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Your Potable Water; How Safe? A Characterization of Groundwater Quality in Some Selected Areas in Delta State

Doris Fovwe Ogeleka*, Rukeme Freedom Uruejoma

Department of Chemistry, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria

Abstract Water is life and without this viable resources to living organisms and humans, life would cease to exist. This assessment was necessitated due to failure in public water supply system in most part of Delta State, which made most residents dig their privately owned underground water and use such waters untreated for drinking and major household purposes. The pH of most of the water samples was very low- acidic to slightly acid. The waters were practically ‘‘fresh’’ considering the electrical conductivity, total dissolved solids and salinity as chloride concentrations. The respective values ranged from (31.0 ± 1.6 µS/cm to 318.0 ± 6.0µS/cm), (15.0 ± 1.0mg/L to 158.0 ± 2.3mg/L) and (11.88 ± 0.14 mg/L to 38.0 ± 1.0mg/L). The waters were turbid-free (turbidity (0.0 NTU to 0.3 NTU) except in Abraka (1.2 ± 0.4 NTU). The heavy metals concentrations were low and within the regulatory limits except total iron. Concentrations reported for total iron varied between 0.2 ± 0.10 mg/L and 1.35 ± 0.02 mg/L as against the recommended limit of 1.0 mg/L. The risk of consuming untreated waters daily with low pH and high iron content could result in a myriad of health challenges.

Keywords groundwater quality, iron, Niger Delta, pH, safe drinking water

Introduction

No water! No life! Thus for the existence of biological entities (human, animals and plants), water is very crucial. It is also an essential component in animals and plants due to its unique physical, chemical and biological properties. Water plays an important role in the world economy and not only is water used all over the world in vast quantities for drinking purpose, it is also used in even greater quantities for domestic, agricultural and industrial purposes including cooking, washing, bleaching, dyeing, cooling, raising steam to drive engines or turbines to generate electricity, irrigation and as a solvent in industrial processes [1,2,3]. Some major sources of water include: surface water [4], rain water [5], ground water [6,7] amongst others.

Water is nature’s most wonderful and abundant compound, covering 75% of the earth's surface [8]. On Earth, 96.5% of water is contained in oceans, 1.7% in ground water, 1.7% in glaciers and the ice caps, 0.099% in other large water bodies and 0.001% in air as vapour, clouds and precipitation. However, out of the 2.5% of the Earth’s water that is fresh water, only about 1% is readily available for use while 99% is contained as ice and in ground water. Approximately 0.3% of all freshwater is in rivers, lakes, and the atmosphere, and a minute fraction of the Earth’s fresh water (0.003%) is contained in biological bodies and manufactured products [9].

Water moves continually through the hydrological cycle of evaporation, transpiration and condensation before reaching the sea as precipitation. Evaporation and transpiration contributes to the precipitation over land, which ends up in groundwater aquifers. However, since precipitation carries along with it contaminants from different environmental media into groundwater resources, one question is raised. How safe is your potable water? Since your potable water is extracted from groundwater aquifers untreated. Although, access to safe water has improved over the last decades in some parts of the world, approximately one billion people still lack access to safe water and over 2.5 billion lack accesses to adequate sanitation. However, it has been estimated that by 2025 more than half of the world population would be facing water-based vulnerability. It has also been reported that by 2030, in some developing regions of the world, water demand would exceed supply by 50%[10]. Safe drinking water is essential to humans and other life form and is a fundamental right of human being. The water we drink daily cannot be assumed safe since over 50,000 people die daily as a result of water related diseases - cholera, typhoid, dysentery, diarrheal. Mortality in children under five years from water diseases annually is estimated to be about 4 million in developing countries and over 2.3 billon people worldwide have mortality and morbidity associated with water related ailment [11,12]. This is so because natural water is never completely pure and during precipitation water passes over and through the ground, acquiring a wide variety of dissolved or suspended impurities that profoundly affect its quality. Similarly, impurities in natural water are sometimes added to water during treatment or during the flow of water through pipes or manifolds to recipient points [13].

