Assessment Of Water Quality From Hand Dug Wells In Samaru – Zaria. Nigeria

John Ameh Adakole, Fehintolu Folarin Adegbola and Asabe Christiana Luka

Abstract: Samaru (Zaria), located in Northern Nigeria is a semi urban university satellite-town with urban migration problem and resource limitations. Thus, a high proportion of the population is forced to rely on hand dug well water as source of drinking water. To ascertain the water's potability and seasonal variations, proximity of 10 hand dug wells to pollution sources were investigated during the late dry season (Feb. to June) and late rainy season (Sept. to Nov.), 2009. The physiochemical and bacteriological quality of the well water samples was analyzed using standard methods. The water was hard (188.92 ± 66.56 mg/L $CaCO_3$) and soft (61.80 ± 6.00 mg/L $CaCO_3$) during the dry and rainy seasons respectively. The mean NO_3-N was higher in dry season (84.34 mg/L) than during the rains (11.60 mg/L). However, the water's buffering capacity (alkalinity) was lower during the dry season (82.26 ± 71.03 mg/L $CaCO_3$) than during the rainy season (141.21 ± 54.08 mg/L $CaCO_3$) The mean dissolved oxygen obtained (4.71 mg/L) was higher than the west African sub region's mean (2.60 mg/L). Generally, the physicochemical parameters varied, but several of the values were within the WHO standards for drinking water. However, the ground water has very high concentrations of coliform bacteria, varying between 478 and > 1600 MPN /100 ml of water. This is higher than the WHO's stipulated (0/100 ml) for drinking water. The coliforms isolated from the water samples were identified as E.coli, Entrobacter sp and Klebsiella sp. The high population of coliform bacteria indicates poor sanitary conditions in the study area, arising from poor handling of domestic wastes, especially garbage and sewage. The aquifer is thus contaminated and the groundwater, therefore, is not potable without treatment.

Keywords: groundwater, potability, physichochemical parameters, bacteria, contamination.

Riassunto: *Samaru (Zaria), situata nel Nord della Nigeria, è una città universitaria satellite con problemi di migrazione urbana e risorse idriche limitate. Un'alta percentuale della popolazione è costretta a fare affidamento su pozzi scavati a mano come unica risorsa di acqua per uso umano. Per accertare la potabilità dell'acqua e come questa varia durante le stagioni, sono stati studiati 10 pozzi scavati a mano vicini a fonti di inquinamento durante l'ultima stagione secca (da Febbraio a Giugno) e durante l'ultima stagione delle piogge (da Settembre a Novembre) nell'anno 2009.*
La qualità fisico-chimica e batteriologica dei campioni di acqua prelevati dai pozzi è stata analizzata usando metodi standard. L'acqua era dura (188.92 ± 66.56 mg/L $CaCO_3$) e dolce (61.80 ± 6.00 mg/L $CaCO_3$) rispettivamente durante la stagione secca e quella piovosa. Il valore medio NO_3-N era più alto nella stagione secca (84.34 mg/L) che durante quella piovosa (11.60 mg/L). Tuttavia, la capacità tampone dell'acqua (alcalinità) era più bassa durante la stagione secca (82.26 ± 71.03 mg/L $CaCO_3$) che durante quella piovosa (141.21 ± 54.08 mg/L $CaCO_3$). Il valore medio dell'ossigeno disciolto che si otteneva (4.71 mg/L) era più alto di quello della media delle sub regioni dell'Africa occidentale (2.60 mg/L).
Generalmente, i parametri fisico-chimici variano, ma alcuni valori risultavano entro gli standard WHO per l'acqua da bere. Tuttavia, la falda ha un'alta concentrazione di batteri coliformi, che varia tra 478 e > 1600 MPN/100 ml di acqua. Questo valore è più elevato di quello definito dal WHO (0/100 ml) per l'acqua da bere. i coliformi isolati nei campioni di acqua sono risultati essere E.coli, Entrobacter sp and Klebsiella sp. L'elevata prolificazione di batteri coliformi indica cattive condizioni sanitarie nell'area studiata, derivanti dalla cattiva gestione dei rifiuti domestici, specialmente spazzatura e acque reflue. L'acquifero viene così contaminato e le acque sotterranee, dal canto loro, risultano non potabili se non trattate.

