Assessment of the Impact of Industrial and Anthropogenic Activities on the Drinking Water Qualities of Borehole Water in Bundu – Ama Environs Port Harcourt, Nigeria.

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Abstract
The objective 0f this research was to investigate the drinking water qualities of borehole water used by inhabitants of Bundu-Ama environs; Port Harcourt, by comparing the chemical, physical and bacteriological qualities with WHO, NIS standards. Samples were collected in the dry season month of December, 2011 and analysed for pH, Turbidity, TDS, Conductivity, Total Hardness, Mineral Oil, BOD, COD, Chloride, Total Alkalinity, Nitrate, Phorsphate, Sulphate, Reactive Silica, Cyanide, Ammonium, Aluminum, Calcium Magnesium, Potassium, Sodium, Arsenic, Total Mercury, Selenium, Lead, Zinc, Total Iron, Copper, Manganese, Cadmium, Total Chromium, Total Coliform, Feacal Coliform, E-coli, Feacal Streptococci and Total Plate Count. Standard methods were adopted for field and laboratory studies. Results of the comparisons from the four sampled stations showed that the water was not acidic as the pH was within acceptable limits. The turbidity level was high in three of the sampled stations with the highest in Macoba (74.0 NTU). BOD exceeded the limits with the highest in Bundu water side (20.8mg/l). The metals were within the safe limits. The heavy metals investigated were within tolerable limits of WHO and NIS with the exception of Lead and Total Iron. Lead and Total Iron were detected in all the sampled stations but exceeded tolerable limits in Union Dicon industry. The Total Plate Count exceeded the tolerable limits for drinking water. However the hardness levels were within tolerable limits. These results showed that the borehole water from Bundu environs is contaminated with some pollutants entering the water table some distant from both the industries and sewage entering the boreholes. The borehole water should therefore be protected and treated before consumption. There is need for periodic monitoring of water samples from boreholes sources to ascertain their qualities.
Keywords: Bundu – Ama, Borehole Water, Physicochemical, Bacteriological

Introduction

Drinking water supplies must obviously be fit for human consumption i.e of potable quality, and they should also be palatable i.e aesthetically attractive (Tebbutt, 1998). This also includes that public water supplies should be suitable for other domestic uses such as clothes washing and so on. The presence of a safe and reliable source of water is an important pre-requisite for the establishment of a stable Community since the absence of water for only a few days has fatal consequences. The supply of water of wholesome quality helps to reduce the incidence of water related diseases. Water supply to communities may be public or private, and all private supplies e.g borehole can pose a threat to health unless they are properly protected and treated. In Bundu – Ama Port Harcourt the public water supply is not provided and the cost of obtaining water from commercial borehole operators for domestic use is quite high (Braide et al, 2004).

Quality and quantitative measurement are needed from time to time to constantly monitor the quality of water from boreholes (FAO, 1999). Most boreholes may become contaminated with bacteria, Protozoa, Viruses or other substances that may dissolve Lead if the water supply passes through a Lead Tank or pipe since they are naturally acidic (Drinking Water Inspectorate, 2002). Emerging empirical facts have shown that Port Harcourt region (Bundu - Ama inclusive) is susceptible and sensitive to ecological changes (Chinda and Braide, 2001) as a result of increased anthropogenic inputs from human and Industrial activities (Braide et al, 2004). Contamination of boreholes may arise from pollutants entering the water table some distance from the industries or from sewage entering the borehole itself through cracked or corroded cases. To determine drinking water quality it is often necessary to measure several different properties by carrying out physical, chemical and biological analysis (Ubong and Gobo, 2001). Physical test indicate properties detectible by senses. Chemical test determine the amount of minerals and organic substances that affect water quality; while bacteriological test show the presence of bacteria, characteristic of feacal pollution. Bundu-Ama, a heavily populated community is one of the shanties in Port Harcourt and the people also live in squalid environment (Ikaderinyo, 2012). It is enclosed by a network of rivers and creeks traversing, dissecting the landmass; prominent among them is the Dockyard Creek, Primose Creek, Dick Fibresima Creek and Isaka River all linked to Bonny River which is the largest river in the area with an average width of 0.5km (Aisuebeogun, 1995). The community is host to many multinational industries and establishments, such as PZ Cussons, MI Drilling Fluids, Ibeto Cement Company, Oando, National Oil, Union Dicon industry, African Petroleum, Conoil, Sun and Gas Oil among others. The indiscriminate waste effluents dumped into the water bodies and poor domestic waste management pollutes the area (Ajayi, S. O. and Osibanjo, O. 1981 and Oguzie, 2000).