The potability of drinking water is of great importance due to the fact that it is meant for consumption. The state of human health is dependent on the intake of substances into the body, and so if water must be consumed conveniently, enjoyable and without fear, it is therefore expedient that the quality must be up to standard without any complications. It is important to understand that water as important as it is to man, can also become a threat to health when it is consumed contaminated. Water pollution arises from excessive demand of water for both industrial and agricultural uses; since these processes could lead to the release of toxic substances into the environment which may eventually come in contact with water sources (groundwater and surface water), thereby polluting them and making it toxic to all forms of life, including plants and animals [14]. Four potential sources of contamination of groundwater include: oil and gas and related industry activities [6,9,15,16], leachates from open waste dumps [17], waste and storm water runoffs [18] and wrong agricultural practices / chemical applications[19].

The quality of potable water in the densely populated hub of the oil and gas city in the Niger Delta area of Delta State, have attracted serious concerns because of the absence of reliable Government public water supply systems. In Delta State, the State Government water utility board can barely provide potable water for 5% of its populace and this is without treatment. Thus, driven by thirst and demand for water, people switch to drinking untreated water from their own privately dug underground boreholes with the perception of being pure. However, even with all of the importance water holds in our lives, a lot of people are not concern with the results of water quality assessment but the availability of the water they consume each day. We drink tap water, enjoying the conveniences and cost-effectiveness of this practice yet fail to recognize the serious threat that water may pose to our health if its quality and purity are not access. Since contaminated groundwater and other water supplies could impact the health of humans that consume such waters, this research was therefore aimed to determine the potability (safe quality) of groundwater from some selected areas across Delta State.

Materials and Methods

Sampling Location

The study area is Delta State, which is in the Niger Delta ecological zone of Nigeria. The state has 21 Local Government Areas (LGA) with a 17,698 km^2 land mass and a global positioning system coordinate of 5.5325° N and 5.8987° E. Monthly average rainfall is usually above 300 mm from June to October but less than 50 mm from December to March. Human activities include farming, fishing, trading, burning of fossil fuels, wood, improper waste management, poor / wrong agricultural practices and so on.

Table 1: Geo-references for the sampling points

Sampling Area	Latitude	Longitude
Warri	N 05° 31” 18.2”	E 005° 44” 34.3”
Oghara	N 05° 57” 34.3”	E 005° 42” 04.1”
Effurun	N 05° 33” 56.8”	E 005° 45” 35.9”

Udu	N 05° 30” 12.7”	E 005° 47” 44.7”
Ughelli	N 05° 28” 52.0”	E 006° 01” 09.2”
Ozoro	N 05° 33” 11.6”	E 006° 14” 15.7”
Abraka	N 05° 47” 07.4”	E 006° 06” 16.0”
Asaba	N 06° 11” 33.8”	E 006° 43” 00.1”

Water Sampling

Water samples from ninety six (96) boreholes in areas cut across Delta State were collected in triplicates and analyzed for physico-chemical and heavy metal analysis. The specific areas sampled include: Warri (Okere road), Oghara (DELSUTH), Effurun (Jakpa road), Udu Local Government Area (Orhuwonru road), Ughelli (Patani express road), Ozoro (Kwale road), Abraka (PO express) and Asaba (Koko road). The sample containers were rinsed three times with the water to be sampled before collection. The water samples for physico-chemical parameters were stored in 1 L polyethylene bottles and preserved by cooling at 4^{o}C while samples for metals was preserved with 1-2 mL of 1:1 nitric acid (AR) [20].

