Contaminants Evaluation as Water Quality Indicator in Ago-Iwoye, South-western, Nigeria

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The study evaluates some functional parameters of well water in a densely populated university town, Ago-Iwoye, South-western, Nigeria. Well water samples were collected at ten sites across the town. Analysis of the presence of *Coli* form count, *Salmonella* count, standard plate count, physicochemical properties (14 elements and 2 physical parameters) as indicators of water contaminants in the wells were carried out on water samples. 40% of the well samples were contaminated with coli form, whereas 20% were contaminated with salmonella, thus indicating the source of contamination (faecal contaminant). Further analysis revealed that most of the wells have their mineral values within the tolerant level according to WHO standard, however, the two most toxic chemicals from the recommendations of WHO were identified in well 2, 3, 5 and well 10 with values exceeding tolerant level of 0.05 mg/L for lead and 2.56 mg/L value for nitrate in well 2. Results confirm the presence of bacterial growth highly dangerous to life in these samples. Also, wells 2, 4, & 8 were contaminated with excess concentration of Fe mineral which could make the water tasty and have bacteria grow and wells 1, 2, 3, & 7 have excess concentrations of Cu mineral which could cause a stringent taste.

1. Introduction

Nigeria with a population of 130 million has about 70% of its population residing in rural areas. The Nigerian government is committed to playing an active role in reaching the Millennium Development Goals (MDG) through Presidential Water Initiative programs. In this program, the Government targets 100% coverage by 2007 in all state capitals, 75% in small towns, and 67% in rural communities which is the area of our study (Water Quality Policy, Water Aid Nigeria, Oct. 2004). In the late 1980s, Nigeria began to make serious efforts to address the water resources management problems. A national body was created to co-ordinate all environmental protection activities in the country, while a comprehensive national policy was formulated which, among other things, addressed the issue of water and leading to the promulgation of the hazardous waste decree with the intention of discouraging reckless and illegal dumping of hazardous and harmful wastes on land and into water courses [1].

Groundwater is the major source of water for human activities (consumption inclusive) and agricultural sector, especially in the rural area of Ago-Iwoye geographically located on longitudes 3 degrees 50 minutes and 3 degrees 56 minutes East, and latitudes 6 degrees 55 minutes and 7 degrees North. Geologically, the area is within the basement complex of Southwestern Nigeria, comprising the migmatites and porphhyroblastic gneiss. In large areas of the basement complex the principal source of groundwater is wells. These wells are approximately 18 to 32 meter deep. Even though the waste products are disposed by septic tanks and the minimum distance required between septic tanks and wells should be about 30 m [2], this was not so with the wells at the study area where some are close to septic tanks, i.e., only about 10-20 m away. Water is a universal solvent on earth whose main sources are: rivers, springs, wells, and other water bodies, and once such source is available for drinking water then it may serve as a route of exposure to contaminants [3]. The importance of well water, which is one of the main sources of drinking water in the study area, is for the existence of human society (Agriculture sector and human consumption) and most importantly for body detoxification through drinking since more water in essence can build a stronger immune system. According to [4], well water is an important and integral part of the hydrological cycle, its availability then depends on the rainfall and recharge conditions.

If the bacteria infected water quality problem is detected, it could be occurring in the water system such as the well (or less likely) the aquifer [5]. The

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quality of well water is getting severely affected because of the wide spread pollution of surface water. Besides, discharge of untreated waste water through bores and from unscientific disposal of solid waste also contaminates well water, thereby reducing the quality of fresh water resources. It has been shown that in the presence of any members of the *Enterobacteriaceae* family, whether *E.coli*, *Coli forms* or others, the presence of *Salmonella* is also highly likely. It has also been observed that there are only few numbers of *E. coli* present in faecal samples if *salmonella* is present, which may be at substantially higher level due to infection or a persistent carrier state (www.foodhorizon.com). *Coli form* is the bacteria most commonly associated with water quality especially in the investigated region. The World Health Organization (WHO)/ U.S Environmental Protection Agency (EPA) standard for acceptable drinking water is a total *Coli form* count of zero [6, 7]. *Coli form* consists of a large group of different species of bacteria. The group includes bacteria that occur naturally in the intestines of warm blooded animals (faecal C*oli form*) and non-faecal C*oli form* bacteria [8].