John Ameh ADAKOLE, Fehintolu Folarin ADEGBOLA and
Asabe Christiana LUKA
Department of Biological Sciences,
Ahmadu Bello University,
Zaria - Nigeria

John Ameh ADAKOLE
Email: drjaadakole@yahoo.com

Received: 29 august 2010 / Accepted: 18 november 2010
Published online: 31 december 2010

Introduction

Most of the water requirement for Samaru, Zaria is met from surface and ground water supplies. Samaru located in north central Nigeria, has urban migration problems and resource limitations. Thus, as found in many Nigerian towns, a certain proportion of the population is force to rely on hand dug well water for drinking and other domestic uses. According to Asonye et al. (2007), availability of safe and reliable source of water is an essential prerequisite for sustained development. However, high population growth of Samaru, coupled with poor development plan, chronic unhygienic habits and lack of enforcement of regulations have served collectively as recipe for environmental pollution. The availability and purity of groundwater are affected by location, construction and operation of wells (Egbulem, 2003). Due to lack of guidelines governing groundwater exploitation being not properly enforced in Nigeria (Eduvie et al., 2003), community wells meant to serve the growing population are often left uncovered. Furthermore, inadequate and inefficient tap pipe borne water supply has resulted to construction of wells that have close proximity to pit latrines, household trash, gutters (waste

DOI 10.4409/Am-017-10-0018

water channels) and therefore prone to storm water.

Dauda (1993) and Yerima et al. (2008) observed that as surface water becomes increasingly polluted, people turn to groundwater for alternative supplies. Therefore the development and efficient management of groundwater resources is of particular concern in Africa, Middle East and Latin America, particularly the Sudano-Sahelian belt (WHO, 2000). In these areas, not only is there relative scarcity of water resources and quality degradation but also they face high evaporation rates and high levels of anticipated future demands (Offodile, 2002)

Variations in groundwater physico-chemical characteristics are more pronounced during the dry season probably due to evaporation (Gelinas et al., 1996). Dug wells are generally the worst groundwater sources in terms of faecal contamination, and bacteriological analysis serves primarily to demonstrate the intensity of contamination and hence the level of the risk to the consumer (WHO, 1997; Chiroma et al., 2007). However, groundwater is generally a very good source of drinking water because of the purification properties of the soil (Langenegger, 1994).

For a water supply, precise evaluation of quality can be made only when the results of laboratory examinations are interpreted in light of sanitary survey data (APHA, 1998; WHO, 1997). Thus, after a sanitary survey, the current investigation evaluates the physico-chemical and bacteriological quality of Samaru groundwater during the late dry and late rainy seasons.

Materials and Methods

Study Area and Sampling

The study area, Samaru-Zaria is underlain by rocks of a basement complex (igneous and metamorphic) of the Precambrian age. The complex is composed of granodiorite, biotite granite, granite igneiss, schist and quartize. They are usually overlain by the overburden materials except in few places where they are exposed as inselbergs, whalebacks and platforms. The ground is sandy-clay-loam and permeable. The principal sources of groundwater in Samaru-Zaria are the fractured crystalline and unconsolidated overburden aquifers. The overburden unit has an average thickness of about 50 m. Groundwater occurs at shallow depths under unconfined to semi-confined conditions. Water levels in wells could drop to about 19 m below the ground surface at the peak of the dry season (Alagbe, 2002).

Samara – Zaria is approximately within latitudes 11°09'30.99"N and longitude 7°38'15.68 to 7°39'20.68"E (Figure 1). Samaru

