of the water quality since the study area is host to the Port Harcourt Refinery Company. The pH values for the boreholes and hand dug well samples ranged from 5.40-9.20 and 5.27-5.30 respectively. 70 % of the boreholes and hand dug wells studied had pH below the SON (2007) and WHO (2004) range of 6.5-8.5 considered acceptable and satisfactory for potable use. The remaining 30 % had values within the range of 8.6-9.2 thereby meeting the WHO maximum allowable range. The result showed that no borehole water going by the National SON Standard (2007), has acceptable, satisfactory water quality. It also showed that 70 % of boreholes and hand dug wells were acidic, unacceptable and below the national and international guideline limits while 30 % of the boreholes had pH above the guideline limit though within the maximum allowable limit of the World Health Organization. However, the physicochemical parameters were within the allowable limits though BH 1 borehole showed elevated concentrations in some parameters. Iron ranged from below <0.001-0.218 mg/l for boreholes and <0.001- 1.593 mg/l in the Hand-dug wells. In one privately owned borehole (BH 6 at 42 kings Road, Okochiri), Iron was approaching the guideline limit while in one hand dug well, iron was five times (1.5 mg/l) more than the standard allowable value of 0.3 mg/l. Other boreholes were free of iron content. Manganese is a metal to be watched as it was present in all boreholes except one (BH 3 at 78 Ekerekana, behind Okrika General Hospital) and exceeded the National SON limit in two boreholes (BH 6 & BH 7) and in the well water HW 1 at Oko ama (0.56 mg/l). There were traces of copper and zinc in the sampled waters though within the allowable limits of WHO and SON. Lead, Cadmium and Mercury were below detection levels in all the boreholes and hand-dug wells.
Key words: Groundwater quality, boreholes, hand-dug wells, physicochemistry, metals, Okrika mainland, Rivers State, Nigeria.

1.0 INTRODUCTION

Groundwater is a major source of fresh drinking water. According to the World Health Organization the safety and accessibility of drinking water are major concerns throughout the world (WHO, 2011). Health risks may arise from consumption of water contaminated with infectious agents, toxic chemicals and radiological hazards. Improving access to safe drinking water can result in tangible improvement to health. As a resultof frequent outbreak of water borne diseases, the International Small Community Water Supply Network was formed to promote the achievement of substantive and sustainable improvements to the safety of small community water supplies particularly in rural areas as a contribution to the Millennium Development targets related to water sanitation (WHO, 2011).

Effluents discharge into the the neighbouring Ekerekana Community in Okrika has been a daily affair since the commencement of operations of the Port Harcourt Refinery in 1962 and has continued till date. All effluents (both toxic and non-toxic) from the two refineries are channeled through the neighbouring Ekerekana community into the larger Okrika creek. Both surface and groundwater areat the risk of contamination of leaking, aged tanks and washouts within the perimeter of the refinery. Effluents are channeled through the Ekerekana Community into the Okrika river system. This proximity implies that Ekerekana and the rest of Okrika communities may be impacted on all fronts: air, water and soil by the Effluents of the refinery. The refinery drainage which has been operating since 1962 stretches for over one kilometer within Ekerekana community terminating at the Okrika river bank.

Following the establishment of the Port Harcourt Refining Company (PHRC, 1962) and Pipeline Product Marketing

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Company (PPMC), there are speculations that in the process of refining and production, different harmful chemicals could be released into the environment. Relatively, the complex combination of toxic substances that are simultaneously present in refinery effluents may act synergistically and therefore impose a higher toxicity burden on the ecosystem than may be predicted in laboratory studies on individual toxicants (Mizella and Romig, 1997).

Studies have shown that the major components of the refining effluents which are considered most toxic and carcinogenic to biota are heavy metals, phenolic substances and dissolved hydrocarbons (Achebe, 2001).Their presence may be toxic or carcinogenic and capable of causing changes in the physicochemical parameters of groundwater. However, pollution caused by the oil and gas industry has led to groundwater contamination, leading to outbreaks of diarrhea, causing birth deformities and certain soft tissue cancer (Achebe, 2001).It has been reported that there is good aquifer distribution in the area of study but with an alarming concentration of heavy metals on the ground surface, there is strong likelihood of their leaching toward the groundwater bodies (Tamunobereton-ari *et al*., 2010). A study has also shown that hydrocarbon may remain buried in sediment for up to 30 years without major alteration in concentration (Reddy *et al.*, 2002). Once polluted, a groundwater body could remain so for decades or even for hundreds of years because the natural processes of thorough-flushing are so slow. Secondly, there is a considerable degree of physiochemical and chemical interdependence between the water and the containing materials. Theaim of this work is to determine, assessand document the present status of groundwater quality, using physicochemical parameters and heavy metals in some communities in Okrika mainland in order to ascertain the degree of risks posed to users in the community.

