Available online at www.elixirpublishers.com (Elixir International Journal)

Pollution

Elixir Pollution 58 (2013) 14762-14766

Elixir ISSN: 2229-712X

Physiochemical and microbiological analysis of surface and underground water in Ikono local government area, Akwa ibom state, Nigeria

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ARTICLE INFO

Article history:
Received: 20 February 2013;
Received in revised form:
17 April 2013;
Accepted: 6 May 2013;

Keywords
Water,
Physiochemical,
Microbiological,
Analysis.

ABSTRACT

Surface and underground water, veritable sources of drinking water to the Ikono inhabitants were investigated. Water samples were collected randomly from the area within a period of 30days and characterized for various physical, chemical and microbial parameters including nitrate, pH, total dissolved solid (TDS), total hardness, calcium, magnesium, chloride and total alkalinity and *E. coli*. Results showed variability in chemical and biological composition and informed that water sources were not polluted when compared with reference standards which serves as guidelines with respect to parameters examined. However, some points showed elevated microbial count which indicates some level of pollution of water points with human faeces and other warm blooded animals. From the result of the analysis, water in most parts of the area is fit for drinking and other domestic purposes.

Introduction

The term *water quality* describes the physical, chemical, biological and aesthetic properties of water which determine its fitness for a variety of uses and for protecting the health and integrity of aquatic ecosystems. Many of these properties are controlled or influenced by constituents which are either dissolved or suspended in water. Water quality is determined by physical, chemical and microbiological properties of water. These parameters throughout the world are characterized with wide variability. Therefore the quality of natural water sources used for different purposes should be established in terms of the specific water-quality parameters which most affect the possible use of water. The main sources of water to Ikono dwellers are streams, ponds, wells and boreholes. Most human activities (like washing of clothes, vegetables and cassava fermentation) are performed in streams and pond. Wells are open to all categories of pollutant such as creeping animals like millipedes, earthworms, snakes etc. Since inhabitants of the area depend on these water bodies there is risk of associated water-borne diseases like cholera, dysentery, diarrhea and typhoid fever as a result of contamination of various forms including trace or heavy metals and anions. Hence the aim of this work was to provide an overview of water quality characteristics-physiochemical and microbiological characteristics of water sources (surface and underground water), veritable sources of drinking water to the Ikono LGA inhabitants.

Materials and Methods

Area Description and sampling locations

The study area, Ikono (13°21' 16" N and 5°5' 37" E) a local government of in Akwa Ibom state, Nigeria, is of important for study because of the large deposits of natural resources and other minerals. The climatic setting of the area is warm with good vegetation and characterized by wet and dry season.

Eight (8) samples sites were selected, each with codes for experimental conduct.

Boreholes samples (BH)
BH1 = Nung Udoe borehole
BH2 = Ikot Ayan borehole
BH3 = Ikot Efre borehole
BH4 =Asanting borehole
Stream samples (ST)
ST1 =Ekpe Atai stream
ST2 =Ekpemiong stream
ST3 =Ibaiku Ntok Okpo stream
ST4=Ukpom stream

Sample Collection and treatment

Four (4) samples each of underground and surface water at various points randomly selected were collected in 2-litre plastic containers free of impurities prior to analysis. Samples were collected between 1st and 30th April 2010 at about 7:00 am to 8:00 am local time. The water samples were collected from the main source of the running water at the site and placed in a cooler (with ice). The pH was measured at the sampling time using a pH meter, model H18421. All the samples were transported to chemistry laboratory, University of Uyo, Nigeria for various analyses. The grid references of the sampled spots were mapped using a portable Global Positioning System (GPS). Groundwater samples were filtered through 0.45 µm filters and acidified to pH (< 2) using ultra pure HNO_3. All samples were spiked with an internal standard (2 ppb) prior to analysis. All reagents used were of analytical grade and results are replicates of measurements.