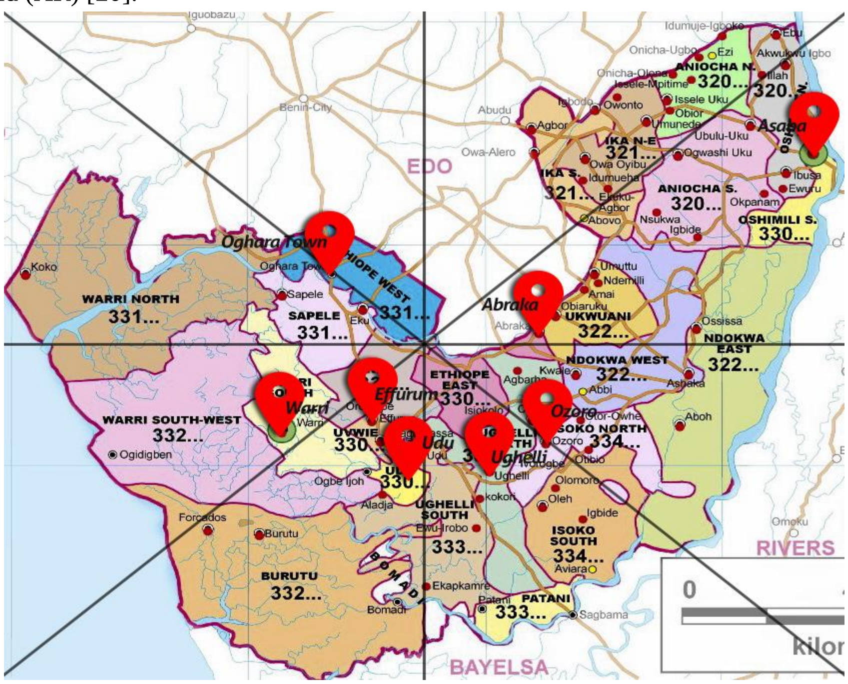

Figure 1: Map of Delta State showing the sampling locations

Table 2: Analytical methods for some parameters analysed in this study

Parameters	Analytical Methods
pH	pH, (APHA 4500 H^{+}
Temperature, ^{o}C	Thermometer (APHA, 2550-B)
Total dissolved solids (TDS), mg/L	TDS (APHA 2540-C)
Salinity (Cl^{-}), mg/L	Mohr's Argentometric method (APHA 4500 Cl-B)
Conductivity, µS/cm	Conductivity (APHA 2510 B)
Metals	Atomic Absorption Spectrophotometer (AAS)

Determination of metals in water samples

The water samples were thoroughly mixed and 50 mL was transferred into a beaker and 5 mL of concentrated nitric acid (AR) was added. The samples were heated on a hot plate to boiling until the volume reduced to 15 to 20 mL. This was allowed to cool and then filtered. The filtrate was diluted with distilled water to the 50 mL mark of a volumetric flask [20]. The concentration of metals in the samples was analyzed using Atomic Absorption Spectrophotometer (AAS) by direct aspiration into a standardized computer interfaced Schimadzu AAS-6701F.

Results

The results for physico-chemistry and microbiological analysis are presented in Tables 3-4 and Figures 1-2. The waters from the sampled areas indicated that the pH ranged from 4.18 ± 0.05 and 6.02 ± 0.04. The results implied that the waters were acidic in PO express, Abraka and slight acidic in Okere, Warri. The pH of the water samples were not within the World Health Organization (WHO), Department of Petroleum Resources (DPR) and Federal Ministry of Environment (FME) standards of 6.5 – 8.5 (Figure 2).