Study Area

The study area is Okrika Mainland, in Rivers State, Nigeria and is located in the coastal area of the South-West Niger Delta region characterized by its beaches, mangroves, swamps and barrier bars. The area lies between Longitude 7°.00'- 7°.50'E and Latitude04° 43.842 to 04° 45.050N. Okrika is bounded in the North by Eleme Local Government Area, on the East by Ogu/Bolo; on the South by Bonny Local Government Area; On the South-West by Degema and on the North-West by Port Harcourt City (Mbaneme and Okoli, 2012). The area is host to the Port Harcourt Refinery Company (PHRC) and Pipeline Product Marketing Company (PPMC), all subsidiaries of the Nigerian National Petroleum Corporation (NNPC). The area is also the host of the Okrika jetty and terminal used for loading and off-loading of oil and gas products and related activities. These have led to the continuous influx of associated companies and people into the area, thereby resulting to increase in anthropogenic activities and corresponding discharges of pollutants into the environment.The research covered six communities namely Aborindendemie Ama, Daka Ama, Ekerekana, Okochiri, Oko and Okoro communities, all in Okrika mainland. Selection of locations was based on communities that were within the possible zone of impact of the potential refinery effluents.

2.0 MATERIALS AND METHODS

A Global Positioning System (GPS) tool was used to measure the coordinates (Latitude, Longitude and ground elevation) of the boreholes and hand-dug wells sampled.A dip meter (model ELE – 200) was used to measure the depth to water table (hydraulic heads) of the hand-dug wells. This provided information for the determination of the structure and the flow direction of the groundwater. Standard field methods were used for the sample collection while iced-pack coolers were used for carrying samples back to the laboratory in accordance with international protocol (APHA, 1998).To ensure the integrity of samples, pH, Electrical Conductivity, Dissolved Oxygen (DO), Turbidity and Total Dissolved Solids (TDS) were measured using HANNA range of in-situ meters.

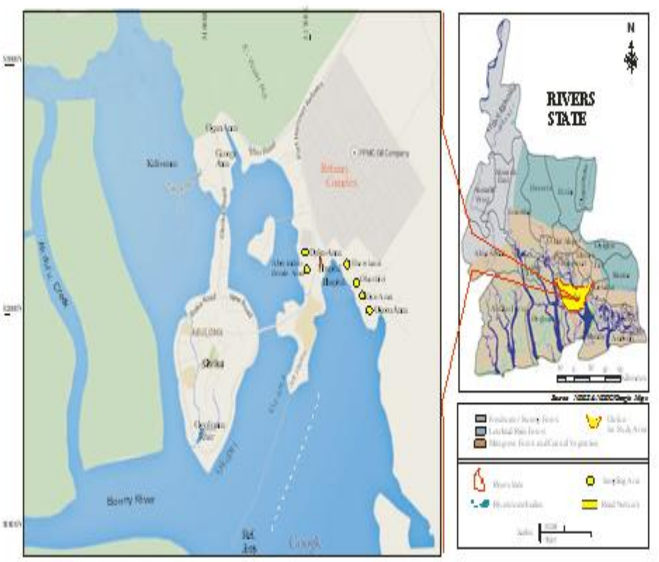

Fig. 1: Map of Rivers State showing Okrika Mainland, the Study Area

3.0 RESULTS AND DISCUSSION

The results of the field/on-site study for the borehole and hand-dug well samples are presented in Tables 4.1 – 4.7.

On-Site Data

The on-site data showed the co-ordinates, ownership and location of borehole and some characteristics of water samples, elevation readings and dates for boreholes and hand-dug wells drilled (Table1). The result showed a total of 8 boreholes and two hand dug wells. The eight boreholes were classified as; five private boreholes, one community borehole, one Government borehole at the health centre, one Local Government borehole and one NNPC borehole. The two hand-dug wells each belonged to a private person and the other to the community. Five out of ten bore holes/hand dug wells had objectionable odour while six out of the ten borehole/hand dug well samples had no colour.

