Physicochemical Assessment of Groundwater as a Source of Domestic Water Use in Some Selected Settlements in Minna, Niger State

J J Musa[1], J K Adewumi[2], A P Adeoye[3], I H Mustapha[4] and E S Adebayo[5]

Lack of safe drinking water and adequate sanitation measures lead to a number of diseases, such as cholera, dysentery, salmonellosis and typhoid, and every year millions of lives are claimed in developing countries. Some rural and major populations are heavily dependent on small reservoirs, other sources for their water supply, and are concerned about the quality for direct consumption and other uses. Water samples from different areas, i.e., within Minna and Niger State were collected and tested for their chemical and physical parameters. It was discovered that all the water samples had a common room temperature of 29.1 °C. Sample F had the highest electrical conductivity of 560 μs/cm and sample A had the lowest value of 80 μs/cm. Sample F had a higher value of 280 mg/L of total dissolved solids, while sample A had the lowest of 40 mg/L. The pH of the water for all the samples fluctuated greatly with sample A and F having the lowest values of 6.8, while sample G had the highest value of 7.4 though they all are still within the range. Samples C, E and F were within the maximum permissible limit of 5.0 when turbidity was analyzed. It was also observed that sample H had the highest value of nitrate content (6.2) which was closely followed by sample F, while sample B had the lowest value of 0.3. It was concluded that the water quality for some of the samples was contaminated due to lack of proper treatment thus endangering the lives of the consumers.

Keywords: Domestic, Drinking, Health, Household, Hygienic, Public, Water

Introduction

Water is mainly important for domestic purposes. Water is generally supplied in two ways—by a city/county water department and by a private company or people. These people supply

[1] Lecturer, Department of Agriculture & Bioresources Engineering, Federal University of Technology, P M B 65, Minna, Nigeria; and is the corresponding author. E-mail: jogric2000@yahoo.com

[2] Senior Lecturer, Department of Agriculture Engineering, University of Agriculture, Abeokuta, Nigeria. E-mail: jjkadewumi@yahoo.com

[3] Lecturer, Department of Agriculture & Bioresources Engineering, Federal University of Technology, P M B 65, Minna, Nigeria. E-mail: pheterhardey@yahoo.com

[4] Lecturer, Department of Agriculture & Bioresources Engineering, Federal University of Technology, P M B 65, Minna, Nigeria. E-mail: ibrahimsafa@yahoo.com

[5] Lecturer, Department of Agriculture & Bioresources Engineering, Federal University of Technology, P M B 65, Minna, Nigeria. E-mail: oluvictor4life@yaoo.com

© 2011 IUP. All Rights Reserved.

their own water, normally from wells and boreholes. Water delivered to houses through public water supply pipeline is called 'public supplied', while that supplied by the public to their houses is called 'self-supplied', which is usually obtained from the underground. Quite a few of the residents of Minna gets their water delivered from a public-supply system (Gleick, 1996).

Lack of safe drinking water and adequate sanitation measures lead to a number of diseases, such as cholera, dysentery, salmonellosis and typhoid, and every year millions of lives are claimed in developing countries. Diarrhoea is the major cause for the death of more than two million people per year worldwide, mostly children under the age of five. It is a symptom of infection or the result of a combination of a variety of enteric pathogens (Ahmed, 2000).

Water-borne pathogens infect around 250 million people every year resulting in 10 to 20 million deaths worldwide. In Nigeria alone, more than 47 million people do not have access to potable water supply and nearly 42 million (about 54% of the population) lack basic sanitation. This highlights the potential of infection due to water-borne pathogens (Ajayi, 1996).

The evaluation of potable water supplies for coliform bacteria is important in assessing the quality of drinking water. High levels of coliform counts indicate a contaminated source, inadequate treatment or post-treatment deficiencies (Byamukama *et al.*, 2000). Many developing regions suffer from either chronic shortages of freshwater or the readily accessible water resources are heavily polluted (Lawrence *et al.*, 2002). Microbiological health risks remain associated with many aspects of water use, including drinking water in developing countries (Petrella, 2001), irrigation reuse of treated wastewater and recreational water contact (Goni *et al.*, 2000). It has been reported that drinking water supplies have a long history of association with a wide spectrum of microbial infections (Renault and Wallender, 2000).