STUDY AREA

The city of Port Harcourt had a humble beginning in 1913 as a fishing settlement with an initial population of 5000 persons (Oyegun,1999). The current population of the metropolis (Port Harcourt and Obio – Akpor) according to the official gazette of the 2006 census final results is 1,000,908 (Fed. Republic of Nigeria Official gazette, 2009). The rapid growth of the city and its region has spatial and socio economic implications. The Port Harcourt city, capital of Rivers State, Nigeria (Fig 1) is also the hub of the oil and gas industry in Nigeria with Bundu – Ama playing host to many industries in the downstream of the petroleum sector. Bundu – Ama community experiences the injection of large quantities of effluents due to the activities of industries on one hand and improper domestic waste management that creates poor sanitary conditions. Water related diseases are the most critical health problems in the Port Harcourt region generally and in Bundu – Ama in particular (Oyegun,1999). In their study, Moffat and Lindan (1995) observed that although few water quality studies exist, the data available on water related diseases water supply and water management practices illustrate that water contamination and associated diseases are a problem in the region. Poor sanitation and lack of clean water are the primary reasons why feaces transmitted diseases are common in the region, they concluded. Cases of acidification of rain water in the industrial areas of Port Harcourt (Bundu – Ama inclusive) are already being reported and this is a serious threat to the use of rain water as a source of water supply (Ologunorisa, 1995. Ologunorisa and Arokoyu, 1998). The major sources of water in the Port Harcourt region are rain water, pipe borne water, hand dug wells and bore holes

Design of sample collection and procedure

Four sample stations were established after a reconnaissance visit to the area. The criteria for the choice of the sampling stations were to assess the impact of activities taking piace on the physicochemical and bacterlogical parameters of the bore hole water. Station one (Ibeto) lie in co-ordinates N: 04.75183, E: 007.00941. The industry located here is Ibeto cement company and the water body where the effluents are discharged is Dick Fibresima Creek. Borehole water samples were collected here with plastic containers and glass containers for some parameters requiring such containers. The main industrial activities taking place here is cement bagging and related operations. Station two is Bundu waterside drained by Dockyard Creek. Domestic waste products are often dumped here and residents use the water as public toilet. Fishing activities take place here by local fishermen. Station three (Macoba) lie in coordinates N: 04.75616, E: 007.00585 The industry located here is Macoba Drilling fluids company, MI that deals on mud engineering and also Naval operations by Nigerian Navy. All effluents are discharged into a section of PrImose Creek and Isaka River. Organic wastes and human excreta are also discharged here. The River serves as a means of marine transport and fishing activities. Station 4 (Union Dicon industry/Jetty) lie in coordinates N:04.76019, E:007.00635 Bagging of salt take place at the industry. The jetty serves as a loading point of petroleum products e.g gasoline, diesel etc. Effluents from here are discharged into Primose Creek.

Sampling Procedure and Collection:

All liquid samples were collected in a container of 1 liter volume. A space of at least 2.5cm was left in the container to facilitate mixing by shaking. The containers used were according to the 18^{th} edition of standard methods for the examination of water and wastewater. Samples were collected in non-reactive glass or plastic bottles that had been cleansed and rinsed carefully. Containers were lowered under the tap of the borehole pump and the handle released for water to flow into them to fill. Sample collection spanned the dry months of December, 2011 and samples were transported to the laboratory in iced coolers after labeling. Hydrocarbon samples were collected in glass containers since plastic bottles contain plasticizers and could present a source of error. Metals samples were collected in 2 litre plastic bottles; while a clean 100ml polyethylene container for heavy metals was used. Samples for microbiological examination were collected with sterile polyvinyl chloride plastic vial water bottles.