Faecal c*oli form* can include diseases-causing and non diseases-causing species. *Coli form* bacteria are gram negative organisms capable of fermenting lactose. *Coli forms* tests, as a group, are used as an overall indication of sanitation efficiency. Most *Coli forms* are not harmful (pathogenic), but if a *Coli form* test indicates their presence, it is considered to be an indication of unsanitary conditions. *Salmonella* had its sources from infected water and food. Its germs are actually a group of bacteria that can cause diarrhoea illness in humans; it had been known to cause illness for over 100 years. Standard Plate Count (SPC) is used to determine the total number of aerobic bacteria (needing air) present at mesophylic temperatures (30-37 ^{0}C) [9]. The SPC can be used as a general, relative gauge, of the overall bacterial load of a product (www.fplabs.com).

Ground/well water usually has fewer micro-organisms than surface water because of its long travel time in the sub-surface environment [10]. However, ground/ well water can become contaminated by domestic sewage, feedlots and surface runoff, as well as other pollution sources. Where the sub-surface geology permits rapid downward movement of water from the surface, or where the ground water source are tapped near the surface, aquifers may be vulnerable. Shallow wells, or drilled wells in which the well casing is not properly grouted, are particularly susceptible to contamination. Bacteriologic and protozoa pathogens are known to cause typhoid fever, dysentery, cholera, diarrhoeas, hepatitis and some types of gastroenteritis (Box 1) [10, 11, 12]. Some of the microbes discovered [13] (www.agwt.org) cause diseases but various other forms also were considered in this study. Sub-surface dwelling organisms are usually attached to the rock particles in soils and aquifers. During periods of high water table, such as after prolonged rainfall, ground water has greater contact with soil organisms and nutrients. The result can be an increase in organisms found in water from wells.

The occurrences of bacteria in water is however common, treatable, and in most cases preventable. A number of the most important chemical contaminants (i.e., those that have been observed to cause adverse health effects as a consequence of exposure through drinking–water) are considered in this study, even though some of these chemical contaminants fall into the category of naturally occurring chemicals, many naturally occurring chemicals do have other primary sources [14]. For instance, chemicals from diffuse sources arising from the use and disposal of materials and products containing chemicals can reach drinking-water directly from discharges, some of which are latrines and septic tanks poorly sited. These can lead to contamination of drinking–water source with nitrate. Records from the health care unit of the university showed that from year 2003 till 2005, there has been a great increase in reported cases of water borne diseases especially diarrhoea. For instance, 81 cases of typhoid and 103 cases of diarrhea were reported in 2003 at the university health center. By 2005, the number of typhoid cases reported has increased significantly to 213, while 232 cases of diarrhea were reported. This suggests that if the remote root causes of these outbreaks are not exposed and dealt with, the whole university community stands a very grave risk.

Previous studies, however, of microbial contaminations in southern Nigeria [15] and in neighbouring Ghana [16] showed very high levels of contaminations in drinking water. Having identified the significance of good drinking water and myriads of diseases associated with water contamination, this study is designed to provide detailed and technical information that would checkmate the causes of the illness breakout in the study area through the analysis of the biological and physico-chemical properties of the water sources and the impacts of minerals on bacterial growth. The information would also be relevant to other communities in Nigeria with similar problems as it is common in West Africa, upon

which the government of Nigeria might pay more attention to implementing the appropriate policy in rural areas of the country.