Drinking water can be defined as the water delivered to the consumer that can be safely used for drinking, cooking and washing. A certification by a licensed professional engineer specialized in the field is no longer sufficient. The public health aspects are of such importance and complexity that the health authority having jurisdiction in the community now reviews, inspects, samples, monitors and evaluates on a continuing basis the water supplied to the community, using constantly updated drinking water standards. Such public health control helps to guarantee a continuous supply of water maintained within the safe limits.

Water analysis alone is not sufficient to maintain quality but must be combined with the periodic review and acceptance of the facilities involved. This approval consists of the evaluation and maintenance of proper protection of the water source, qualifications of personnel, water supplier's adequate monitoring work and also evaluation of the quality and performance of laboratory work.

Hence, it could be summarized that drinking water must meet the physical, chemical and bacteriological parameters when supplied by an approved source, delivered to a treatment and disinfection facility of proper design, construction and operation and in turn delivered to the consumer through a protected distribution system in sufficient quantity and pressure.

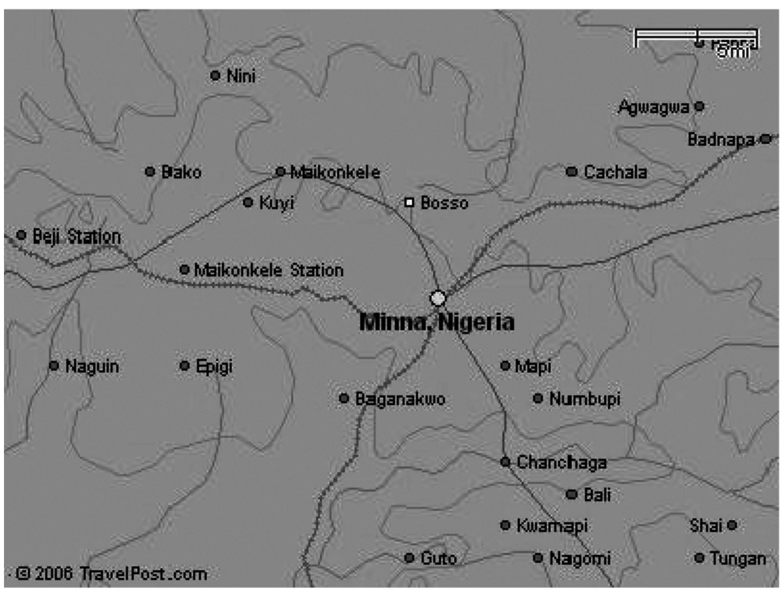
Introduced in opposition to a traditional supply side management, the water demand management has been conceived as a flexible tool that is offered in accordance with the community's needs. On the basis of the local systems, an assessment is provided about the efficiency of the water consumed, and consequently about the management solutions that can be proposed in order to realize savings of water, which can avoid heavy and costly interventions on the environment for acquiring more volumes of water (e.g., for new dams, wetland drainage, canalizations, etc.). The regulatory mechanisms provided by the demand side management have the effect to reduce the global water demand, protecting at the same time the fundamental water needs for human activities and for the ecosystem functioning (Scanlon *et al.*, 2004).

This study investigated the hygienic handling practices of groundwater used for domestic purposes in Minna and its quality parameters to ascertain the quality of groundwater delivered to the various houses/areas of Minna and its environs.

2. Materials and Methods

Niger State is one of the 36 states created in Nigeria with her capital in Minna located between latitude 9° 34′ – 9° 37′ N and longitude 6° 36′ – 6° 39′ E, (Musa and Egharevba, 2009) with an annual rainfall of 578 mm and a mean temperature of 34° (Figure 1) (Minna Metrological Centre, 2008).