Physio-Chemical Analysis

Physiochemical parameters; Turbidity, Temperature, pH, Electrical conductivity, Alkalinity and Total Hardness of the water samples were determined according to methods adopted by Prior and Jones (Prior & Jones, 2002) while the Total Dissolved Solids (TDS), Chloride, Biochemical Oxygen Demand (BOD), Suspended Solids (SS) and Dissolved Oxygen (DO) were determined using methods of Ademorati (Ademoroti, 1996a).

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Metal and Nutrient concentrations

Nitrate, phosphate, ammonium, chloride and sulphate contents of the water samples were determined using standard methods. Metals concentration in the water samples were determined using Atomic absorption spectrophotometer (AAS, Model 210 VGP).

Bacteriological Analysis

The membrane filtration techniques described by APHA, AWWA & WEF, 1998 and ISO/DIS 11731-2 were adopted. 100mL of each sample was filtered via sterile oxide membrane filters (0.45µm) using vacuum pump (Es 50) and placed grid slide upward on absorbent pad saturated with sodium lauryl sulphate broth. The sterile micro petri-dish containing the parts and the filter was incubated in an incubator (INA-300 and INA-305 series), Gallenkamp, at 44±0.5^{o}C and 37±0.5^{o}C for 24 h for *Escherichia coil (E.coli)* and controlled respectively.

Results and discussion

Physicochemical parameters

The results obtained from the physicochemical analysis of surface and underground water samples from the study area are presented in Tables 1 and 2. The underground water pH ranges from (5.94 – 6.50) and that of the surface water was (5.87 – 6.40). These values indicate that water samples are slightly acidic and are little below specification limits (6.5-8.5) by the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standards of 2007 and 2006 respectively. Water acidity may be recorded as a result of water treatment using chemicals such as chlorine for drinking purposes. Again this values point to suitability water for drinking and domestic purposes. It should also be noted that between 9.0-11.0 there is probability of toxic effects associated with deprotonated species (for example, ammonium deprotonating to form ammonia) increases sharply. Water tastes bitter at a pH of greater than 9.0 and at pH > 11.0, severe danger of health effects due to deprotonated species results (SAWQG, 1996).

Temperature of a waterway is significant because it affects the amount of dissolved oxygen in water. The amount of oxygen that will dissolve in water increases as temperature decreases. Water at 0^{o}C will hold up to 14.6 mg of oxygen per litre, while at 30^{o}C it will hold only up to 7.6 mg/L (www.waterwatch.nsw.gov.au). If the overall water body temperature of a system is altered a shift in aquatic communities may results. In water above 30^{o}C, a suppression of all benthic organisms can be expected. Also, different planktons will flourish under different temperatures. For instance, diatoms dominate at 20-25^{o}C, green algae dominates at 30-35^{o}C and cyano-bacteria dominates at 35^{o}C and above. Temperatures measured do not vary significantly. Values are slightly above room temperature (27±0.5^{o}C) for both samples. However, surface water recorded up to 2.4% decrease in mean temperature (29.48±0.45^{o}C) compared with the underground water samples. This may have been caused by high specific heat capacity of the surface water in the day (Reynolds, 2005). Temperature of the stream samples even though lower than that of the borehole samples are slightly higher than standards recommended by regulatory bodies (Table 3). The amount of oxygen in water, to a degree, shows its overall health. That is, if oxygen levels are high, one can presume that pollution levels in the water are low. Conversely, if oxygen levels are low, one can presume there is a high oxygen demand and that the body of water is not of optimal health. The dissolved oxygen levels for water samples in this study are above recommendations by WHO, 2006. This is an indication that the water is stressed with regards to this parameter (www.waterwatch.nsw.gov.au). Suspended solids above 10m/L are not acceptable in drinking water (NSDWQ, 2007) as it contributes to turbidity in water. Turbidity in water is caused by suspended matters like clay, silt, organic matter, by-plankton and other microscopic organisms that interfere with the passage of light through the water. Greater than 10 NTU, water carries an associated risk of disease due to infectious disease agents and chemicals adsorbed onto particulate matter. A chance of disease transmission at epidemic level exists at high turbidity (SAWQG, 1996). All water samples (borehole and streams) except S2 (conc. 10m/L) fall within limit sets by WHO (WHO, 2006).