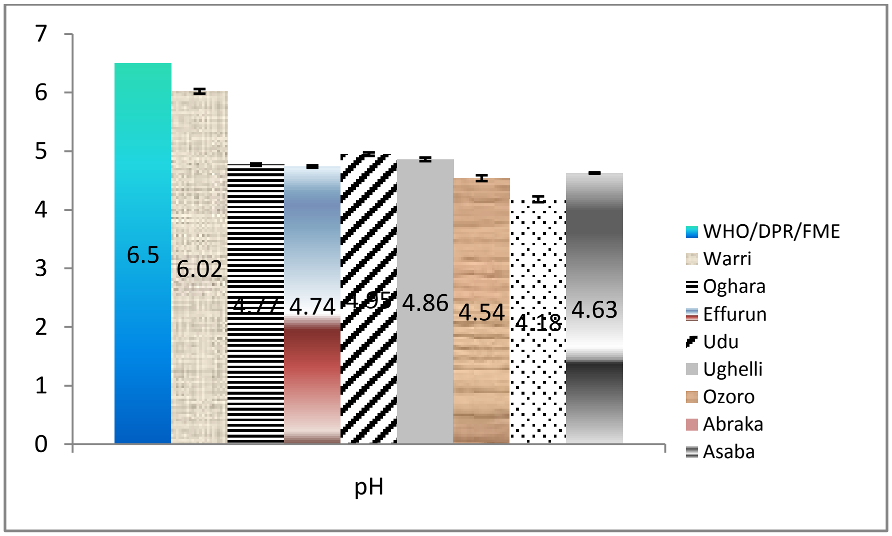

Figure 2: Mean values of pH in borehole waters from the study area

The values of electrical conductivity range from a minimum of 31 ± 1.6 μs/cm in Patani express road, Ughelli to 318 ± 6.0 μs/cm for PO express, Abraka. High values of conductance indicate high dissolved solids, saltiness and other chemicals in the water. The recommended regulatory WHO value for electrical conductivity is 250 μs/cm. However, the chemical quality of the underground borehole water sample from Abraka was higher than the regulatory standards. Total dissolved solids (TDS), which is the total amount of mobile charged ions (i.e. sum of the cations (positively charged) and anions (negatively charged) ions), including minerals, salts or metals dissolved in water was relatively low. Concentrations determined for TDS range from a minimum of 15.0 ± 1.0 mg/L inUghelli to a maximum of 158.0 ± 2.3 mg/L in Abraka.

Salinity as chloride recorded concentrations ranged between 11.88 ± 0.14 (Ughelli) and 38.0 ± 1.0 mg/L (Abraka), which indicated ‘‘fresh water’’. High concentration of chloride may indicate pollution of organic origin, as well as results in corrosively and impaired taste. The maximum permissible limit of chloride according to the WHO is 600 mg/L. Drinking water is often chlorinated for disinfection. The underground waters from all the sampled locations were relatively ‘soft’ as indicated in the concentrations obtained for total hardness. Values reported varied from 8.0 ± 0.2 mg$CaCO_3$/L in Ozoroto 48.0 ± 4.0 mg $CaCO_3$/L in Abraka. The physical appearance of water becomes cloudy, murky or otherwise coloured when it is turbid. The turbidity of all the water samples was clear of contaminating particles except in Abraka (1.2 ± 0.4).The results of the heavy metals were within the stipulated limits except Iron (Fe), which exceeded the stipulated limit of 1.0 mg/L. Among all samples, Abraka had the highest iron concentration. The concentration for iron ranged from 0.20 ± 0.1 (Ozoro) to 1.35 ± 0.02 mg/L (Abraka) (Figure 3).

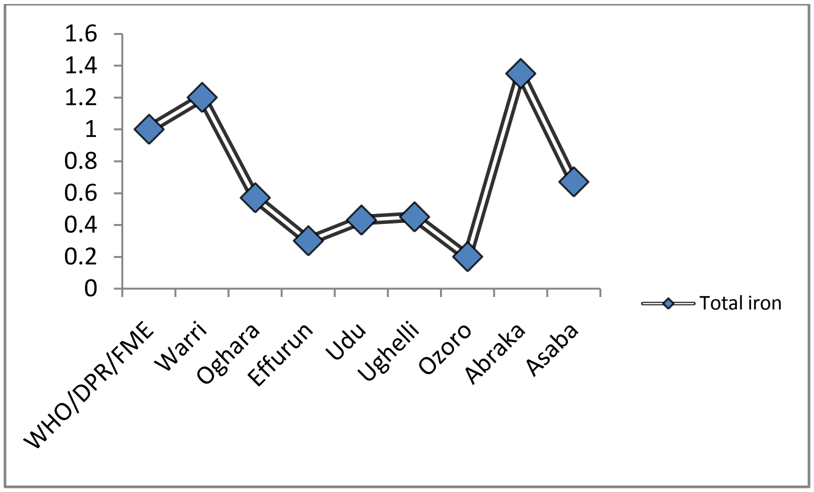

Figure 3: Mean concentrations of Total iron in borehole water from selected areas in Delta State

All the borehole water sampled were lead and cadmium-free as concentrations reported was below the detection limit of <0.001 mg/L. The bacteriological examination of water samples collected for total coliforms from all the locations indicated that the waters were free from microbial contamination.