Figure 1: Map of Minna



Author pl clarify the sentence

Water samples were collected between 800 h and 1000 h, treated for trace metals in a two (2) L plastic bottle and acidified with nitric acid (HNO_3) to pH < 2. Plastic was used to prevent sample contamination from metallic samples while that for physiochemical parameters, the samples were collected in 2 L separate plastic bottle. The plastic containers were thoroughly washed and rinsed three times with the effluents to be sampled before they were collected. These samples were then preserved in a refrigerator at the laboratory.

To identify and locate samples easily, all samples carried self-adhesive labels. These were affixed on the sample bottles instead of the cover to prevent loss or misplacing, causing sample mix-up. The information on the sample label includes location, date and time.

3. Results

Some rural and major population is heavily dependent on small reservoirs, other sources for their water supply and are concerned about the quality for direct consumption and other uses. Such concerns can be raised by what appears to be water pollution, or by disease symptoms perceived to be water related. In these cases, chemical, physical and biological water quality measurements were taken to ascertain the suitability of groundwater for different uses. Table 1 shows the physicochemical analyses of some groundwater samples in Minna.

4. Discussion on Results

Drinking untreated groundwater is potentially hazardous, and risks increase as reservoir use intensifies. Where drinking water is sourced from small reservoirs undergoing intensification, alternative sources of drinking water should be sought. Ideally, drinking water supplies should be separated from those used for other purposes. Water in reservoirs typically has numerous uses that conflict with the storage of quality drinking water.

4.1 Physical Properties

Researchers over the years have shown that physical parameters, such as pH, temperature and turbidity have a major influence on bacterial population growth (Byamukama *et al*., 2000; and Goñi *et al*., 2000).

4.1.1 Temperature

Water temperature affects the ability of water to hold oxygen, the rate of photosynthesis by aquatic plants and the metabolic rates of aquatic organisms. Causes of temperature change include weather, removal of shading stream-bank vegetation, impoundments, discharge of cooling water, urban storm water and groundwater inflows to the stream.

The room temperature of most of groundwater before the commencement of various tests was 29.1 °C. Though temperature does not have any direct impact on the groundwater apart from evaporation process which may take place when exposed directly to sun rays.

4.1.2 pH

pH is a term used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. Acidity increases as the pH gets lower. Aquatic organisms differ as to the range of pH in which they flourish. The pH of the water for all the samples fluctuated greatly with sample A and F having the lowest values of 6.8, while sample G had the highest value of 7.4 though they all are still within the range. The overall pH pattern showed that the pH values were relatively within the NAFDAC range of 6.5-8.5.

4.1.3 Turbidity

Turbidity is described as the measure of amount of particulate matter suspended in water.

Table 1: Physicochemical and Bacteriological Analysis of Sampled Sachet Water in Minna

S. No.	Parameters	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G	Sample H	WHO Limit (2004)	NAFDAC Limit (2004)
1.	Electrical Conductivity (us/cm)	80	130	110	90	510	560	380	320	1,000	–
2.	Total Dissolved Solids (mg/L)	40	65	55	45	255	280	190	160	1,000	500
3.	Temperature (°C)	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.1		Ambient
4.	Suspended Solids (mg/L)	2.0	6.2	0	8.5	0	2	0	12	25	–
5.	pH	6.8	7.2	7.0	6.9	7.2	6.8	7.4	6.9	7.0-8.5	6.5-8.5
6.	Turbidity (NTU)	8	24.1	0	32.3	2.0	7.0	1	9.2	5.0	5
7.	Color (TCU[2])	2	28.0	0	85	14	39	10	47	15	15
8.	Iron Content (mg/L)	0.18	0.04	1.12	0.4	0.04	0.07	0.05	0.09	0.05-0.3	–
9.	Total Hardness (mg/L)	42	50.8	28	34	95	88	86	82	100	
10.	Hardness (Ca) as $CaCO_3$ (mg/L)	16.8	20.6	11.2	13.6	38	35.2	34.4	31.3	50	75
11.	Hardness (mg) as $CaCo_3$ (mg/L)	25.2	30.2	16.8	20.4	57	52.8	51.6	51.3	50	30
12.	Nitrate as Nitrogen (mg/L)	0.8	0.3	0.8	0.9	2.7	4.5	1.5	6.2	50	–
13.	Nitrite (mg/L)	3.52	1.32	3.5	4.2	3.96	19.8	6.6	24.7	0.2	0.2
14.	Sulphate (mg/L)	2	25	4.2	3.2	14	11.3	17.2	12.4	200	200
15.	Phosphate	0	0.023	0.13	1.16	0.03	0.01	59.2	32.6	0.3	–
16.	Total Alkalinity (mg/L)	20.0	15.3	18.1	13.8	40	26.2	38.7	43.2	100	100