PHYSICOCHEMICAL PARAMETERS

The physicochemical parameters for the boreholes and hand dug well samples are presented in Tables 2& 3 and Fig.2.The pH ranged from 5.40 – 9.20in the boreholes and5.27 – 5.30in the hand-dug wells. The highest recorded pH occurred in BH3 (9.2) while the lowest occurred in BH4 with a value of 5.4 (Table 2 and Fig. 2). The result showed that no borehole had acceptable pH [0% was within 6.5 – 8.5] value while five boreholes (62.5 %) had pH less than 6.5 and three boreholes (37.5%) had pH greater than 8.5. HW2 recorded a higher pH value of 5.3 while HW1 had a lower pH value of 5.27 (Table 2, Fig. 2). The result showed that all hand-dug wells had pH less than 6.5. None had acceptable water quality (6.5 – 8.5).

Table1: On-site Data of Boreholes and Hand-dug Wells at Okrika Mainland June, 2015

No.	Drill Date	Location	Smell	Colour	Read-ings	Co-ordinate	Ownership
Boreholes							
1	1997	Aborindendemie Ama opp. Gen. Hospital, Okrika	No smell	Colourless	8	N04^{o} 44.270 E007^{o} 05.921	Private
2	2013	Karo Villa, Daka Ama	No smell	Colourless	12	N04^{o} 45.050 E007^{o} 05.922	Private
3	2009	Behind Gen Hospital, Ekerekana	Faint smell	Not clear	4	N04^{o} 44.973 E007^{o} 05.921	NNPC
4	2014	Primary Sch. Board, Ekerekana	No smell	Colourless	11	N04^{o} 44.270 E007^{o} 06.083	LGA
5	1997	Kings Montessori Nur. & Pri Sch. Okochiri	Very strong smell of chlorine	Colourless	21	N04^{o} 45.060 E007^{o} 06.216	Private
6	2010	End of King's Road Okochiri (sharing fence with NNPC)	No smell	Colourless	18	N04^{o} 45.134 E007^{o} 06.407	Private
7	2014	Town Hall, Okochiri	No smell	Colourless	5	N04^{o} 44.844 E007^{o} 06.591	Com-munity
8	2008	Primary Health Centre, Okochiri	Faint smell	Not clear	15	N04^{o} 44.435 E007^{o} 06.978	RSG
Hand-dug Wells							
9	1970s	Oko-Ama (Tomina Au Ama)Depth:	Faint smell	Brownish	10	N04^{o} 43.842 E007^{o} 06.821	Private
10		Okoro-Ama (Leki Erebo Community) Depth:	Faint smell	Brownish	10	N04^{o} 43.762 E007^{o} 06.048	Com-munity

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Table 2: **Physicochemical Parameters of Borehole Samples from Okrika Mainland, June, 2015**

Parameters	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	WHO 2004	SON 2007
pH	8.8	5.6	9.2	5.4	5.71	5.74	5.64	8.9	6.5 - 9.0	6.5 - 8.5
Temperature (^oC)	29.5	29.3	29.3	29	30.1	28.7	29.3	29.3	-	Ambient
Electrical Conductivity (µS/cm)	686	10	38	17	19	11	16	11	-	1000
Turbidity (NTU)	0.613	0.808	2.11	0.622	0.9	0.805	0.839	1.09	5	5
Salinity (mg/l)	44	1	2.1	1.5	1.5	1.1	1.3	2	-	250
DO (mg/l)	7.11	6.49	7.61	7.43	8.6	7.05	7.92	6.92		
TDS (mg/l)	377	6	21	10	11	6	9	6	600	500
PO_4^{3-} (mg/l)	0.34	0.04	0.15	0.06	0.09	0.03	0.05	0.21	0.5	-
NO_3^- (mg/l)	1.6	0.01	1.1	0.7	1	0.01	0.62	0.4	50	50
SO_4^{2-} (mg/l)	2.1	0.7	1.5	1.04	1.2	0.85	1.1	1	250	100
Hardness (mg/l)	6.4	0.25	0.86	0.45	0.5	0.3	0.4	0.3	-	150
Alkalinity (mg/l)	10.2	0.5	1.6	1.1	1.2	0.7	1	0.7	-	-
Ca^{2+} (mg/l)	2.22	<0.001	0.195	0.072	0.078	<0.001	0.059	<0.001	-	-
Mg^{2+} (mg/l)	1.055	<0.001	0.062	0.039	0.043	<0.001	0.022	<0.001	-	0.2

Note: BH = Borehole; HW = Hand-dug Well; WHO = World Health Organization; SON = Standard Organization of Nigeria

Table3: Physicochemical Parameters of Hand-dug Well Samples from Okrika Mainland, June, 2015