The results also show that the turbidity and the total hardness are within the maximum permitted limit of the European Union (EU), World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ) for drinking water [SON, 2007; Chapman, 1996]. Alkalinity measures the amount of alkaline compounds in water such as HCO_3^-, OH^- and CO_3^{2-}. These compounds are natural good buffers. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes and makes water less vulnerable to acid rain (Taylor & Symons, 1984). WHO standard (2006) stated alkalinity standard of 100-200mg/L. Therefore the result of analysis of both stream and borehole water samples are within specification. Values are up to 50% lower than specifications in the samples studied (Fig. 1 & 2). The normal hardness of the water may be because the excavated pit from which the water flows out has reached the water table (SAWQG, 1996). Comparing the result of analysis of both borehole and stream samples, it can be seen that all samples are within the maximum permitted level specified by NSDWQ and WHO (Table 3). Electrical conductivity (EC) is the measure of the ability of water to conduct or pass electric current. This ability is as a result of the presence of ions in water such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge. Most organic compounds dissolved in water do not dissociate into ions, consequently they do not affect the EC. The result of analysis generally shows that some of the stream samples are more conductive than the borehole samples. Relatively, stream samples 2, 3 and 4 show higher dissolved solids than those of the borehole samples.

Trace metals

Tables 1 and 2 show the results of the trace metals analysis. This study is of interest to both environmental and soil scientists because of the possibility of groundwater contamination through metal leaching (Eduvie, 1997). The concentration of Mn from analysed samples could be attributed to background soil concentration because Mn is widespread in the environment, occurring in all rocks and soils (Adelana et al., 2006). Calcium helps in the formation of strong bones and teeth. WHO (2006) specified > 75.00 mg/L calcium as threatening in water meant for consumption. But, the results of analysis for the various borehole and stream water samples have low calcium which is normal for proper functioning of the body. Magnesium (Mg) and iron (Fe) have concentration ranges of 1.24–13.29mg/L and 0.01 – 0.4mg/L respectively. The concentration of dissolved iron in water is dependent on the pH, redox potential, turbidity, suspended matter, the concentration of aluminium and the occurrence of several heavy metals, notably manganese. The natural cycling of iron may also result in the coprecipitation of trace metals such as arsenic, copper, cadmium and lead (SAWQG, 1996). Iron causes discolouration of water supplies when present at low concentrations in association with aluminium. Iron that settles out in distribution systems gradually reduces the flow rate of water. The only associated health effects are those that could arise from the presence of microbial deposits on internal surfaces of plumbing. These concentrations for the metals falls below the specification of WHO (50-150mg/L) for magnesium and (0.2-0.4mg/L) for iron, and therefore water sources are polluted with these elements.