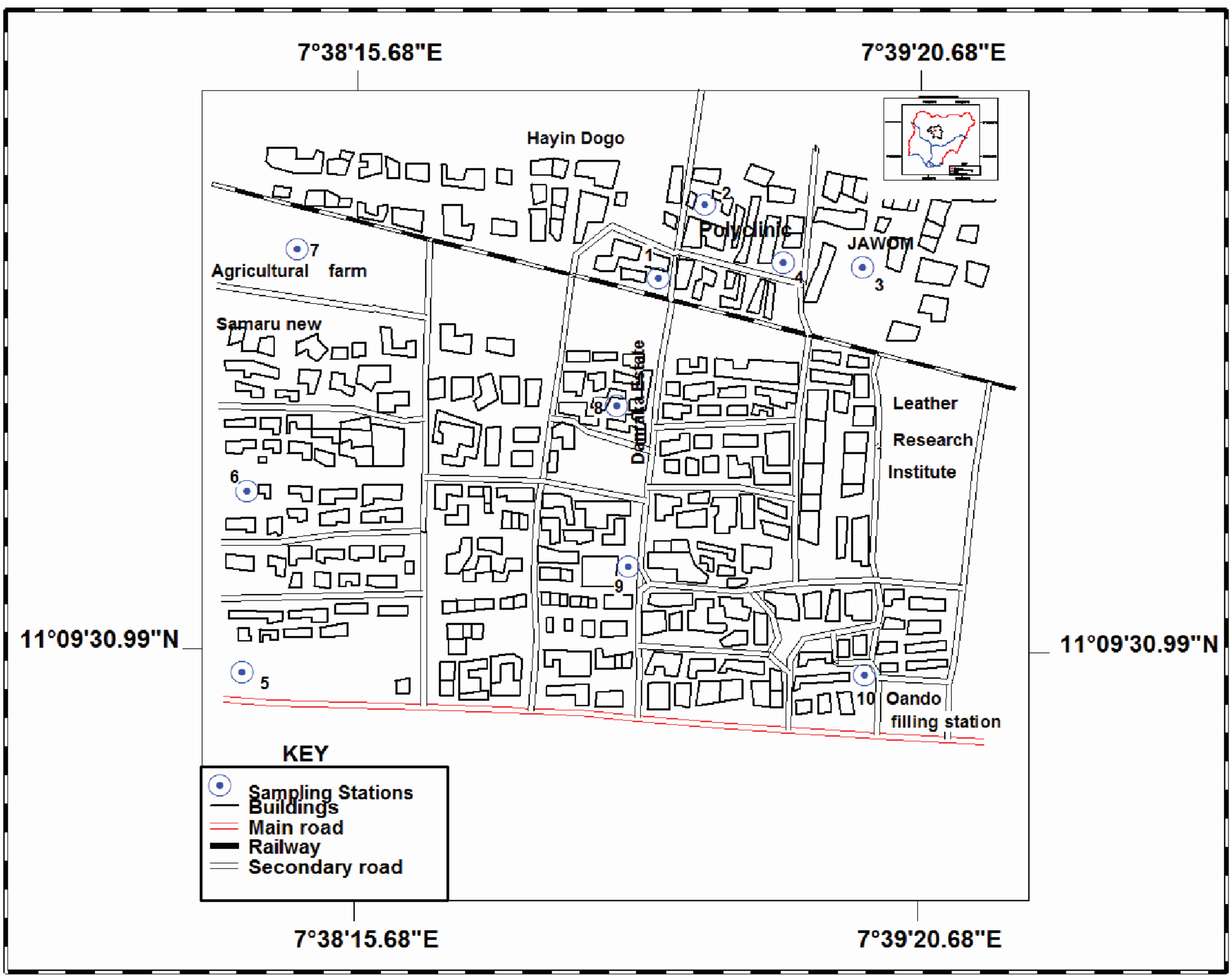

Fig. 1: *Samaru - Zaira showing locations of sampling stations. Source: adapted and modified from Samaru street map*

(Zaria), located in the Northern guinea savanna zone of Nigeria, has two main seasons (rainfall and dry). It was planned as a semi urban University satellite town but because of neglect over the years, slums and uncoordinated residential buildings sprang up. A railway across Samaru divides the town into two parts. The dug-well waters are used mainly for domestic and irrigation purposes. Heaps of refuse dumps, stagnant water in pools or in gutters and pit 'laterines' could be found in close proximity to the wells. Plastic or rubber pails attached to a rope that are used for drawing water are left lying on the ground between uses. Based on a preliminary survey, 10 hand dug-wells (sampling stations), with mean depth of 12.66 ± 1.76 m and mean diameter of 0.85 ± 0.21 m were chosen for the purpose of carrying out the set objectives. 6 stations were located south of the railway road while 4 were located on the Northern part. Of the 10 wells sampled, 4 were public wells, 5 were located in private/residential compounds while 1 was located on a hospital compound.

In each station, duplicate water samples were collected monthly for physico-chemical analysis for a period of 5 months (February - June 2009) and three months (August – October, 2009). Bacteriological analysis was separately carried out at the end of dry and rainy seasons. Samples were collected aseptically, taken to the laboratory and analysis carried out within 2 - 4 hours of collection.