Parameters	**HW1**	**HW2**	**WHO 2004**	**SON 2007**
pH	5.27	5.3	6.5 - 9.0	6.5 - 8.5
Temperature (^oC)	28.9	29.4	-	Ambient
Electrical Conductivity (µS/cm)	64	57	-	1000
Turbidity (NTU)	2.41	3.61	5	5
Salinity (mg/l)	4.5	4.2	-	250
DO (mg/l)	6.88	6.76	-	-
TDS (mg/l)	3.5	31	600	500
PO_4^{3-} (mg/l)	0.24	0.18	0.5	-
NO_3^- (mg/l)	1.45	1.22	50	50
SO_4^{2-} (mg/l)	1.7	1.63	250	100
Hardness (mg/l)	1.25	1.1	-	150
Alkalinity (mg/l)	2	1.8	-	-
Ca^{2+} (mg/l)	0.436	0.425	-	-
mg^{2+} (mg/l)	0.188	0.18	-	0.2

Note: HW = Hand-dug Well; WHO = World Health Organization; SON = Standard Organization of Nigeria

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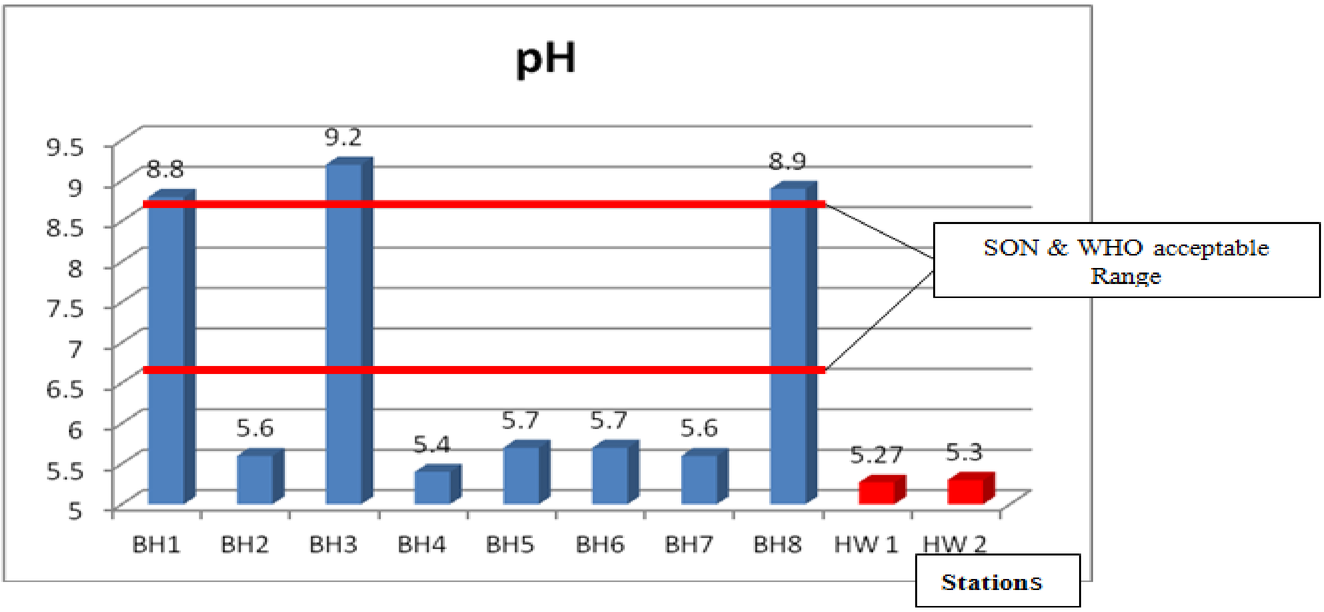

Fig. 2: Distribution of pH in boreholes and hand dug wells in Okrika mainland

Water Temperature ranged from 28.70- 30.10°C with a mean of 29.31±0.14°Cfor the Borehole and 28.90- 29.40°C, with a mean of 29.15±0.25°Cfor the hand-dug wells. The highest recorded temperature occurred in BH5 (30.1°C) while BH6 (28.7°C) had the lowest (Table 2).Electrical Conductivity ranged from 10.0 - 686.0µS/cm with a mean of 101.0±83.6µS/cm for borehole and57.00 - 64.00µS/cm, with a mean of 60.50±3.50µS/cm for hand-dug wells. While BH1 had the highest Conductivity of 686.0µS/cm, BH 2had the lowest Conductivity of 10.0µS/cm. Turbidity ranged from 0.61 - 2.11 NTU with a mean of 0.97±0.17 NTU for borehole and 2.41 - 3.61 NTU with a mean of 3.01±0.6 NTU for the hand-dug well.

