Underground Water Assessment using Water Quality Index

J. Yisa
Federal University of Technology Minna

Jimoh Tijani Oladejo
Federal University of Technology Minna

Underground Water Assessment using Water Quality Index

Jonathan YISA*, Tijani Oladejo JIMOH, and Ohiemi Michael OYIBO

Chemistry Department, Federal University of Technology, Minna, Niger State, Nigeria.
E-mail*: teejayola01@yahoo.com
*Corresponding author: +2348057344464

Abstract

This study was designed to assess the quality of selected hand dug wells in Maikunkele area of Niger State, Nigeria using Water Quality Index (WQI). Ten hand dug wells were randomly selected in Maikunkele area of Bosso Local Government and were tested for nine (9) parameters of National Sanitation Foundation (NSF) using standard analytical procedures. WQI results indicated that the quality of the selected well water samples were medium except for sample 2 that was extremely bad. The findings also revealed that all the samples except samples 2 and 3 had high coliform levels as high as 91 coliform/100cm^3. This was an indication of faecal contamination substantiating the proximity of some of the wells to septic systems. The nitrate levels in all the samples exceeded the Maximum Contaminant Level (MCL) of WHO, EPA, APHA and the Nigerian Drinking Water Standards. Based on the results obtained, the quality of the well water samples was therefore not suitable for human consumption without adequate treatment. Regular monitoring of groundwater quality, abolishment of unhealthy waste disposal practices and introduction of modern techniques were highly recommended.

Keywords

Quality; Assessment; Well water; Maikunkele; Water Quality Index.

Introduction

Water is one of the most indispensable resources hence life is not possible on this planet without water. Recent research conducted by [1] showed that there was an increase in the demand for freshwater due to rapid growth of population as well as the accelerated pace of industrialization in the last few decades. This demand has led to the use of ground water not only for its wide spread occurrence and availability but also for its constituent good quality which makes it ideal supply of drinking water [2]. The supply of fresh water to Nigerians has been inadequate and forced inhabitants to resort to drinking water from wells [3]. People around the world have used ground water as a source of drinking water and even today more than half the world's population depends on ground water for survival [2]. Groundwater has long been considered as one of the purest forms of water available in nature and meets the overall demand for rural and semi-rural people [4]. This was considered as the major source of water for human activities (consumption inclusive) especially in the rural area [5].

However, the large scale industrial growth has caused serious concerns regarding the susceptibility of groundwater contamination due to discharge of waste materials. Waste materials near factories are subjected to reaction with percolating rain water and therefore reach the aquifer system and as such degrade the groundwater quality [4]. Contaminants also find their way into ground water through activities like seepage of municipal landfills, septic tank effluents etc. Indiscriminate dumping of waste can be serious in cities lacking efficient waste disposal system or treatment plants and this we found in most cities in Nigeria especially Maikunkele area in Niger State [6].

Furthermore, it is of prime importance to have prior information on the quality of water resources available which will aid planning developmental projects. [7] reported that once ground water is contaminated, its quality cannot be restored. It therefore becomes imperative to protect it in other to prevent water borne diseases such as typhoid, cholera, diarrhea and dysentery which are potentially communicable [8, 9].

Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers [1]. It thus, becomes an important parameter for the assessment and management of surface water. WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of surface water for human consumption

[10]. Water Quality Index (WQI) provides a single number (like a grade) that expresses the overall quality of water at certain location and time based on several water quality parameters The objective of this research is to evaluate the quality of selected hand dug wells samples in Maikunkele district of Bosso Local Government area Niger State and to determine its suitability for drinking purpose using Water Quality Index.

Materials and Method

***Description of the Study Area*:** Bosso Local Government, with Maikunkele as Local Government Headquarters was created from the former Chanchaga Local Government of Niger State in the year 1991 by Former Nigeria President Ibrahim Badamasi Babangida. It is located along the Minna-Zungeru Road at longitude 9° 38' 0" North and latitude 6° 25' 0" East. It has an approximate population of 9599 who are predominantly Gwari, Nupe, Yoruba and Igbo. The soil of Maikunkele, belongs to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks [11]. Just like any other towns in Nigeria, Maikunkele experiences two seasons, the wet and dry seasons. The average annual rainfall is about 1,400mm. The duration of the rainy season is approximately 180 days. Mean average temperature hovers around 32°F, particularly in March and June. December and January have the mean lowest temperatures.