Table 3: Results of Physico-chemical and biological parameters of groundwater samples from Warri, Oghara, Effurun and Udu in Delta State

Parameters	**WHO'S Max Acceptable limit**	**WHO'S Max Allowable limit**	**DPR Standard**	**FME Standard**	**Warri**	**Oghara**	**Effurun**	**Udu**
Temperature °C	N/A	N/A	25	25	28.80 ± 0.10	29.1 ± 0.1	29.2 ± 0.06	30 ± 1.0
Total Dissolved Solids (TDS) mg/L	1500	1500	N/A	2000	32.0 ± 2.0	31.0 ± 1.3	23.0 ± 1.0	55.0 ± 2.5
Electrical Conductivity (EC) µS/cm	250	N/A	N/A	N/A	63 ± 0.74	61.0 ± 1.2	46.0 ± 1.5	110.0 ± 5.0
Turbidity NTU	5	5	N/A	10	0.3 ± 0.01	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Salinity mg/L	200	600	N/A	600	11.88 ± 0.19	11.88 ± 0.18	19.0 ± 1.0	19.0 ± 0.03
Total Hardness mg $CaCO_3$/L	500	500	N/A	N/A	28 ± 0.71	12.0 ± 1.0	16.0 ± 0.5	16.0 ± 2.0
Metals								
Total Lead mg/L	0.05	1.5	1.5	1.5	<0.001 ± 0.0	<0.001 ± 0.0	<0.001 ± 0.0	<0.001 ± 0.0
Total Copper mg/L	0.05	1.5	1.5	1.5	0.02 ± 0.01	0.01 ± 0.003	0.02 ± 0.0	0.03 ± 0.0
Total Zinc mg/L	5	15	1	1	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.0
Total Cadmium mg/L	0.05	0.5	N/A	N/A	<0.001 ± 0.0	<0.001 ± 0.0	<0.001 ± 0.0	<0.001 ± 0.0
Microbiological								
Total Coli form MPN/100 mL	Nil	Nil	N/A	N/A	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

Table 4: Results of Physico-chemical and biological parameters of groundwater samples from Ughelli, Ozoro, Abraka and Asaba in Delta State

Parameters	WHO'S Max Acceptable limit	WHO'S Max Allowable limit	DPR Standard	FME Standard	Ughelli	Ozoro	Abraka	Asaba
Temperature °C	N/A	N/A	25	25	27.1 ± 0.10	27.9 ± 0.5	29.30 ± 0.0	29.20 ± 0.10
Total Dissolved Solids (TDS) mg/L	1500	1500	N/A	2000	15.0 ± 1.0	52.0 ± 3.0	158.0 ± 2.3	30.0 ± 2.41
Electrical Conductivity (EC) µS/cm	250	N/A	N/A	N/A	31.0 ± 1.6	104.0 ± 8.0	318.0 ± 6.0	61.0 ± 5.0
Turbidity NTU	5	5	N/A	10	0.0 ± 0.0	0.0 ± 0.0	1.2 ± 0.4	0.0 ± 0.0
Salinity mg/L	200	600	N/A	600	11.88 ± 0.14	21.38 ± 1.34	38.0 ± 1.0	16.63 ± 0.18
Total Hardness mg $CaCO_3$/L	500	500	N/A	N/A	8.0 ± 0.5	8.0 ± 0.2	48.0 ± 4.0	12.0 ± 1.0
Metals								
Total Lead mg/L	0.05	1.5	1.5	1.5	<0.001 ± 0.0	<0.001 ± 0.0	<0.001 ± 0.0	<0.001 ± 0.0
Total Copper mg/L	0.05	1.5	1.5	1.5	0.02 ± 0.0	0.001 ± 0.0	0.08 ± 0.01	0.01 ± 0.0
Total Zinc mg/L	5	15	1	1	0.02 ± 0.001	0.001 ± 0.0	0.02 ± 0.01	0.02 ± 0.01
Total Cadmium mg/L	0.05	0.5	N/A	N/A	<0.001 ± 0.0	<0.001 ± 0.0	<0.001 ± 0.0	<0.001 ± 0.0
Microbiological								
Total Coli form MPN/100 mL	Nil	Nil	N/A	N/A	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