Salinity ranged from 1.0 - 44.0mg/l with a mean of 6.81±5.3mg/l for the boreholes and 4.20 – 4.50 mg/l with a mean of 4.35±0.15mg/lfor the hand-dug wells. Salinity distribution showed that BH1 (44mg/l) had the highest concentration, while the lowest value was recorded in BH2 (1mg/l).Dissolved Oxygen ranged from 6.49 - 8.60mg/l with a mean of 7.39±0.23mg/l for the boreholes and 6.76–6.88 mg/l with a mean of 6.82±0.23mg/lfor the hand-dug wells (Tables 2 & 3). The DO distribution showed BH5 (8.6mg/l) having the highest concentration, while BH2 (6.49mg/l) had the lowest.

The Total Dissolved Solids (TDS) ranged from 6.00 – 377.0 mg/l with a mean of 55.75±45.9mg/l in boreholes and3.50 - 31.0mg/l with a mean of 17.25±13.7mg/lin the hand dug wells. The highest concentration of TDS wasin BH1 (377 .0 mg/l) while the lowest was recorded in BH2, BH6& BH8 (6.0 mg/l) respectively. Phosphates ranged from 0.03 – 0.34mg/l with a mean of 0.12±0.04mg/lfor the boreholes and 0.18 – 0.24 mg/l with a mean of 0.21±0.03mg/lin theh and-dug wells. The highest Phosphate concentration occurred in BH1 (0.34mg/l) and the lowest in BH2 (0.04 mg/l). Nitrate concentrations ranged from 0.01 - 1.60mg/l with a mean of 0.68±0.19in the boreholes and 1.22 – 1.45 mg/l with a mean of 0.68±0.19mg/lin the hand-dug wells. The highest nitrate was obtained in BH1 (1.60mg/l), while the lowest occurred in BH2 (0.01mg/l).Sulphate ranged from 0.70 – 2.10mg/l with a mean of 1.19±0.1 6mg/lfor boreholes and 1.63 - 1.70mg/l with mean of 1.67±0.03mg/l for the hand-dug wells. The highest concentration was recorded in BH1 (2.1mg/l) and lowest in BH2 (0.70 mg/l).

Total hardness ranged from 0.25 - 6.40mg/l in boreholes and1.10- 1.251mg/l in hand-dug wells with a mean of 1.18±0.07mg/l and1.18±0.75 mg/l in borehole. BH1 recorded the highest concentration of Total Hardness (6.40mg/l) while the lowest value was recorded in BH2 (0.25mg/l). Total Alkalinity ranged from 0.50 – 10.20mg/l in the boreholes and 1.8 - 2.0 mg/l in hand dug wells. The means were 2.13±1.16 and 1.90±0.1 mg/l respectively. The highest concentration of Alkalinity was recorded in BH1 (10.2mg/l) while the lowest occurred in BH2 (0.5mg/l). Calcium concentrations ranged from <0.001- 2.22mg/l in the boreholes and 0.43– 0.44 mg/l in the hand-dug wells. The means were 0.33±0.27 mg/l and0.43±0.01mg/l for borehole and hand dug wells respectively. The Magnesium concentration ranged from <0.001– 1.06mg/l in boreholes and 0.18 - 0.19mg/l in hand-dug wells. Themean concentrations were 0.15±0.13 mg/l and 0.18±0 mg/l for borehole and hand dug wells respectively.

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HEAVY METAL CONTENTS

The heavy metal results for boreholes and hand-dug wells are presented in Tables 4& 5.Manganese ranged from 0.001 - 0.229mg/l in borehole and 0.10 – 0.56mg/l in hand-dug wells. The means were 0.119±0.031 mg/land 0.33±0.23 mg/l respectively. Iron ranged from <0.001 – 0.218mg/l in the boreholes and <0.001- 1.593mg/l in theHand-dug wells. The means were0.028±0.03 mg/l and0.80±0.8 mg/l for borehole and hand dug wells respectively. The highest concentration of Iron was recorded in HW 1 (1.59 mg/l). Lead was less than<0.001mg/l in the borehole and all hand-dug wells. Copper ranged from <0.001 – 0.018 mg/l in borehole and 0.0 - <0.001 mg/l in hand dug wells. The means were 0.003±0.002mg/l and < 0.001 mg/lfor borehole and hand dug wells respectively. Zinc ranged from 0.070 - 1.185mg/l in the boreholes and0.11 – 0.27mg/l in hand-dug wells. The means were0.122±0.015mg/l and 0.19±0.08 mg/l for borehole and hand dug wells respectively. Cadmium ranged from <0.001 – 0.001 mg/l in the boreholes and all hand dug wells.Mercury ranged from <0.001 – 0.001mg/l in the boreholes and hand dug wells.