Ten wells samples were randomly picked in Maikunkele District of Bosso Local Government area of Niger State. The locations of the sampling points were spread within the length and breadth of the community. All samples were collected same day and kept in two litres rubber bottles, which was previously washed with 10% HNO_3 and 1:1 HCl for 48 h. The rubber bottles were labeled and immediately few drops of HNO_3 was added in order to prevent loss of metals, bacterial and fungal growth. Temperature, turbidity, and pH of water samples were also measured at the time of collection.

The ten well water samples were analyzed for nine parameters: pH, Turbidity, temperature, Total suspended solids, phosphate, nitrates, Biochemical oxygen demand, and Faecal coliform count. The [12] procedure was adopted for the determination of these physico- chemical parameters. The statistical analysis was done for correlation using SPSS 12:0. Water quality index was calculated from the point of view of suitability of the water for human consumption as seen below. The Water Quality Index (WQI) was calculated using the National Sanitation Foundation (NSF) water quality index. This index has been widely field and applied to data from a number of different geographical areas all over the world to calculate WQI for various water bodies.

Mathematical expression for NSF WQI is given by

$$\text{NSF WQI} = \sum_{i=1}^{p} W_i Q_i$$

where Q_i is the sub-index for i_{th} water quality parameters; W_i is the weight in terms of importance associated with i_{th} waters quality parameter; p is the number of water quality parameters.

Results and Discussion

The physico-chemical properties obtained for each sample are presented in Table 1.

Table 1. Results of the Physico-chemical properties for the Ten well samples investigated

Sample	Dissolved Oxygen (%sat)	Faecal Coliform (count/100 cm^3)	pH	Biological Oxygen Demand (mg/L)	Temperature (^0C)	Nitrates (mg/L NO_3-N)	Phosphate (mg/L PO_4^{3-}-P)	Turbidity (NTU)	Total Suspended Solids (mg/L)
1	5.51	24	5.84	4.42	28.30	4.20	0.015	27.00	18
2	5.08	0	5.81	3.84	27.60	3.10	0.003	16.96	8
3	4.92	0	6.11	1.71	29.20	0.002	0.001	3.25	3
4	6.29	2	6.37	6.64	30.00	2.30	0.001	1.97	9
5	5.84	4	6.43	4.97	28.47	1.40	0.002	1.50	7
6	5.68	5	6.34	2.32	28.00	0.05	0.0015	0.32	0
7	6.31	8	6.49	3.42	31.00	1.20	0.002	6.10	15
8	6.40	59	6.66	2.94	29.32	1.10	0.006	4.38	14
9	4.14	42	6.83	3.50	27.78	3.20	0.001	31.20	58
10	5.88	91	6.76	4.20	30.42	1.50	0.002	8.81	15

From Table 1, the coliform count/100 cm^3 of the investigated samples revealed that apart from sample 2 and 3 which showed zero count, others have coliform count as high as 91/100 cm^3 count which could probably due to contamination of faecal origin. These values are above the [14-15] minimal contaminant level (MCL) recommended value of 0/100 cm^3 of sample [16] and [17]. Another plausible reason for this occurrence may be due to the fact that most of the wells were unprotected without lids and concrete linings. The sampling environments were located very close to septic systems and refuge dump sites. Hence such samples which had high coliform count were not fit for drinking because its potential risk of cholera, diarrhoea and other associated diseases. This is in agreement with the result obtained by [1, 7, 18, 19].

Correlation matrix of parameter associated to water quality is presented in Table 2.

Table 2. Results of the correlation coefficient matrix of water quality parameters

	Dissolved Oxygen	FC	pH	BOD	Temperature	Nitrates	Phosphate	Turbidity	TSS
Dissolved Oxygen	1.000								
FC	-.229	1.000							
pH	.124	.547	1.000						
BOD	.340	.064	.007	1.000					
Temperature	.659	.137	.382	.183	1.000				
Nitrates	-.301	.302	-.285	.528	-.341	1.000			
Phosphate	.076	.127	-.456	.039	-.212	.549	1.000		
Turbidity	-.662	.501	-.118	.043	-.461	.833	.477	1.000	
TSS	-.565	.610	.481	.051	-.200	.532	.032	.777	1.000

Table 3. Weighted mean for the nine WQI parameters (Source [13])

Factor	**Weight (W_i)**
Dissolved Oxygen	0.17
Faecal Coliform	0.16
pH	0.11
Biochemical Oxygen Demand	0.11
Temperature Change	0.10
Phosphate	0.10
Nitrates	0.10
Turbidity	0.08
Total Suspended Solids	0.07

The Q-values were obtained from the graphs.