Discussion

Groundwater is a valuable resource for potable water and over 36% of potable water supplies are drawn from aquifers in the ground. For drinking water (potable water), to be consumed safe or use with low risk of getting contaminated or harmed, it must be of quality that is free from disease organisms, poisonous substances, excessive minerals / organic matters and also free from colour, turbidity, taste and odour. Humans need potable water for drinking, cooking and personal cleanliness among other domestic uses in addition to industrial and agricultural purposes. Waters drawn from ground resources must be given specific treatments to make it safe or suitable for human consumption and other important uses since some may contain contaminants [21].

The public water supply and treatment system in Delta State had failed for some decades now and this was evident in the results for most of the ground waters determined for this appraisal, hence the waters could not be adjudged potable. The pH for drinking water should be closed to neutral (7); hence, the regulators (WHO, DPR, FME etc.) set the tolerance level to be within the range of 6.5 – 8.5. Beyond this range of pH, health implication sets in. The health risk of consuming waters without treatment and with low pH is enormous with health related problems, which include: severe gastrointestinal disorders, stomach disorders, abdominal disorders etc. The health impact of consuming waters with low pH has been confirmed by WHO / UNICEF, [22]. In addition, acidic water could impact metallic taste (drinking), corrode materials and could lead to the damage to valuable products [23]. Similarly, high iron content in water could impact taste and stain (laundry) [24]. The recommended minimum concentration of iron in drinking water should be 0.3 mg/L for it to be safe for drinking [25].

The slight variations between some parameters in the different locations could be as a result of anthropogenic activities and dense population in these areas. While some areas had less industrial activities others had intense businesses and industrial activities with high urban population. The low pH was peculiar to most areas cut across the Delta State, in the Niger Delta ecological area. The reason could be the fate and effects of air pollutants that drifts from one location of high industrial activities / zones to others of low and less concentrated activities. Noxious substances from anthropogenic activities, agricultural and industrial processes including gas flaring, solid waste incineration, oil pipeline explosion and input of agrochemicals on farms, could increase the impact of contaminants in water resources thus lowering the pH of waters. In addition, industrial processes likere fining, incinerators, thermal desorption unit (TDU) and other thermal plants could contaminate the atmosphere by releasing oxides of sulphur, nitrogen and carbon from their stakes which mixes with rainwater and decreases the pH of waters that percolates into underground aquifers that are then drilled for potable water consumption [26,27,28]. The results from this assessment are in line with researches conducted by Ogeleka *et al*., [3], Rim-Rukeh *et al*., [29], Kolo *et al*., [30]; Akpoveta *et al*., [31],, Adekola *et al*., [32] and Dirisu *et al*., [33].

Extreme measures should be taken to ensure that the waters consumed should be tested for potability. If deviations from regulatory standards are reported, such waters should be properly treated before use for drinking and other domestic purposes. Similarly, one or more of the following options could be used to treat non-conformances in pH. One method to adjust the pH is with acid neutralizing filters, which uses lime [calcite or powdered limestone (calcium carbonate)] for normal pH correction or a mixture of calcite and magnesium oxide, for pH level that is very low. Another way is to use a chemical feed pump system, which injects a neutralizing solution at controlled rate. The process stabilizes the pH. Since the water absorbs these minerals when it passes through the filter, the alkalinity and hardness levels would increase. However, for particles and high iron contents, the water could be passed through resins, ion exchangers / filters, which could be cleaned regularly [3].

Conclusion

We conclude that not all of the groundwater samples from the selected locations in Delta State could be considered safe(potable). However, for such waters to be used for drinking or any other domestic and industrial purposes, they should be subjected to treatment and water quality test to ensure conformance with standard regulatory limits for the various specific parameters.

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