Table 4:Heavy Metal Results of Borehole Samples from Okrika Mainland, June, 2015

Parameters	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	WHO	SON
									2004	2007
Fe (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	0.218	<0.001	<0.001	0.3	0.3
Mn (mg/l)	0.168	0.049	<0.001	0.141	0.015	0.229	0.209	0.14	0.4	0.2
Pb (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.01
Cu (mg/l)	<0.001	0.018	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2	1
Zn (mg/l)	0.079	0.082	0.150	0.110	0.076	0.185	0.151	0.155	3	3
Cd (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.003
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.001

Note: BH = Borehole; WHO = World Health Organization; SON = Standard Organization of Nigeria

Table 5:Heavy Metal Results for Hand-dug Wells from Okrika Mainland, June, 2015

Parameters	HW1	HW2	WHO	SON
			2004	2007
Fe (mg/l)	1.593	<0.001	0.3	0.3
Mn (mg/l)	0.556	0.102	0.4	0.2
Pb (mg/l)	<0.001	<0.001	0.01	0.01
Cu (mg/l)	0.008	<0.001	2	1
Zn (mg/l)	0.266	0.108	3	3
Cd (mg/l)	<0.001	<0.001	-	0.003
Hg (mg/l)	<0.001	<0.001	-	0.001

Note: HW = Hand-dug Well; WHO = World Health Organization;

SON = Standard Organization of Nigeria

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DISCUSSION

On -site data

Objectionable odour in 5 out of ten borehole/hand dug well samples (50 %) is unacceptable. Objectionable odour is due to the presence of dissolved impurities often organic in nature e.g. Phenols and chlorophenols (Ubong and Gobo, 2001). The National SON and WHO Standards require potable water to be odorless (SON, 2007 and WHO, 2004). The presence of colour is due to organic acids. Highly colored water is undesirable on aesthetic grounds and may not be suitable for some industrial uses. National SON and WHO Standards require potable water to be colorless. The result showed that 70% of the water needs of Okrika mainland had unacceptable and poor water quality characteristics as far as colour and odour are concerned.

PHYSICOCHEMICAL PARAMETERS

The assessment of groundwater pH in Okrika mainland showed that 70 % of boreholes and hand dug well water samples were acidicand that no borehole water had acceptable and satisfactory water quality going by the National SON (2007) Standard. It also showed that 63% of boreholes were acidic, unacceptable and below the national and international guideline limits while 37% of the boreholes had pH above the guideline limit though within the maximum allowable limit of the World Health Organization (6.5-9.2) and not the range for the highest desirable limit (6.5-8.5).The study further showed that the hand-dug well water pH was below the allowable national and international standards, showing acidic, unacceptable and unsatisfactory water quality (Fig. 2).

At low pH, dissolution of metals/absorption of toxic substances increases especially in high Carbonate and low Silicate soils. It promotes colour, affects alkalinity, TDS, CO_2 absorption and Total Coliform presence (Gerard, 1998; Ming-HO, 2001 and Lecherallein *et al*, 1996). Prolonged intake of acidic water may predispose one to the dangers of acidosis, which according to Health Experts may lead to cancer or cardiovascular damage including the constriction of blood vessels and reduction in Oxygen supply even at mild levels (Ogundipe and Obinna, 2008). It could also cause leaching of valuable minerals such as Calcium, Magnesium, Sodium ad Calcium from the body. Closely related to the pH is the alkalinity, which is a measure of the buffering capacity of the system. The recorded values were low (0.5–10.2 mg/l as $CaCO_3$) and they are mostly due to bicarbonate contents.

Water Temperature was satisfactory for the range observed. Electrical Conductivity was generally below 38.0 except a value of (686.0µS/cm)in one borehole (BH 1) only.The allowable range is0-1000.0 µS/cm.Conductivity is due to ionizable salt content or ionizable dissolved substances in solution. BH 1 had enhanced concentration of Conductivity, TDS and Salinity. A possible explanation is BH1being probably in contact with saline effluent. It depends on the quantity of dissolved salts present and for dilute solutions, it is approximately proportional to the TDS content in solution (Ubong and Gobo, 2001). Conductivity was generally higher in hand dug wells than in borehole except BH 1. This may be attributed to dissolved salt content probably coming from recharge of wells. The Turbidity (NTU) ranges in boreholes and hand dug wells were below the National and WHO Standards of 5.0 NTU. The higher level in hand dug wells suggests contact with colloidal solids. Turbidity is due to the presence of colloidal solids which give liquid a cloudy appearance and is aesthetically unattractive and may be harmful (Ubong and Gobo, 2001).Turbidity values were <5.0 NTU Standards (SON, 2007, WHO, 2004). However, BH 1, BH 3 and BH 8 had elevated readings suggesting water with suspended solids caused by clay, silt and other substances that enter boreholes from the aquifer or from the soil surface.