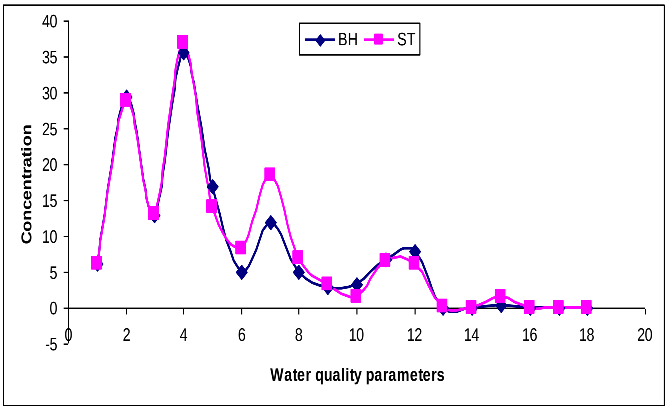

Figure 1: Physiochemical properties of water samples

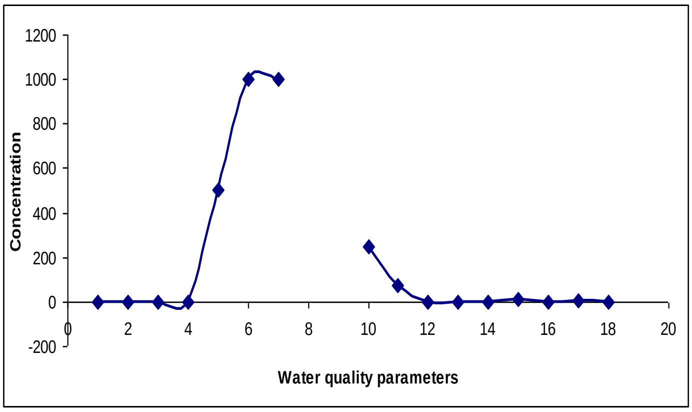

Figure 2: Permissible limits for physiochemical properties of Water (WHO, 2006)

Key:
1 pH
2 Temperature
3 DO
4 Alkalinity
5 Total Hardness
6 Total Dissolved Solid
7 Electrical Conductivity
8 Suspended Solid
9 BOD
10 Chloride
11 Calcium
12 Magnesium
13 Iron
14 Manganese
15 Nitrate
16 Ammonia
17 Phosphate
18 Sulphate

Anions

Ammonia (NH_3) is produced when animals and vegetables matter decay. It is present in variable concentrations in many surface and ground water and is a product of microbiological activity. In surface water, ammonia occurs as a result of dead leaves and animals which fall into the stream since it is open and decay in due course generating ammonia which is commonly seen in the form of ammonical nitrogen. Ammonia is toxic to fish and aquatic organisms, even in very low concentrations. When levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. As levels near 2.0 mg/L, even ammonia tolerant fish like carp begin to die. Ammonia levels greater than approximately 0.1 mg/L usually indicate polluted waters (SAWQG, 1996). In this study ammonia is insignificant with concentration of 0.00 to 0.01mg/l in both water sources compared with WHO standard (Fig.1 & 2) and DWSHA (30mg/L) (Table 3) for drinking water. Phosphate (PO_4^{3-}) is generally found as phosphorus in water. It is used in water for bio-production. Phosphate in potable water is generally very low with permissible level of 3.5mg/l (Table 3). Phosphate may occur in stream water (surface water) as a result of the use of detergent and other natural mineral deposits. In this study phosphorus is negligible in both water samples. Nitrate (NO_3^-) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrate can reach both surface and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks (WHO, 2007). Surface water nitrate concentrations can change rapidly owing to surface runoff of fertilizer, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes. Some ground waters may also have nitrate contamination as a consequence of leaching from natural vegetation. Mean concentration of 0.46 and 1.47mg/L nitrate are recorded for borehole and stream water from the present study. These concentrations are below limit set by WHO, DWSHA and NSDWQ (10, 50 and 50mg/L) respectively (Table 3). In the USA, nitrates are present in most surface water and groundwater supplies at levels below 4 mg/L, with levels exceeding 20 mg/L in about 3% of surface waters and 6% of ground waters. In 1986, a nitrate concentration of 44 mg/L (10 mg of nitrate-nitrogen per litre) was exceeded in 40 surface water and 568 groundwater supplies (USEPA, 1987). Sulphate imparts salty or bitter taste to water. The taste threshold for sulphate falls in the range of 200 - 400 mg/L and depends on whether the sulphate is predominantly associated with any of sodium, potassium, calcium or magnesium, or mixtures thereof. Elevated sulphate concentration also increases the erosion rate of metal fittings in distribution systems. Results of the present study show sulphate concentration of <0.1mg/L in both water sources.

Microbiological Analysis

Total coliform bacteria are frequently used to assess the general hygienic quality of water and to evaluate the efficiency of drinking water treatment and the integrity of the distribution system. They should not be detectable in treated water supplies if found, they suggest pollution of water source with human feaces. In some instances they may indicate the presence of pathogens responsible for the transmission of infectious diseases.