Sample analysis

Bacteriological examination of the water sample carried out includes Most Probable Number (MPN) of presumptive coliforms (MPN/100 ml water) using the Multiple Tube Fermentation Technique (WHO, 1997; APHA, 1998). Suspected colonies of coliform groups were also identified on the basis of morphological, cultural and biochemical characteristics (Seeley and Denmark, 1971; Health Canada, 2006)

Water temperature was determined with a mercury thermometer, pH and electrical conductivity by using conventional meters (Lind, 1979). TS, TDS, TSS and CO_2 were analyzed following standard methods (APHA, 1998). Optical density, PO_4-P and NO_3-N using spectrophotometer while DO, BOD, total hardness, total alkalinity and chloride were evaluated by burette titration.

Results and discussion

Statistical summary of the results obtained is as shown in table 1, while the bacteriological variation among the sampling sites is presented in Figure 2. Analysis of variance for DO, PO_4-P, TS, TSS and optical density revealed that the variation between the monthly

Tab. 1: *Summary of Samaru hand-dug well water quality in comparison with WHO drinking water guidelines.*

Parameter	Seasonal means		Grand mean	Highest	Maximum permissible level
	Dry	Rainy	± SD	desirable level	
Water temperature (°C)	26.16	26.5	26.33 ± 0.89	-	-
Elect. Conductivity (µS/cm)	559.5	635.6	597.60 ± 229.32	-	-
Total dissolved solids (mg/L)	291.04	319.6	305.30 ± 233.09	500	1500
Total suspended solids (mg/L)	143.2	254.2	198.70 ± 88.48	-	-
Total solids(mg/L)	421.02	573.8	497.40 ± 263.52	-	-
Water pH	6.75	6.8	6.77 ± 0.34	7 - 8.5	6.5 - 9.2
Optical density	0.51	0.31	0.41 ± 0.14	-	-
Carbon dioxide (mg/L)	25.84	21.5	23.67 ± 13.06	-	-
Dissolved oxygen (mg/L)	5.52	3.9	4.71 ± 3.19	--	-
B.O.D.(mg/L)	4.17	1.3	2.73 ± 3.02	-	-
Total hardness (mg/L $CaCO_3$)	188.92	61.8	125.40 ± 89.88	100	500
Total alkalinity (mg/L $CaCO_3$)	82.26	105.23	93.74 ± 11.42	-	-
Phosphate-phosphorus (mg/L)	0.15	0.64	0.40 ± 0.08	-	-
Nitrate-nitrogen (mg/L)	43.24	5.8	24.52 ± 22.95	10	12
Chloride (mg/L)	80.06	52.7	66.38 ± 19.34	200	600
Total coliforms (MPN index/100 ml)	1600	479	1039 ± 793	0/100 ml	0/100 ml
Escherichia coli (Col./100 ml)	18	20	19 ± 1.00	0/100 ml	0/100 ml
Enterobacter sp (Col./100 ml)	12	10	11 ± 1.00	0/100 ml	0/100 ml
Klebsiella sp (Col./100 ml)	14	11	13 ± 2.00	0/100 ml	0/100 ml

DOI 10.4409/Am-017-10-0018

means were highly significant ($P < 0.05$) while the difference between the stations were not significant ($P > 0.05$). For TS, TDS, TSS, optical density, electrical conductivity, CO_2, total hardness, total alkalinity, DO, BOD, chloride, NO_3-N and PO_4-P there were high significant variation ($P < 0.01$), both between the seasonal means. The mean groundwater temperature (26.33 ± 0.89°C) aggress with the findings of Langeneger (1994), who reported that the West African subregion mean annual groundwater temperature variations are small, with mean deviations of 0.5°C to 1.5°C. The mean pH (6.77 ± 0.34), falls within the pH range (6.5 - 8.5), recommended for drinking water (WHO, 1996). The slight pH fluctuation recorded between the wells indicates that Samaru wells draws water from the same aquifer. The concentration of DO in groundwater from hand pump equipped wells in West African subregion is usually between 0.7 and 4.5 mg/L (Langeneger, 1994). The mean DO (4.71 ± 3.19 mg/L) obtained is higher than normal (DO > 4.5 mg/L) for West African groundwater. Presumably because a significant quantity of oxygen was introduced during sampling. Gelinas et al. (1996) made similar findings on some Republic of Guinean wells. The high dissolved oxygen obtained could also be attributed to the shallow nature of Samaru wells, which could have made aeration easy.