Salinity in borehole was very low except for BH 1(44.0 mg/l), BH 3 and BH 8 which could have come from contact with other sources. The higher hand dug well data were still below the stipulated standards. The Total Dissolved Solids (TDS) range (6.0 – 377.0 mg/l) was low compared to the National WHO (600 mg/l) and SON (500 mg/l) limits for drinking water. TDS correlated positively with conductivity, salinity, chloride, sulfate and nitrate (Table 4).The Dissolved Oxygen distribution was within the range considered acceptable in both borehole and hand dug wells (Fig. 3).

Sulphate contents are attributable to the sedimentary basin of the Niger Delta region. The low Sulphate levels (0.70 – 2.10 mg/l for boreholes and 1.63 - 1.70 mg/l for the hand-dug wells) could be related to the removal of Sulphate by Sulphur bacteria in the sub-surface water (McNeely, *et al.*, 1979). The observed levels are lower than the WHO limit of 250.0 mg/l (WHO, 2004) and SON (2007) limit of 100.0 mg/l. Phosphate concentrations (0.03 – 0.34 mg/l in boreholes and 0.18 – 0.24 mg/l in the hand-dug wells) are approaching the guideline limit of 0.5 mg/l (WHO, 2004). BH 1, BH 3 and BH 8 are to be watched as they show enhanced concentrations. Nitrate levels (0.01 - 1.60 and 1.22 – 1.45 mg/l are lower than both SON (2007) and WHO (2006) limits of 50.0 mg/l.

Water hardness is another quality parameter that determines the use of water for drinking/domestic and industrial purposes. Hardness is the capacity of water to lather on application of soap and these increases with the softness of the water. The hardness level of 0.25-6.4 mg/l and 1.1-1.25mg/l as $CaCO_3$ are within the 0 - 60 mg/l as $CaCO_3$ classification of soft water. These hardness values are within

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the national limit of 150.0 mg/l. However, continued intake of soft water has been linked to cardiovascular disease incidents (Miroslav and Viadimir, 1999 and Encyclopedia of Chem. Tech. 1970). Calcium level was low and there is no stated National allowable level for calcium. However, relatively high level was obtained in BH 1. Similarly, magnesium was low except in BH 1 where it exceeded the National SON allowable standard of 0.2 mg/l in the boreholes and approaching the limit in the two hand dug wells.

HEAVY METALS

Total Iron (generally below <0.001 mg/l means they were below the detection limit except in BH6 (42 Kings Road, Okochiri) where a value of 0.218mg/l was obtained in borehole and HW 1 (1.593 mg/l) in hand dug well. The concentration in BH 6 is below the stipulated value of 0.3mg/l (WHO, 2004 and SON, 2007), even though it is approaching the guideline limit. However, hand–dug well one at Oko Ama (HW1) result showed Iron value of 1.593mg/l to be excessive; exceeding allowable limits by several folds. According to Ngahand Nwankwoala(2013), iron values with concentrations ranging from 0.4 – 10.0 mg/l, imply that most water bore-holes in the study area deliver water with iron in the natural state, which are not fit for human consumption. Iron in concentration in excess of 0.3mg/l in water can impart a stringent odour to drinking water (Rdiagoj-evich and Bashkin, 1999). Iron actually presents no health hazards even in excess concentration except for impacting a metallic taste to water if the concentration is above 1.8mg/l. It is mainly for aesthetic reasons that large concentrations of iron in water are undesirable (Etu-Efeotor, 1998). In this respect, Hand dug well and BH 6 need to be placed under watch.

Traces of manganese were detected in most of the water samples analyzedexcept in BH 3 where it was below the limit of detection (< 0.001 mg/l). BH 1, was approaching the limit and BH6(0.229mg/l),& BH 7(0.209mg/l) had levels exceeding the National SON limit of 0.2 mg/l but were below the International WHO limit of 0.4 mg/l.The hand dug well (HW 1) (0.556 mg/l) showed exceedance over the SON National and WHO Standards. Manganese has no particular toxicological impact. Like iron, itis for aesthetic reasons (WHO, 1993); waters with high level of manganese will be rejected by the consumer long before any danger threshold is reached. However, according to the Agency for Toxic Substances and Disease Registry (ATSDR, 1995), manganese toxicity can result in a permanent neurological disorder known as manganism with symptoms that include tremors, difficulty in walking and facial muscle spasms. These symptoms are often preceded by other lesser symptoms, including irritability, aggressiveness and hallucinations. Lead was below the detection limit of <0.001 mg/l in all boreholes and hand dug wells. Copper was generally less than <0.001 mg/l except in BH 2 (0.018) mg/l and HW 1(0.008mg/l)where the detected valueswere below the National SON limit of mg/l and WHO limit of 2.0 mg/l (WHO, 2004 and SON, 2007).