Samples Analysis:

Temperature concentrations were measured in situ using mercury-filled bulb thermometer (APHA, 1998). Measurements of pH, TDS and conductivity were done within one hour of arrival of the borehole water samples in the laboratory using the CORNING pH meter-MODEL 7 and the lovibond conductivity /TDS meter type CM-21 respectively. Hardness concentration was determined by EDTA method by titrating the sample against EDTA solution to give a colour change from pink to blue colour. For chloride concentration the test method was based upon the *mohr* procedure for determining chloride ion by titrating with silver Nitrate until there was colour change to orange at end point. Total Alkalinity was determined by titration involving standardization, quality check starting with blank and titrating the sample of borehole water until there was a colour change to orange at end point, after adding methyl orange indicator. COD was determined by titration using acid dichromate as the oxidizing agent and its consumption was measured by titrating against a standard ferrous ammonium sulphate solution. BOD concentration was measured by dilution method based on measureable depletion of Dissolved Oxygen (DO) after five days. The dilution water and the water sample were fixed with Winkler 1 and 11 and acidified with Conc. H_2SO4. Phosphate was determined by stannous chloride reduction method using UV spectrophotometer.

Turbidimetric method was used to determine sulphate using UV spectrophotometer. Nitrate was measured by the brucine method at 410nm photometrically with spectronic 2ID photometer, and the concentration of nitrate obtained from calculation. The metals Aluminum, Calcium, Magnesium, Potassium, Sodium were measured by Atomic Absorption Spectrophotometer, AAS (Avanta type). The procedure involved running the blank, Quality Check, QC, analysis and reporting values of the absorbance.

Analysis of heavy metals, bacteriological parameters, mineral oil, reactive silica, cyanide and ammonium were based on the principles and procedures outlined in the standard methods for the examination of water and wastewater (APHA, 1998).

RESULTS

Table 1 shows the concentration of the parameter in the borehole water samples from the four different sampled stations. pH ranged between 6.72 and 7.36; while the range of turbidity was from 2 NTU to 74 NTU. The TDS and Conductivity had a narrow range between 18.4mg/l and 18.5mg/l; and 30.6µS/cm and 30.9µS/cm respectively. Total hardness ranged between 6mg/l and 12mg/l. Mineral oil was < 1.00 mg/l in all the stations. BOD and COD ranged between < 0.50 mg/l and 20.8mg/l; and < 0.80mg/l and 42.6mg/l respectively. Chloride concentration ranged between 3. 77mg/l and 6.72mg/l. Total alkalinity ranged between 4mg/l and 15mg/l where Nitrate was from 0.0lmg/l to 2.59mg/l. Phosphate and Sulphate ranged from 0.18mg/l to 0.40mg/l; and 0.08mg/l to 0.87mg/l respectively. Reactive Silica ranged between 4.26mg/l and 6.40mg/l. Cyanide, Ammonium and Potassium were < 0.01, < 0.02 and < 0.10 respectively in all the sampled stations. Calcium ranged between 1.29mg/l and 2.99mg/l and 2.99mg/l. Magnesium range was between 0.81mg/l and 1.89mg/l. Potassium had a narrow range between 1.57mg/l and 1.78mg/l. Sodium ranged between 2.02mg/l and 4.21mg/l. For the heavy metals, Arsenic, Total Mercury, Selenium, Zinc, Copper, Total Chromium and Cadmium had <0.001, <0.0002, <0.001, <0.05, <0.05, <0.01 and <0.002 mg/l respectively in all the sampled stations. Lead ranged between <0.01mg/l and 0.06mg/l; while Total Iron range was from 0.08mg/l to 0.51mg/l. For bacteriological results Total Plate Count ranged between 1.25x10^2 and 5.4x10^1 cfu/ml