2. Materials and methods

Samples of well waters for the physical and chemical examination were collected into one-litre bottles from 5 cm depth. The Total Hardness, Copper, Iron, Magnesium, Zinc, Sulphate, Total Dissolved Solids, pH and colour measurements were performed according to accepted procedures [14, 17], while sodium and potassium concentrations were measured by the flame photometric method. The biological procedures recommended by the Water Aid Nigeria using the Delagua Portable Water testing kit, developed by the Robens Institute and lately by the Centre for Environmental Health Engineering, Surrey University, were adopted for the analyses of microbes in this study. Clean sterile stopper bottles were used to collect the well water samples at 5 cm depth and processed within 3 hrs, this is because stopping of the bottles may disturb some of the organism especially the aerobic micro-organisms. This kit was operated on the membrane filtration technique, which allows bacteria to be counted more directly. In this method, water is filtered through cellulose membranes having pores size of only 0.45 µm. These retain all bacteria on their surface and the membrane is then placed on a nutrient medium (Eosin-Methylene Blue (EMB) agar) and incubated for 24 hours at 35 ^{0}C. Bacteria belonging to those species or group that are favoured by the particular medium will grow into visible colonies on the membrane and will take on a particular colour depending on the stains contained in the medium; the evidence of the brilliant green lactose bile broth is used as indicator of the presence of C*oli form*. Grain staining revealed a gram negative and non-sporulating *bacilli* type, which is now confirmed and finally completed. They may then be counted.

3. Results and discussions

Presently, there is no known water quality standard in Nigeria [18, 19]. Hence, the study made use of the laid down maximum and minimum values, i.e., tolerance limit, for the microbes and the physico-chemical properties of good quality water set by WHO and which was adopted by the State Water Agencies and the Federal Ministry of Water Resources in Nigeria. The World Bank studies [20], however, revealed that uncurbed problems of ground and surface water contaminations could cost the nation in the excess of one Billion US dollars per year to correct such problems. More than 70% of water sources in Nigeria are contaminated and injurious to health. This was the conclusion of a joint UNICEF/WHO 2005 report on rapid assessment of drinking water quality in Nigeria (www.irc.nl/page/29433).

Well water being the source of human activities (including the consumption) in the study area, there is a need to investigate some properties which correlate with the WHO standards for quality water. Even though there are other effects due to water contamination, we will rather be concerned with the health effects, since it was the health problem of the study area that necessitates the study. From the chemical analysis carried out (Table 1), the two toxic chemicals identified by W.H.O to be the most dangerous to health are unfortunately the defaults of this analysis.

Well water are contaminated by the excess concentration of mineral elements such as nitrate (NO_3^-) in well 2 (exceeding the tolerant level with 0.25 mg/L), Lead (Pb) values in wells 2, 3, 5, & 10 exceeding the tolerant level of 0.05mg/L), while Iron (Fe) observed in wells 2, 4, and 8 (exceeding the tolerant level of 0.1-1.0mg/l), could cause the water to have taste, discoloration and bacteria growth. Also, wells 1, 2, 3, 5, and 7 have excess concentration of Copper (Cu) (exceeding the tolerant level of 0.5-1.5 mg/L) mineral which could cause a stringent taste and pipe corrosion.

Every other physical and chemical property agrees and exists within the tolerant limit. From Tables 1 and 2, it can be observed that well 2 was located very close to a soak-away and this could have contributed to its high nitrate, copper and iron concentrations.

This was further confirmed by the presence of *Salmonella* bacteria and further buttressed by the highest value of 0.08 cfu/100 ml for standard plate count among other samples which is an identification of bacteria (Table 3). There were also traces of *Coli form* bacteria and the standard plate count indicates that the well calls for attention. Under natural conditions, the nitrate level in drinking water is generally less than 2 mg/L [3].

Table 1: Results obtained from the observation of chemical properties.