Table 1: Heavy metal concentrations and Physiochemical parameters for Borehole samples

PARAMETERS	SAMPLES					COEFFICIENT OF
	BH1	BH2	BH3	BH4	MEAN±SD	VARIATION
pH	6.50	6.30	5.94	6.15	6.22±0.24	3.86
Temperature (^oC)	30.00	29.70	29.30	28.90	29.48±0.45	1.53
Dissolved Oxygen (DO) (mg/l)	12.24	13.88	11.06	14.18	12.84±1.46	11.37
Suspended Solid (mg/l)	4.00	2.00	8.00	6.00	5.00±2.58	51.60
Alkalinity (mg/l)	36.00	32.00	32.00	42.00	35.50±4.73	13.32
Total Hardness (mg/l)	12.00	16.00	16.00	24.00	17.00±5.03	29.59
Total Dissolved Solid (TDS)	4.80	4.90	5.60	5.00	4.95±0.39	7.88
Conductivity (µs/cm)	11.43	11.45	12.83	12.00	11.92±0.66	5.53
Chloride (Cl^-)(mg/l)	4.28	4.28	1.46	2.84	3.22±1.35	41.93
Biochemical Oxygen Demand (mg/l)	2.45	1.63	4.34	3.13	2.89±1.14	39.45
Calcium (Ca) (mg/l)	8.24	7.22	7.64	4.19	6.82±1.18	26.54
Magnesium (Mn) (mg/l)	6.10	13.29	1.24	11.24	7.97±5.41	67.88
Iron (Fe) (mg/l)	0.03	0.02	0.04	0.01	0.03±0.10	100.0
Manganese (Mn) (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00
Nitrate (NO_3^-) (mg/l)	0.42	0.34	0.63	0.42	0.46±0.11	23.91
Ammonia (NH_3) (mg/l)	0.00	0.01	0.08	0.13	0.07±0.07	100.0
Phosphate (PO_4^{3-}) (mg/l)	0.00	0.01	0.00	0.01	0.01±0.00	0.00
Sulphate (SO_4^{2-})(mg/l)	0.07	0.13	0.13	0.02	0.09±0.05	55.56

Table 2: Heavy metal concentrations and Physiochemical parameters for Surface water samples.

PARAMETER	**SAMPLES**					**COEFFICIENT OF VARIATION**
	ST1	**ST2**	**ST3**	**ST4**	**MEAN±SD**	
pH	6.10	6.40	6.35	5.87	6.18±0.24	3.89
Temperature (^0C)	28.60	28.20	29.70	28.60	28.78±0.64	2.22
Dissolved Oxygen (DO) (mg/l)	12.24	14.69	13.20	12.16	13.07±1.17	8.95
Suspended Solid (mg/l)	6.00	10.00	8.00	4.00	7.00±2.58	36.86
Alkalinity (mg/l)	20.00	24.00	56.00	48.00	37.00±1.77	47.83
Total Hardness (mg/l)	8.00	10.00	12.00	26.00	14.00±2.87	58.36
Total Dissolved Solid (TDS)	5.30	15.80	5.80	6.00	8.23±5.10	61.97
Conductivity (µs/cm)	12.21	34.10	13.26	14.00	18.39±1.43	56.72
Chloride (Cl^-)(mg/l)	2.84	1.42	1.42	0.68	1.59±0.90	56.60
Biochemical Oxygen Demand (mg/l)	4.08	3.27	3.42	2.17	3.23±0.79	24.46
Calcium (Ca) (mg/l)	6.27	7.19	7.13	5.93	6.63±0.62	9.35
Magnesium (Mn) (mg/l)	5.12	6.45	6.22	6.44	6.10±0.63	10.32
Iron (Fe) (mg/l)	0.04	0.03	0.43	0.03	0.13±0.24	184.61
Manganese (Mn) (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00
Nitrate (NO_3^-) (mg/l)	0.15	2.99	0.90	0.84	1.47±1.01	68.70
Ammonia (NH_3) (mg/l)	0.00	0.00	0.05	0.00	0.05±0.01	0.05
Phosphate (PO_4^{3-}) (mg/l)	0.01	0.02	0.00	0.00	0.02±0.01	1.50
Sulphate (SO_4^{2-})(mg/l)	0.10	0.08	0.08	0.12	0.01±0.02	20.00