TABLE 1: BOREHOLE WATER RESULTS

PARAMETER	METHOD	STATION ONE IBETO CEMENT COMPANY	STATION TWO BUNDU WATERSIDE	STATION THREE MACOBA/N.SHIPYARD	STATION FOUR UNION DICON IND.	WHO LIMIT	NIS
COORDINATES		N:04.75183 E: 007.00941		N:04.75616 E: 007.00586	N: 04.76019 E:007.00635		
General appearance	APHA 2110	BROWNISH	CLEAR	BROWNISH	BROWNISH	CLEAR	
P^H @25.6^{0}C	APHA 45OOHB	7.36	6.72	7.18	7.10	6.5-8.5	6.5-8.5
TURBIDITY (NTU)	APHA 2130 B	6.00	2.00	74.0	26.0	5	5
TDS (mg/l (mg/l)	APHA 2510 B	18.5	18.4	18.4	18.5	500	500
CONDUCTIVITY (US/CM)	APHA 2510B	30.9	30.7	30.6	30.9	1000	1000
TOTAL HARDNESS (mg/l)	APHA 2340C	6.00	12.0	10.0	16.0	150	150
MINERAL OIL (mg/l)	ASTM D3921	<1.00	<1.00	<1.00	<1.00	-	0.003
BOD (mg/l)	APHA 5210D	<0.50	20.8	10.0	10.0	-	3-6
COD (mg/l)	APHA 5220D	<0.80	42.6	17.0	17.0	-	-
CHLORIDE (mg/l)	APHA 4500C1^-B	3.77	6.72	4.96	6.03	250	250
TOTAL ALKALINITY (mg/l)	ASTMD1067B	12.0	4.00	15.0	12.0	-	-
NITRATE (mg/l)	EPA 352.1	0.01	2.59	0.67	1.21	10.0	50
PHOSPHATE (mg/l)	APHA 4500PD	0.18	0.24	0.26	0.40	-	-
SULPHATE (mg/l)	APHA4500S0^{2-}_4E	0.08	0.09	0.08	0.87	250	100
REACTIVE SILICA (mg/c)	APHA4500Si0_2C	6.40	4.26	4.84	4.68	40.0	-
CYANIDE (mg/l)	APHA4500CN-	<0.01	<0.01	<0.01	<0.01	0.07	0.01
AMMONIUM (mg/l)	APHA4500NH_3	<0.02	<0.02	<0.02	<0.02	1.5	-
ALUMINUM (mg/l)	APHA3111D	<0.10	<0.10	<0.10	<0.10	0.2	0.2
CALCIUM (mg/l)	APHA3111D	1.29	1.46	1.49	2.99	70	-
MAGNESIUM (mg/l)	APHA3111B/ASTM D3561	0.81	1.37	1.65	1.89	30	0.20
POTASSIUM (mg/l)	APHA3111B/ASTM D3561	1.74	1.73	1.57	1.78	-	-
SODIUM (mg/l)	APHA3111B/ASTM D3561	2.02	4.21	3.20	2.92	200	200
ARSENIC (mg/l)	APHA 3030B/3114B	<0.001	<0.001	<0.001	<0.001	0.01	0.01
TOTAL MERCURY (mg/l)	APHA 3112B	<0.0002	<0.0002	<0.0002	<0.0002	0.001	0.001
SELENIUM (mg/l)	ASTMD3859	<0.001	<0.001	<0.001	<0.001	0.01	-
LEAD (mg/l)	APHA3111B	<0.01	<0.01	<0.01	0.06	0.01	0.01
ZINC (mg/l)	APHA3111B	<0.05	<0.05	<0.05	<0.05	3.0	3
TOTAL IRON (mg/l)	APHA3111B	0.08	0.09	0.21	0.51	0.3	0.3
COPPER (mg/l)	APHA3111B	<0.05	<0.05	<0.05	<0.05	1.0	1
MANGANESE (mg/l)	APHA3111B	0.19	<0.10	<0.10	<0.10	0.5	0.2
CADMIUM (mg/l)	APHA3111B	<0.002	<0.002	<0.002	<0.002	0.003	0.003
TOTAL CHROMIUM (mg/l)	APHA3111B	<0.01	<0.01	<0.01	<0.01	0.05	0.05
TOTAL COLIFORM (cfu/100ml)	APHA 9222B	1.28X10^2	0	0	0	0	10
FAECAL COLIFORM (cfu/100ml)	APHA9222B	1.02X10^2	0	0	0	0	-
E-COLI (cfu/100ml)	ASTM D5392-93	0	0	0	0	0	0
FAECAL STREPTOCOCCI (cfu/100ml)	ASTM D5295-92	5.7X10^1	0	0	0	0	0
TOTAL PLATE COUNT (cfu/ml)	APHA 9215C	3.60X10^2	1.25X10^2	5.4X10^1	2.00X10^2	100	