Well No	pH	Na (mg/L)	K (mg/L)	Mg (mg/L)	Zn (mg/L)	Pb (mg/L)	Cl^- (mg/L)	Cu (mg/L)	Fe (mg/L)	NO_3^- (mg/L)	PO_4^- (mg/L)	SO_4^{2-} (mg/L)
1	6.70	44.00	73.00	1.05	0.18	0.05	88.75	1.80	0.00	1.99	5.40	1.60
2	6.50	34.00	50.00	1.88	0.24	0.08	35.50	1.77	1.28	2.56	6.50	1.30
3	6.80	55.00	10.00	1.65	0.73	0.06	53.25	2.08	0.00	1.64	4.31	3.20
4	6.50	46.00	39.00	1.92	0.98	0.00	71.00	0.10	1.98	0.94	2.71	1.80
5	6.70	44.00	11.00	1.52	1.59	0.09	88.75	0.78	0.00	1.02	1.34	2.40
6	6.50	59.00	7.00	1.97	0.49	0.01	53.25	0.12	0.00	1.57	2.08	4.80
7	6.70	69.00	41.00	0.87	0.84	0.00	82.58	2.09	0.80	0.59	3.78	2.05
8	6.90	58.00	8.00	2.01	0.96	0.04	71.51	0.50	1.10	0.66	1.49	0.93
9	6.80	64.00	24.00	0.80	0.98	0.02	64.20	0.43	0.00	1.01	2.18	0.97
10	6.50	47.00	13.00	0.64	0.74	0.07	75.05	0.12	0.00	1.15	2.11	1.05

Table 2: Results obtained from the observation of physical properties.

Well No	Colour	Odour	TDS (mg/L)	TH (mg/L)
1	Colourless	Odourless	14.00	32.00
2	Colourless	Odourless	13.00	38.00
3	Colourless	Odourless	18.00	42.00
4	Colourless	Odourless	16.05	55.00
5	Colourless	Odourless	20.15	47.00
6	Colourless	Odourless	17.04	61.00
7	Colourless	Odourless	10.71	52.00
8	Colourless	Odourless	11.89	49.00
9	Colourless	Odourless	15.20	37.00
10	Colourless	Odourless	9.45	25.00

TDS- Total dissolved Solids
TH- Total Hardness

Table 3: Results obtained from the observation of microbial properties**.**

Well No	Total plate count (cfu/100ml)	*Coli form* count (cfu/100ml)	*Salmonella* count (cfu/100ml)
1	0.05	0.01	0.00
2	0.08	0.01	0.01
3	0.04	0.00	0.00
4	0.01	0.01	0.00
5	0.01	0.00	0.00
6	0.03	0.00	0.00
7	0.02	0.00	0.00
8	0.06	0.02	0.00
9	0.01	0.00	0.00
10	0.01	0.00	0.00

While, wells 1, 2, 4, 8 & 9 from Table 3 have *Coli form* count values of 0.01, 0.01, 0.01, 0.02, 0.02, cfu/ml, respectively, this in itself is not an indication of danger, but only of the presence of *Coli form* bacteria. The recommendation of WHO/EPA is to have zero level of bacteria. This, if not treated, could aid the thriving of other forms of bacteria which could be dangerous to health. Wells 1, 3, & 4 also require special attention with the traces of *Coli form* count, *Salmonella*, lead and iron in excess concentrations. Health wise, nitrite can interact with secondary amines and amides in the stomach to form *N-nitrosamines* and *N-nitrosamines*, which could cause cancer and other diseases in infants [3]. This study then revealed that there are still ill-defined and uncoordinated roles of Federal, State and Local Government agencies responsible for water resources development in Nigeria, especially the rural communities. This was also recognized by UNICEF/WHO and called on the Nigerian Government to establish a national regulatory agency for sanitation and water supply schemes (www.irc.nl/page/29433).