The result showed traces of zinc in all borehole samples which were below the SON and WHO limit of 3.0 mg/l. However, level in HW 2 was approaching the guideline limit of 3.0 mg/l.Zinc is essential to man but if ingested in large amounts, has an effect. The concern for Zinc level in water supply is not with regard to toxicity but taste and quite high levels are permissible (WHO, 1993). High levels of zinc intake may increase the production of protein known as metallothioein that can bind copper and reduce its levels in the body. Excessive zinc intake is a well known cause of copper deficiency (Hall *et al.*, 1979). Although the Redox Chemistry catalyzed by copper is essential for a number of immune functions, copper also may play a role in Alzheimer's disease. Copper levels generally rise in the body with age but seem to rise more sharply in those with Alzeheimer's disease; copper levels have been linked to Alzeheimer's symptom severity (Bush and Tanzi, 2008). Cadmium and mercury were less than <0.001 mg/l (not detected) in the borehole and hand dug wellsamples. Cadmium and Lead in this studycan be compared to values reported by Ogbuagu, *et al*. (2012), for lead and cadmium in their study which ranged from 0.005 – 0.009 mg/l.

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Parameters	pH	Temp. (°C)	Cond.	Turb.	Sal.	DO	TDS	PO_4^{3-}	NO_3^-	SO_4^{2-}	Hard	Alk.	Ca^{2+}	Mg^{2+}
pH	1													
Temp. (°C)	0.174	1												
Cond.(µS/cm)	0.457	0.195	1											
Turbidity (NTU)	-0.120	-0.045	-0.187	1.000										
Salinity	0.459	0.193	1.000	-0.189	1.000									
DO (mg/l)	-0.013	0.570	-0.112	-0.284	-0.124	1								
TDS (mg/l)	0.477	0.225	0.996	-0.218	0.996	-0.091	1							
PO_4^{3-} (mg/l)	0.556	0.153	0.731	0.301	0.738	-0.254	0.694	1						
NO_3^- (mg/l)	0.213	0.318	0.563	0.459	0.557	0.180	0.524	0.764	1					
SO_4^{2-} (mg/l)	0.335	0.199	0.722	0.439	0.717	-0.006	0.686	0.857	0.951	1				
Hardness	0.446	0.190	0.995	-0.104	0.994	-0.117	0.986	0.771	0.633	0.783	1			
Alkalinity	0.451	0.207	0.996	-0.132	0.995	-0.079	0.989	0.757	0.630	0.775	0.999	1		
Ca^{2+} (mg/l)	0.410	0.182	0.988	-0.046	0.987	-0.143	0.976	0.787	0.662	0.810	0.998	0.995	1	
Mg^{2+} (mg/l)	0.404	0.189	0.992	-0.080	0.991	-0.135	0.981	0.775	0.643	0.790	0.998	0.996	0.999	1

Fig. 3: Correlation matrix of physicochemical parameters

CONCLUSION

Groundwater quality in Okrika mainland showed that no borehole water by the National SON Standard (2007) had acceptable satisfactory water quality. Most of the boreholes were acidic, unacceptable and below the national and international guideline limits while 37% of the boreholes had pH above the guideline limit though within the maximum allowable limit of the World Health Organization.The study further showed that the hand-dug well water quality was below the allowable national and international standards, showing acidic, unacceptable and unsatisfactory water quality. However, the physicochemical parameters were within the allowable limits.Iron was approaching the guideline limit in a privately owned borehole (BH6 at 42 kings Road, Okochiri) and outrightly exceeded by five times the guideline limit. Other boreholes were free of iron content. The result showed that Manganese is a metal to be watched as it was present in all boreholes except one (BH3 at 78 Ekerekana, behind Okrika General Hospital) and exceeded the national SON limit in two boreholes (BH6 & BH7).The hand-dug well water quality at (HW1 at Oko ama) showed excessive Iron content about 5 times the standard, while Manganese also exceeded the standard in the well water. There were traces of copper and zinc elements in the sampled water though within the allowable limits of WHO and SON. Lead, Cadmium and Mercury were below detection levels in all the boreholes and hand-dug wells. There is need for more studies of such community wells so consumers will know the quality of water and the risks posedby the consumption of such quality of water.

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