ASTM = American Society for Testing and Materials (1999 Edition)
APHA = American Public Health Association (20th Edition 1998)
EPA = Environmental Protection Agency (2nd Edition 1996)
NIS = Nigerian Industrial Standard for Drinking water quality (NIS 554: 2007)
WHO = World Health Organization Guideline for Drinking Water Quality (3rd Edition 2008)

Discussion

All of the pH levels at the sampled stations for the borehole water samples were found to be within normal range of NIS and WHO standard which is usually between 6.5-8.5 although variations are known to occur. The turbidity of three of the sampled stations exceeded the requirements of WHO and NIS except that of Bundu waterside. Turbidity in water occurs as a result of suspended solids and colloidal matter. It may be due to eroded soil caused by dredging or due to the growth of micro-organisms (Drinking Water Inspectorate, 2002). High turbidity makes filtration expensive. If sewage solids are present, pathogens may be encased in the particles and escape the action of chlorine during disinfection.

The conductivity levels were parallel to the TDS results in that both data were lowest at Macoba and highest at Union Dicon Industry. BOD and COD measure the amount of organic compounds in water. BOD is widely used as an indication of the organic of quality of water (Tebutt, 1998). However, COD is less specific, since it measures everything that can be chemically oxidized, rather than just levels of biologically active organic matter. BOD levels exceeded the allowable limits in stations 2, 3 and 4. The higher value of these points meant that there were greater quantities of degradable wastes probably from the effluents coming from them.

The highest BOD level of 20.8 at Bundu was probably due to poor sanitary condition of the area; hence the people use the creek as public toilet. The total hardness values in the four sampled stations were within allowable limits and as a result the borehole water can leather effectively which makes it suitable for washing in the homes. The metals investigated in the study, Aluminum, Calcium, Magnesium, Potassium and Sodium were all within allowable limits of the standard of NIS and WHO. The heavy metals analyzed were within permissible range except lead and total Iron. Lead exceeded the limit at Union Dicon Industry. This may be due to loading of refined petroleum products at a jetty situated in the environs of this industry. Deposition of hydrocarbon products from the atmosphere is an important source of heavy metal contamination of fresh water and terrestrial ecosystems (Providence, 2011). Another likely source of lead in the drinking water from the borehole might be plumbing with lead or lead soldered pipes. The health impact of lead includes cancer, interference with vitamin D metabolism, affect mental development in infants, toxicity to the central and peripheral nervous systems (NIS, 2007).

Total Iron was defected in all the sampled stations but the level in Union Dicon Industry exceeded the allowable limits. Water that is high in Iron appears brownish (Ubong and Gobo, 2001). This may account for the brownish colour in the sampled stations. Iron in drinking water is safe to ingest, but the Iron sediments may contain trace impurities or harbor bacteria that can be harmful (EDA, 1996). The total plate count exceeded the limits. This is an indication of feacal contamination or index of intermittent faecal contamination (NIS, 2007).

Conclusion

This research has proven that borehole water sources in close proximity to effluents from industries and sewage will experience some negative effects on water quality overtime. Contamination of borehole may arise from pollutants entering the water table some distance from the industries or from sewage entering the bore hole itself through cracked or corroded cases. The presence of bacteria was an indication of feacal pollution. The elevated level of turbidity makes filteration expensive, pathogens may be enclosed in the particles and escape the action of Chlorine during disinfection. Although the values in some cases were lower than the allowable limits, the continued discharge of the effluents in the river may result in severe accumulation and unless the authorities implement laws governing the management of effluents and domestic waste, this may in turn affect the lives of the inhabitants. From the result of this study the escape of degradable organic wastes into the bore hole gave rise to elevated level of BOD; especially at Bundu where improper disposal of domestic waste and defeaction on open surfaces was observed. Lead and Total iron were detected in all the sampled point but exceeded the limits of Union Dicon where a jetty for loading of refined petroleum products is located. Total Iron makes the water appear brownish and Iron sediments may contain trace impurities or harbor bacteria that can be harmful. Lead affects the development in infants, toxic to the central and peripheral nervous systems. The Total Plate Count exceeded the limits and this is an index of intermittent feacal contamination. It is therefore recommended that the careless disposal of effluents by industries and poor sanitary conditions should be discouraged and industries should treat their wastes before disposal.

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