The BOD value obtained ranged as low as 0.10 mg/L in the dry season to as high as 9.80 mg/L at the onset of the rains and dropping to as the rainy season progresses to mean rainy season of 1.31 ± 0.05 mg/L. BOD is used as an approximate measure of the amount of biochemical degradable organic matter present in a sample (WHO, 1996). The high BOD at the onset of rains could be attributed to the high organic load at the wells' surrounding which could had been washed into the wells by runoffs. This is because most of the wells do not have walls above the ground. Free carbon dioxide also followed a similar pattern as the BOD. This could be attributed to the fact that decomposition of high organic matter in the topsoil resulted in the formation of CO_2 via microbiological processes in the topsoil. According to Langenegger (1994), this CO_2 enriched air in the interstices of the microbiologically active vadose zones are usually picked up by rain water as it percolates downward through the zone on its way to the aquifer. The mean electrical conductivity obtained during this study is 597.60 μS/cm. Langenegger (1994) and Adakole (2007), stated that electrical conductivity is not a good indicator of water quality with regards to health hazards. It is however, an indicator of salinity, which is an important factor in taste and taste is an important factor in user acceptance of water points.

World Health Organization does not directly consider electrical conductivity in guidelines for drinking water quality (WHO, 1984), but it does give recommendations for dissolved solids because of taste considerations. The TS, TDS and TSS obtained in dry season were low while higher values were obtained during the rainy season. The mean TDS obtained was 305.30 ± 233.09 mg/L. Ground water with TDS < 600 mg/L (electrical conductivity of about 850.00 μS/cm), is considered "good", while groundwater with TDS > 1200 mg/L (electrical conductivity of about 1700.00 μS/cm) becomes progressively less palatable. The WHO guideline value for TDS in drinking water is 1000 mg/L (electrical conductivity of about 1400.00 μS/cm).

Optical density is a function of turbidity. The mean optical density obtained is 0.41. According to Langenegger (1994), turbidity does not have effect on health but high turbidity reduce the effectiveness of disinfection procedure because microorganisms can be protected from disinfection by suspended materials. In addition, turbid water is less acceptable to consumers from an aesthetic viewpoint.

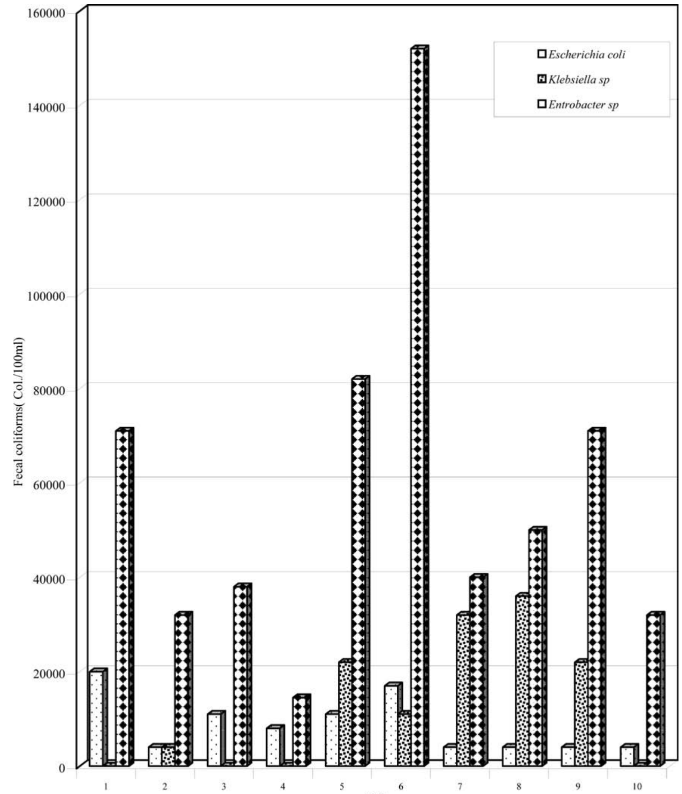

Fig. 2: *Mean variations in feeal coliforms in selected dug- wells of Samaru - Zaria.*

The WHO drinking water guideline value for total hardness is 500.00 mg/L $CaCO_3$. However, this is not based on health considerations but on "taste and household-use" (WHO, 1984). A mean total hardness value of 125.40 ± 89.88 mg/L $CaCO_3$ was obtained during this study period. Based on WHO standard for water hardness, Samaru well water has a good taste and is also good for household uses. According to Lind (1979), the expected total alkalinity in natural water usually ranges from 20.00 to 200.00 mg/L $CaCO_3$. During this study on Samaru groundwater, a range of 10.00 to 323.00 mg/L $CaCO_3$ and a mean of 141.29 mg/L $CaCO_3$ were obtained. Stations 1, 7 and 10 recorded higher values throughout the study period, presumably due to poor maintenance of these wells.