The pH results showed that only sample 1 and 2 were below the tolerable limit of the Nigerian Drinking Water Standards, APHA and WHO standards of 6.5 - 8.5. This means that they were slightly acidic, soft and corrosive. Drinking water with a pH level above 8.5 could indicated that the water was hard. Hardness did not pose a health risk, but could caused aesthetic problems, such as difficulty in getting soap and detergent to foam and lowered efficiency of electric water heaters. All the samples were highly turbid.

Table 4. Results of the samples and their Water Quality Indexes (WQI)

Sample	WQI	Quality
1	50.88	Medium
2	44.03	Bad
3	52.91	Medium
4	61.47	Medium
5	61.83	Medium
6	63.21	Medium
7	61.07	Medium
8	61.31	Medium
9	55.65	Medium
10	59.11	Medium

Table 5. Water Quality Index Legend (source [13])

Range	Quality
90 – 100	Excellent
70 – 90	Good
50 -70	Medium
25 – 50	Bad
0 – 25	Very bad

The results exceeded the Nigerian Drinking Water Standard Maximum Permissible Limit of 5 NTU, APHA's MCL of 0.5 NTU, and Environmental Protection Agency MCL of 1 NTU with sample 1 having as high as 17 NTU. This also agreed with the findings of [1, 19, 20]. High turbidity indicated high risk to disease causing microorganisms such as viruses, parasites and some bacterial and carriers of variety of materials such as pesticides, heavy metals. The suspended particles absorb heat from the sunlight, making turbid waters become warmer, and so reducing the concentration of oxygen in the water.

The nitrate level of the investigated samples was low. They fall below the MCL for the Nigerian Drinking water standards, WHO, and APHA which was 10 mg/L NO_3-N or 50 mg/L NO_3. This corroborated with the previous studies reported by [7, 18, 19, 25, 27]. Temperature in all the samples was found to be high. High temperature in drinking waters leads to low oxygen because the rate of dissolution of gases in water decreases with increasing temperature and low oxygen in water affects the taste and other aesthetic property of water. Dissolved Oxygen in all the samples exceeds 2 mg/L or 1.5 % Sat which was the MCL of the Nigerian Drinking Water Standard and the WHO. Oxygen is necessary in sufficient quantity to give the taste required in water. Total Suspended Solids in the samples did not exceed the 500 mg/L U.S. EPA and secondary standard. This was probably because there are no activities such as construction that will allow the quick influx of sediment into groundwater via overland flow. The suspended particles clouding the water may be due to such inorganic substances as clay, rock flour, silt, calcium carbonate, silica, iron, manganese, sulfur, or industrial wastes. Again, the clouding may be caused by organic substances such as various microorganisms, finely divided vegetable or animal matter, grease, fat, oil, and others.

Phosphorous levels in the well samples were negligible with none exceeding 0.1 which is far below the MCL of the Nigerian Drinking Water Standard and the World Health Organization (WHO).

The obtained results were subjected to correlation analysis as shown in Table 2 and the nine parameters shows no correlation. This agrees with the findings of [5, 21, 22]. The overall WQI indexes according to the NSF WQI legend showed in Table 5 and 6 revealed that only sample 2 was bad and all other samples were of medium quality. This observation is in line with what was reported by [26, 27].

Conclusions

From the information deduced from this study using water quality index, sample 2 was found to be bad while other were within the medium range. This was due to the environments in which these well samples were situated, some were very close to septic systems and 80% of the wells were without cover, equally some of them do not extend above the ground. These water samples were not fit for drinking without proper treatment.

Acknowledgements

The authors wish to express their unreserved gratitude to Mal. Jamilu Ringim of the

Quality Control Department, Upper River Basin, Federal Ministry of Water Resources, Niger State, Nigeria who was of great help in the Chemical analysis aspect of this work.