Water that cloudy or opaque in nature is said to be highly turbid which can cause increased water temperatures because suspended particles absorb more heat and can also reduce the amount of light penetrating the water.

It was observed from Table 1 that sample D had the highest turbidity value of 32.3 which was closely followed by sample B with a value of 24.1, while sample C had a 0 value of turbidity which was closely followed by sample G, which had a value of 1. Only samples C, E and F were within the maximum permissible limit of 5.0.

4.1.4 Color

Color of water when collected from various sources appeared to be clear in most cases. Infinitely small microscopic particles are known to add color to water. Colloidal suspensions and noncolloidal organic acids as well as neutral salts also affect the color of water. The color in water is primarily of vegetable origin and is extracted from leaves and aquatic plants. Naturally, water draining from swamps has the most intense coloring though this is usually filtered, as it travels downwards to locate the underground water table. When exposed to the bleaching action of sunlight plus the aging of water, it gradually dissipates this color, however. All surface waters possess some degree of color. Likewise, some shallow wells, springs and an occasional deep well can contain noticeable coloring. In general, however, water from deep wells is practically colorless. Water regulations recommend that potable water possesses color of less than 15 units. In general, color is reduced or removed from water through the use of coagulation, settling and filtration techniques which, in Nigeria context, are not available for water extracted from underground.

From the tests conducted, it was discovered that the color of various samples of water ranged between 0 and 85 with sample D having the highest value of color.

4.1.5 Suspended Solids

Suspended minerals are a measure of the amount of sediment moving along in a stream. Solids present within water bodies is highly dependent on the flow of water which usually increases during and immediately after rain events. As the sediment settles out of the water, it gradually becomes clearer, but in most cases, the aquatic habitats are often destroyed. It was discovered that some samples of groundwater are known to have this suspended solids inside them with sample H having the highest value of 12, while samples C, E and G having the lowest value of 0. All the values were observed to be within the permissible limit of the recommendations of WHO (2004).

4.1.6 Total Suspended Solids

One of the biggest sources of water pollution in Nigeria is suspended solids. When these suspended particles settle to the bottom of a water body, they become sediments. Sediment and silt are words constantly used to refer to suspended solids. Suspended solids consist of both inorganic and organic fractions which are carried along by various water bodies, as it runs off the land. Both organic and the inorganic fractions are known to contribute to turbidity, or cloudiness of the water. Waters with high sediment loads are very obvious because of their ‘muddy’ appearance. Only sample A was discovered to have some suspended solids inside it. Suspended solids affect parameters, such as temperature and dissolved oxygen. The effect of excess chlorine in water is most observed in plants if within the maximum permissible limit of 100 mg/L.

4.2 Chemical Properties

4.2.1 Nitrogen

The most common gas within the air is nitrogen. About 80% of the air we breathe is nitrogen. This is found in the cells of all living things and is a major component of proteins. Inorganic nitrogen may exist in the free state as a gas (N_2), or as nitrate (NO_3^-), nitrite (NO_2^-) or ammonia (NH_3). Organic nitrogen is found in most protein compounds, and are continually recycled by plants and animals.