The mean PO_4-P (0.64 mg/L) obtained is higher than the drinking water limit (0.2 mg/L) set by Canada. The only well with close proximity to farmlands (Station 7) persistently recorded higher NO_3-N values than other stations throughout the study period. It recorded as high as 1368.00 mg/L NO_3-N. Groundwater nitrates in agricultural areas are usually known to originate from fertilizers while in non-agricultural area; groundwater nitrate could be attributed to disposal of human excreta and domestic sewage. This observation concur with those of Gelinas et al. (1996), who also reported that after a long period of dryness (about 6 months), high quantities of nitrogen are accumulated in the superficial layers of the ground. At the beginning of the raining season, a high proportion of this nitrogen is leached and reaches the aquifer as soluble nitrate. The very high concentrations of NO_3-N value measured in the well water are worry some, considering that the values were obtained during the dry season and the onset of the rains (period of water scarcity). The mean value obtained during this study is many times greater than the standard of 10.00 mg/L NO_3-N (45.00 mg/L NO_3-) for drinking water. According to Lind (1979), NO_3-N value greater than 20.00 mg/L in drinking water could cause methemoglobinemia. The chloride value obtained ranged between 7.0 - 163.45 mg/L. However, this range is below the permissible criteria (250.00 mg/L) for raw water. The higher chloride values at stations 2, 7 and 9 could be a direct consequence of the proximity of these wells to pit "latrines" and wastewater channels ("gutters"). According to APHA (1998), chloride (Cl^-) concentration is higher in wastewater (sewage) than in raw water because sodium chloride (NaCl) is a common article of diet and passes unchanged through the digestive system.

In addition to the guideline values for un-piped water supplies (0 fecal coliform organisms per 100 ml), WHO recommends that coliform organisms should not occur repeatedly (WHO, 1986). However, this level cannot be reached without an adduction system and/or a treatment of the water. To simplify the interpretation of the high counts measured in open wells of developing countries, Feachem (1980), proposed a division into three categories corresponding to the relative quality of the water: >100 fecal coliforms/100 ml should be considered satisfactory; between 100 and 1000 col./100 ml suggests a strong contamination and risks to health; and above 1000 col./100 ml, the water should be considered seriously pathogenic. The bacteriological analysis of Samaru groundwater reveals that the aquifer/groundwater has very high concentration of coliform bacteria varying between 478 to > 1600 col./100 ml. A mean total of 85 bacteria comprising of 44 and 41 organisms for dry and rainy seasons respectively were isolated from the well water. These were typed to be 38 Escherichia coli, 22 Enterobacter sp and 25 Klebsiell sp. These bacterial species had been previously isolated from well water source, although with varied densities (Byamukama et al., 2000; Chiroma et al, 2007; AlOtalbi, 2009). These situation is assumed to be a direct consequence of close proximity of the wells to toilets, poor maintenance and shallow nature of the wells. Rahman (1996), also reported that groundwater from various parts of Karachi city (Pakistan) indicated the presence of coliform and fecal bacteria several magnitudes higher than any standards permit, due to poor sanitation services.

Conclusion

Due to widespread nitrate-nitrogen and bacteriological contamination of Samaru-Zaria dug-well water, its long-term use as a major drinking water source could have an impact on the health of the inhabitants. Although it appears that poor well maintenance is the main factor contributing to the bacteriological contamination, and that nitrate contamination is more closely linked to infiltration of organic contaminants from the soil surface, a thorough hydro-geological study and a careful determination of the contaminant pathways must be investigated before any definitive conclusion is drawn.

Standards for location, construction and operation of wells, if enforced, will help in reducing pollution/contamination problems. However, for now, we suggest that the well water should be treated before use. Simple methods like sieving, addition of aluminum or ferric hydroxide and disinfection with chloride could be employed. This will help to reduce the risk the water may likely cause to human health.