Table 3: WHO, DWSHA and NSDWQ for Physiochemical parameters of water

PARAMETERS	**DWSHA STANDARD (2012)**	**WHO STANDARD (2006)**	**NSDWQ (2007)**
pH	6.5-8.5	6.5 – 8.5	6.5 – 8.5
Temperature (^oC)	-	27 – 28	-
Dissolved Oxygen (DO) (mg/l)	-	1.0 – 5.0	-
Suspended Solid (mg/l)	-	–	-
Alkalinity (mg/l)	-	100 – 200	-
Total Hardness (mg/l)	-	500	150
Total Dissolved Solid (mg/l)	500	1000	500
Conductivity (µs/cm)	-	1000	1000
Chloride (mg/l)	250	250	250
Biochemical Oxygen Demand (mg/l)		–	-
Calcium (mg/l)	-	75.0	-
Magnesium (mg/l)	-	50 – 150	0.20
Iron (mg/l)	0.3	0.2-0.4	0.3
Manganese (mg/l)	0.05	0.10	0.2
Nitrate (NO_3^-) (mg/l)	10	50	50
Ammonia (mg/l)	30	0.2-0.5	-
Phosphate (PO_4^{3-}) (mg/l)	-	3.50	-
Sulphate (SO_4^{2-})(mg/l)	250	42-45	100

Microbiological analyses of various borehole samples show less concentration of thermo-tolerant bacteria *Escherichia coli* (*E. coli*). NSDWQ (2007) stated that if the coliform count is 10counts/100mL, that the water is fit for consumption. The South African water quality guide (SAWQG, 1996) stipulated that if Total coliform range (counts/100mL) is 0-5 the water has negligible risk of microbial infection; 5-100, the water has indication of inadequate treatment, post-treatment contamination or growth in the distribution system, risk of infectious disease transmission with continuous exposure and a slight risk with occasional exposure and if >100, the water shows indication of poor treatment, post-treatment contamination or definite growth in the water distribution system, and significant and increasing risk of infectious disease transmission. Thus, water samples collected from boreholes BH3 and BH4, and ST1 and ST4 with total coliform count of 11, 21, 28 and 13 per 100mL respectively (Table 4) are unclean. From the result of analysis, water from these points is unfit for drinking. They may contain human faeces and other warm blooded animal pollutants. However, this can be controlled or treated by the use of water treatment chemicals e.g High Test Hypochlorite (HTH), soda ash etc. High level of thermo-tolerant *E. coli* may result in the following activities in human; urinary tract infections (UTI), diarrhea, acute failure and haemolytic anaemic.

Table 4: Microbiological Consideration for water from Ikono Local Government Area

SAMPLE	*ESCHERICHIA COLI*	TOTAL COLIFORM
BH1	1×10^0	1×10^0
BH2	2×10^0	4×10^0
BH3	10×10^0	11×10^0
BH4	7×10^0	21×10^0
ST1	13×10^0	28×10^0
ST2	2×10^0	6×10^0
ST3	5×10^0	8×10^0
ST4	9×10^0	13×10^0

Conclusion

The results presented in this work imply no serious environmental or health challenges since all the physiochemical parameters analyzed are within the maximum allowable levels for drinking water. The analyses have also shown that water contains relative amount of some macro elements (cations and anions) like, magnesium, calcium, phosphorus, nitrogen and chlorine. Thus, the paper concludes that trace metal concentrations of the sites studied pose no contamination threat to water flowing from and through it. However, microbial consideration of the water sources shows level of concern at some points. It is therefore advisable that water samples obtained be subjected to treatment before drinking.

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