It was observed that sample H had the highest value of nitrate content (6.2) which was closely followed by sample F, while sample B had the lowest value of 0.3.

4.2.2 Nitrate Nitrogen

This indicates nitrogen content in the oxidized NO_3 form. Nitrate levels can be indicative of cumulative effects of contamination from wastewater systems, but may also be derived from rural activities and natural sources. Nitrates are available for use by plants and soil organisms and can also be removed from the soil to the atmosphere via natural denitrification and uptake by plants. As nitrates can be utilized by microbes and plants, they can be detrimental to natural waterways if levels get to high. Nitrates also can pose a potential health risk to babies as they can convert back to nitrites in the body, which can cause methemoglobinemia (Blue Baby Syndrome). It was observed that sample H had the highest value of 24.7, closely followed by samples F and G. It is important to note that none of the samples under consideration were within the recommended values of both WHO and NAFDAC of 0.2.

4.2.3 Electrical Conductivity

Electrical conductivity is said to be the measurement of an aqueous solution that carry an electrical current while ion is an atom of an element that has gained or lost an electron to create a negative or positive state. The presence of sodium chloride (table salt) in water which consists of sodium ions (Na^+) and chloride ions (Cl^-) held together in a crystal; when broken up into an aqueous solution of sodium and chloride ions will conduct electrical current. The equation shows:

Na (atom) + Cl (atom) $Na^+ Cl^-$ (ionic crystal)

$Na^+ Cl^-$ (in a water solution) = Na^+ (ion) + Cl^- (ion)

There are several factors that determine the degree to which water will carry an electrical current. These include the concentration or number of ions, mobility of the ion, oxidation state (valence) and temperature of the water. It was observed that the samples had values ranging from 80 and 510 which were below the maximum permissible limit of 1,000 μs/cm.

4.2.4 Water Hardness

The presence of multivalent metal ions (calcium and magnesium) which come from minerals dissolved in the water is known to cause hardness in water bodies. Hardness of water is dependent upon the ability of these ions to react with soap to form a precipitate or soap scum. The reaction of iron and manganese in fresh water may contribute to the hardness of such water for domestic use.

The most important impact of hardness is that it affects some ions such as lead, cadmium, chromium and zinc. Generally, the harder the water, the lower the toxicity of other metals to life. It was observed that for calcium hardness the values obtained ranged between 11.2 and 38 mg/L with all the samples within the permissible limit of 50 mg/L recommended by WHO and 75 mg/L recommendation of NAFDAC ,while the magnesium hardness was discovered to range between 16.8 and 57 mg/L which indicates that the same sample E had exceed the permissible limit of WHO of 50 mg/L. Only samples C, D and A were within the permissible limits of NAFDAC.

4.2.5 Iron

Making up at least 5% of the earth's crust, iron is one of the earth's most plentiful resources and it is believed to be because of its reaction with the other ions present within the water it is said to be the one of the most troublesome elements in water supplies. When iron was tested, the samples A, D and C had values of 0.18, 0.4 and 1.12, respectively, which were far higher than the recommend value by both WHO and NAFDAC. The other samples had their values within the NAFDAC and WHO limits. When the values of iron present in drinking water is far above the recommended values of WHO and NAFDAC, it is known to cause water turn into reddish brown.

The soluble ferrous iron and the insoluble ferric iron are the most common states, of which iron exists in water. Water containing ferrous iron is clear and colorless because iron is completely dissolved. With the presence of iron in water, when exposed to air any storage device, water turns cloudy and a reddish brown substance begins to form on its surface.

4.2.6 Alkalinity

Alkalinity of natural water is generally due to the presence of bicarbonates formed in reactions in the soils through which the water percolates and sometimes may also be attributable to carbonates and hydroxides. It is a measure of the capacity of the water to neutralize acids and it reflects its so-called buffer capacity (its inherent resistance to pH change).

There is a little known sanitary significance attaching to alkalinity (even up to 400 mg/L $CaCO_3$), though unpalatability may result in highly alkaline waters. It was discovered that all the parameters were within the recommended limits of WHO and NAFDAC.