References

Adakole J.A. (2007) - Bacteriological quality of an urban stream in Northern - Nigeria. Journal of Aquatic Sciences, 22(1): 1 - 10

AlOtalbi E.S.(2009) - Bacteriological assessment of urban water sources in Khamis Mushait Governorate, southwestern Saudi Arabia. International Journal of Health Geographics. 8(6): 8 – 16

Alagbe S.A. (2002) - Groundwater resources of river Kan Gimi Basin, north-central, Nigeria. Environmental Geology(42): 4, 404-413.

APHA (1998) - Standard methods for the examination of water and wastewater . 20th edition. American Public Health Association, New York. 1268pp.

Asonye C.C., Okolie N.P., Okenwa E.E. and Iwuanyanwu U.G. (2007) - Some physico-chemical characteristics and heavy metal profiles of Nigerian rivers, streams and waterways. African Journal of Biotechnology Vol. 6 (5), pp. 617-624

Byamukama D., Kansiime F., Mach R.L. and Farnleitner A.H (2000) - Determination of Escherichia coli contamination with chromocult Coliform agar showed a high level of discrimination efficiency for differing fecal pollution levels in tropical waters of Kampala, Uganda . Appl. Envir. Microbiol. 66(2)864 - 868.

Chiroma T.M., Ugheoke B.I., Patrick D.O. (2007) - Environmental Impact on the Quality of Water from Hand-Dug Wells in Yola Environs Journal: Leonardo Journal of Sciences 6(10): 67-76

Dauda A.M. (1993) - A comprehensive approach in water resources management for the 21st century. Environmental bullets. Vol. 12. Nigeria

Eduvie M.O., Olabode T. and Yaya O.O. (2003) - Assessment of groundwater potentials of Abuja environs. Proceedings of the 29th Water, Engineering and Development Centre - UK. (WEDC) International conference, held in Abuja – Nigeria. Published by WEDC, London. Pp185 – 187.

Egbulem B.N. (2003) - Shallow groundwater monitoring. Proceedings of the 29th Water, Engineering and Development Centre - UK. (WEDC) International conference, held in Abuja – Nigeria. . Published by WEDC, London. Pp188 – 189.

Feachem R.G. (1980) - Bacterial standards for drinking water quality in developing countries. The Lancet August. 2, 255 - 256.

Gelinas, Randall H., Robidous L. and Schmit J.P. (1996) - Well water survey in two districts of Conakry (Republic of Guinea), and comparison with the piped city water. Wat. Res. 30(9) 2017 - 2026.

Health Canada (2006) - Guidelines for Canadanian Drinking water quality: Guideline Technical Document – Escherichia coli. Water Quality and Health bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Langengger O. (1994) - Groundwater quality and handpump corrosion in West Africa. UNDP-World Bank water and sanitation program Report series. No. 8 Washington D.C., U.S.A. 158pp.

Lind O.T. (1979) - A handbook of common methods of water analysis for limnology. C.V.Moshy publishers, St.Loius, U.S.A. 69pp.

Offodile M.E. (2002) - Groundwater study and development in Nigeria University of Ibadan Press. Nigeria.

Rahman A. (1996) - Groundwater as a source of contamination for water supply in rapidly F growing megacities of Asia : Case study of Karachi, Pakistan. Wat. Sci. Tech.34, (7-8), 285 - 292.

Seeley H.W. and VanDemark P.J.(1971) - Microbes in action: a laboratory manual of microbiology. 2nd edition. Heyden press. London. 361pp.

W.H.O.(1984) - Guidelines for drinking water quality. Vol.1. Recommendations. Geneva : World Health Organization. 125pp.

WHO (1996) - WHO guideline values for contaminants in water: Guidelines for Drinking-Water Quality - Second Edition - Volume 2 - Health Criteria and Other Supporting Information 971pp.

WHO (1997) - World Health Organization: Guidelines for drinking-water quality Surveillance and control of community supplies. WHO Library Cataloguing in Publication Data. Drinking water, Standards, Data collection, Methods and Guidelines for Developing countries I. ISBN 92 4 154503 8 (v. 3) (NLM Classification: WA 657. Second Edition. Volume 3. World Health Organization Geneva. 250pp

Yerima F.A. K., Daura M.M and Gambo B.A. (2008) - Assessment of groundwater quality of Bama town, Nigeria. Journal of sustainable development in Agriculture and Environment. 3(2): 128 – 137.

DOI 10.4409/Am-017-10-0018