References

1. Yisa J., Jimoh T., *Analytical Studies on Water Quality Index of River Landzu.* American Journal of Applied Sciences, 2010, 7(4), p. 453-458.
2. UNESCO. *Groundwater UNESCO environmental development briefs no*. 2, 14, 2000.
3. Dawodu M.O., Ipaiyeda A., *Evaluation of groundwater and stream quality characteristics in the vicinity of a batter factory in Ibadan, Nigeria*, Res. J. Applied Sci., 2007, 2, 1071-1076.
4. Tyagi P.D., Buddhi R., Chaudhary K.C., Sawhney R.L., *Degradation of ground water quality in industrial area in India*, Ind. J. Environ. Protect., 2002, 20, p. 174-181.
5. Fasunwon O., Olowofola J., Akinyemi O., Fasunwon B., Akintokun O., *Contaminants Evaluation as Water Quality Indicator in Ago-Iwoye, South-western, Nigeria*, African Physical Review, 2008, 2, p. 12.
6. Okuo J.M., Okonji E.I., Omeyerere F.R., *Hydrophysico-chemical assessment of the Warri coastal aquifer, southern Nigeria*, J. Chem. Soc. Nig., 2007, 32, p. 53-64.
7. Ramakrishnaiah C.R., Sadashivaiah C., Ranganna G., *Assessment of water quality index for the groundwater in Tumkur Taluk*, Karnataka State India., 2009, 6(2), p. 523-530.
8. Okeke C.O., Igboanua A.H., *Characteristics and quality assessment of surface water and groundwater recourses of Akwa Town, Southeast*, Nigeria. J. Niger. Assoc. Hydrol. Geol., 2003, 14, p. 71-77.
9. Suleiman F.B., *Analysis of Some Sachet Water Samples in Katsina, Nigeria*, Chem Class Journal of Chemical Society of Nigeria, Zaria Chapter, 2006, 3, p. 42-44.
10. Atulegwu P.U., Njoku J.D., *The impact of biocides on the water quality*, Int. Res. J. Eng. Sci. Technol., 2004, 1, p. 47-52.
11. Akintola F.A., *Geology and geomorphology of Nigeria in maps*, Hodder and Stoughton, London, 1982, pp. 45.

12. APHA, AWWA, WEF. *Standard Methods for the Examination of Water and Waste waters, 20th Edition. American Public Health Association, Washington*, D.C. 233 pp., 1998.
13. Nigeria Industrial Standard, *Nigerian Standard for Drinking Water Quality* NIS 554, 14, 2007.
14. WHO, *Guidelines for Drinking Water Quality. Addendum: Microbiological agents in drinking water*. World Health Organization, Geneva, 2001.
15. APHA, *American Public Health Association, standard methods for the examination of water and wastewater*, 20th ed., 1998, 1220 pp.
16. Alfred P.D., *Assessing microbial safety of drinking water: Improving approaches and methods*, Organization for economic cooperation, 2003, pp. 25.
17. Sinha S.K., *Bacterial contamination in some rural pond waters of Muzaffarpur*, Journal of Pollution Res., 2008, 10, p. 179-182
18. Adekunle M.T., Adetunji M.T., Gbadebo A.M., Banjoko O.B., *Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria*, International Journal of Environmental Research and Public Health, 2007, p. 3.
19. Adeniyi O.D., Odigure J.O., *Water quality monitoring: A case study of water pollution in Minna and its environs in Nigeria*, Botswana Journal of Technology, 2005, 14, p. 1.
20. Mark W.L., Evans T.M., Ramon J.S., *Effects of turbidity on chlorination Efficiency and bacterial persistence*, Applied Journal of Environmental Microbiology, 1981, 42(1), p. 159-167.
21. Abdul-Razak A., Asiedu A.B., Entsus R.E.M., De Graft-Johnson K.A.A., *Assessment of water quality of the Oti River in Ghana*, West African Journal of Applied Ecology, 2009, 15, p. 7.
22. Senior L.A., Groundwater-quality Assessment, Pike County, Pennsylvania, U.S. *Geological Survey Scientific Investigations Report*, 2009, 51, p. 29.
23. Microsoft Encyclopedia Encarta, 2009.
24. Ogedengbe A.O., Abba M.U., *An assessment of Dug-well water quality and use in Mubi, Nigeria*, Journal of Sustainable Development in Agriculture and Development, 2006, 2(1), p. 10.

25. Rajankar P.N., Gulhane S.R., Tambekar D.H., Ramteke D.S., Waite R.S., *Quality assessment of ground water resources in Nagpur region (India)*, e-Journal of Chemistry, 2009, 3, p. 905-908.
26. Mohammed L.N., Aboh H.O., Emenike E.A., *A regional geoelectric investigation for groundwater exploration in Minna area, North West Nigeria*, Science World Journal, 2007, 2(3), p. 25.
27. Paul D.R., Bryan R.S., *Nitrates in drinking water*, College of Agricultural Sciences, U.S. Department of Agriculture and Pennsylvania Cooperative, 2008, 203 pp.