Hence, the study demonstrates the importance of education for the consumers, who use individual supplies for their drinking water. Efforts are needed to put in place and to increase the awareness of hazard of drinking contaminated water and of ways to prevent contamination. Improper placement of wells, lack of sanitary seals, proximity of grazing animals to the well, and lack of knowledge of the significance of contaminated water were all found to be factors contributing to the poor-quality water supply in this study area. Since contamination has occurred, it deemed necessary now to consider the introduction of treatments. Even though the primary approach to addressing the chemical contaminants is prevention of contamination by encouraging good practices, however, bacteria are most effectively eliminated from drinking water by chlorine disinfection, filtration, ultra-violet irradiation or ozonization [21]. All of these methods require careful attention to equipment selection since some bacteria treatment procedures do not work properly if certain minerals are present [22, 23, 24]. Conventional treatments will remove a variety of secondary contaminants. Coagulation/flocculation and filtration remove metals like iron, manganese and zinc. Aeration removes odours, iron and manganese. Granular activated carbon will remove most of the contaminants which cause odours, colour, and foaming. Non- conventional treatments like distillation reverses osmosis and electrolysis are effective for removal of chloride, nitrates, total dissolved solids and other inorganic substances. However, these are fairly expensive technologies and may be impractical for smaller communities (www.epa.gov).

4. Conclusions

Physico-chemical and biological properties studies indicate that drinking water contaminants are implicated in causing health-related problems. Well 2, particularly, has been able to support the published fact that some compounds such as nitrate and iron might actually support bacterial growth [25] i.e., the presence of some mineral in excess implies presence of bacteria and also aid bacterial growth. Thus, this study has been able to confirm the fact that metals in the environment, human and animal faeces are sources of contamination, which could cause illnesses and diseases in human body (Water Quality Policy, Water Aid Nigeria, 2004). These observations reflect leaching of these minerals probably via rainfall or excessive irrigation which may eventually reach groundwater. Hence, most of the epidemics breakout in the study area, which falls under water-borne diseases category (Box 1) could actually be traced to the observations made about the utilized well waters by inhabitants. Most frequent monitoring will be helpful in detecting contaminated water particularly during and after rainfall periods. Further work on this study is to find out how seasonal variations affect such contaminations.

The National Policy on the Environment, which was launched by the Nigerian President in Abuja on 27 November 1989 [26], has stated clearly one of the goals of that policy to raise public awareness and promote understanding of essential linkages between environment and development and to encourage individual and community participation in environmental improvement efforts [27]. Also the UNICEF/WHO 2005 report on drinking water quality in Nigeria attributed the contamination to the "non-compliance of WHO guidelines for drinking water by many communities in the country" (www.irc.nl/page/29433). This study, therefore, recommends that the gap between the Federal Ministry for Water Resources and Rural Water Sanitation Agencies as well as Local Governments for full implementation of Nigerian laid down policy on Environmental Protection, issues be bridged by adopting very quickly the National Standards and guidelines that most suit our climate, and calls for enforcement and monitoring of the relevant policies in the rural

areas concerning well digging and borehole drilling with its maintenance. Moreover, the public be kept informed about water quality objectives that have been established and measures taken to attain these objectives [28, 29, 30].

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Box 1: Diseases and their agents which might spread by faeces contaminated groundwater

Viral Disease	**Pathogen**
Infectious hepatitis	Hepatitis A virus
Poliomyelitis	Poliovirus
Diarrhoeal diseases	Rotavirus, Norwalk agent, other viruses
Varied symptons and diseases	Echoviruses and Coxsackievirus
Bacterial Diseases	**Pathogen**
Cholera	*Vibrio cholerae*
Typhoid fever	*Salmonella typhi*
Paratyphoid fever	*Salmonella parathphi*
Bacillary dysentery	*Shigella* spp.
Diarrhoeal diseases	Enterotoxigenic E.*coli*
	Enteroinvasive E.*coli*
	Enteropathogenic E. *coli*
	Salmonella spp.
	Campylobacter petus spp.*jejuni*

Source: Lewis, Foster et al. (1980) [31]

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