Conclusion

Among eight water samples analyzed, except for a few of the parameters, all other samples were found to have their values within the standard values prescribed by WHO and NAFDAC.

It was also found that the water quality for some of the samples was contaminated due to lack of proper treatment thus endangering the lives of the consumers. Most of the wells/boreholes water within Minna is usually not tested to ascertain the quality of water that is delivered to public. In most cases, the location of most of these wells and boreholes do not follow the health specification in terms of seepage, as they are usually located around septic tanks and refuse dump areas which may account for poor physical and chemical properties of some of the parameters considered for.

It is therefore advised that relevant agencies be mobilized to supervise building construction works and point out areas where wells/boreholes can be dogged.

Recommendation: The safety of drinking water in our immediate surrounding has become a thing of paramount importance, as most sources of water are believed to be carriers of various diseases thus affecting human lives. From the findings of this study, it is recommended that:

- Various State governments in conjunction with Federal Ministry of Water Resources should provide good, clean and safe water for the people of Nigeria which will in turn reduce digging and drilling of boreholes which will also reduce the environmental risk of landslides.
- Various State governments should enact a law that will overlook the affairs of digging and drilling of boreholes across the country.
- Where wells/boreholes are constructed, relevant agencies should make available mobile laboratories which will enable them move from one home to another to perform spot checks.
- Medical and health institutions should be adequately equipped to meet various medical and health problems that may arise from the consumption of these products.

References

1. Ahmad M (2000), “Water Pricing and Markets in the Near East: Policy Issues and Options”, *Water Policy*, Vol. 2, No. 3, pp. 229-242.
2. Ajayi B (1996), “Industrial Pollution Control, Wemabod’s Giant Stride”, *Tell Magazine*, p. 23.
3. Byamukama D, Knasiime F, Mach R L and Farnleitner H (2000), “Determination of *Escherichia coli* Contamination with Chromocult Coliform Agar Showed a High Level of Discrimination Efficiency for Differing Faecal Pollution Levels in Tropical Waters of Kampala”, *Appl. Environ. Microbiol.*, Vol. 66, No. 2, pp. 864-868, Uganda.
4. Gleick P H (1996), “Basic Water Requirements for Human Activities: Meeting Basic Needs”, *Water International*, Vol. 21, pp. 83-92.

5. Goñi-Urriza M, Capdepuy M, Arpin C *et al.* (2000), "Impact of an Urban Effluent on Antibiotic Resistance of Riverine *Enterobacteriaceae* and *Aeromonas* spp.", *Appl. Environ. Microbiol.*, Vol. 66, No. 1, pp. 125-132.

6. Lawrence P, Meigh J and Sullivan C (2002), "The Water Poverty Index: An International Comparison", Keele Economics Research Papers 2002/19.

7. Musa J J and Egharevba N A (2009), "Soil Grouping of the Federal University of Technology, Minna, Main Campus Farm Using Infiltration Rate", *A. U. J. T.*, Vol. 13, No. 1, pp. 19-28.

8. National Agency for Food and Drug Administration and Control (NAFDAC) (2004).

9. Petrella R (2001), *The Water Manifesto*, Zed Books, London and New York.

Author pl chk ref 10 is not in text

10. Rapport D J, Epstein P R, Levins R *et al.* (1998), *Ecosystem Health*, Blackwell Science Inc. Malden, MA.

11. Renault D and Wallender W (2000), "Nutritional Water Productivity and Diets", *Agricultural Water Management,* Vol. 45, pp. 275-296.

12. Scanlon J, Cassar A and Nemes N (2004), "Water as a Human Right?", *IUCN Environmental Policy and Law Paper*, No. 51.

13. WHO/UNICEF (2004), "Meeting the MDG Drinking Water and Sanitation: A Mid-Term Assessment of Progress", WHO/UNICEF, ISBN: 92 4 156278 1, Geneva.

Reference # 30J-2011-06-0X-01