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An Assessment of Drinking Water Quality Using Water Quality Index in Ado-Ekiti and Environs, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors BMO, JOO and OF designed the study. Author BMO performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BMO, JOO and OF managed the analyses of the study. Author OF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To assess the quality of drinking water sources in Ado-Ekiti and environs, Nigeria, using Water Quality Index (WQI).
Study Design: Experimental study design.
Place and Duration of Study: Department of Microbiology, Ekiti State University, Ekiti State, Nigeria, between January 2014 and August 2014.
Methodology: The Weighted Arithmetic Water Quality Index (WAWQI) method, which classified water quality according to the degree of purity, was adopted in this study. The WAWQI was determined on the basis of various physico-chemical parameters which included pH, total dissolved solids, turbidity, total hardness, calcium, magnesium, sulphate, chloride and nitrate. The parameters were determined using standard methods.
Results: The mean values of the physico-chemical parameters revealed that majority of the

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samples fell below the WHO maximum permissible limits while others were above WHO specifications. The calculated WAWQI revealed the water quality level of the different water sources as follows; 54.16, 65.12, 67.46, 56.29, 46.08 and 49.59 for borehole, stream, pipe-borne, well, spring and packaged water samples, respectively.

Conclusion: This result is an indication that the analyzed water samples from different sources were of poor water quality with the exception of spring and packaged water samples which are of good water quality in terms of physico-chemical qualities and thus safe for human consumption.

Keywords: Water sources; Physico-chemical parameters; Water quality index; WAWQI.

1. INTRODUCTION

Water is the most important natural resource and valuable natural asset which forms the major constituent of the ecosystem. Water can be sourced from rain and surface or ground water [1]. Rain water percolating into the ground constitutes the ground water. Ground water is of higher quality compared to surface water due to the effective filtration [1]. Water plays a vital role in the existence of life and various sector of the economy such as agriculture, livestock production, forestry, industrial power generation, fisheries and other creative activities [2]. Therefore, water quality assessment is an issue in the nation. Water quality is a description of chemical, physical and biological characteristics of water in connection with intended use(s) and a set of standards [3]. The quality of water sources deteriorates due to point source and non-point source pollution. Point source pollution includes industrial effluents and discharges from municipal waste water treatment plant while non-point source pollution includes agricultural run-off, seepage of septic tank effluents into ground water, indiscriminate dumping of wastes into streams and rivers among others [4]. The increase in human population in Ekiti State has exerted enormous pressure on the provision of safe drinking water. Thus, unsafe water poses a health threat to the public and also places the public at risk for diarrhoeal and a host of other diseases as well as chemical intoxication [5].

Water quality of any specific area or source can be assessed using physical, chemical and microbiological parameters [2]. One of the most effective tools to communicate information on the quality of water is by using the term Water Quality Index (WQI) [4]. WQI is defined as a rating reflecting the composite influence of different water quality parameters [6]. WQI provides a single number that expresses the overall water quality at a certain location and time based on several water quality parameters [7]. It was first developed by Horton in 1965. It is basically a mathematical means of calculating a single value from multiple test results [2]. However, a huge number of WQIs include Weighted Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Minister of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI), among others have been formulated by several national and international organizations which have been applied for evaluation of water quality in a particular area [8]. The WAWQI method, which classified water quality according to the degree of purity, was adopted in this study and this has been widely used by various scientists [1,9,10]. Parameter selection could be from any of the five classes which have considerable impact on water quality; namely oxygen level, eutrophi-cation, health aspects, physical characteristics and dissolved substances [1]. The parameters selected in this study included the commonly measured water quality variables from the physical characteristics and dissolved substances which have impact on surface and ground water.

WQI utilizes the water quality data and helps in the formulation of policies by various environmental monitoring agencies. It is computed using nine key water quality variables [1,11] and this describes the general situation of water sources. Therefore, this study was aimed at assessing the quality of various drinking water sources in Ado-Ekiti and its environs and determining their suitability for drinking purpose using WAWQI.

2. MATERIALS AND METHODS

2.1 Study Area

The study took place in Ado-Ekiti, the capital city of Ekiti State and environ. The city is located within the North Western part of the Benin-Owena River Basin Development Area. The city lies between Latitude 7° 34' and 7° 44' North of the Equator and Longitude 5°11' and 5° 18' east of the Greenwich Meridian. It has a number of Satellite towns around it. To the North is Iworoko, about 16 kilometers away from the city; to the east are Are and Afao, about 16 kilometers; to the West are Iyin and Igede, about 20 km and to the South is Ikere, about 18 km [12]. The relief of Ado-Ekiti is relatively low with isolated hills and inselbergs that are dome-shaped. The geology of Ado-Ekiti belongs to the basement complex, igneous rock, rock of South-Western, Nigeria. The lithiological rock units are basically crystalline basement rocks which include coarse grained charnokite (the most abundant in Ado-Ekiti), fine grained granite, medium grained granite and porphyritic biotite, medium grained granite and quartzite [13].

2.2 Sample Collection

A total of five hundred samples of different drinking water from sources which included well, borehole, streams, pipe-borne, reservoir and packaged (sachet) water were randomly collected from Ado-Ekiti and environ. Each sample was collected in a one-litre clean polyethylene bottles and transported to the laboratory within two hours of collection for immediate analysis.

2.3 Analysis of Samples

The samples were analyzed for nine parameters which included pH, total dissolved solids (TDS), calcium, magnesium, total hardness, turbidity, sulphates, chlorides and nitrates using the standard procedures recommended in guidelines for water quality monitoring as described by Maushkar [14]. The pH was assessed by electrometric method using pH meter (Hanna H19813 Grocheck meter), TDS was measured using gravimetric method, turbidity was assessed using nephelometer, hardness, calcium and magnesium were assessed using EDTA titrimetric method and sulphate was detected by turbidometric method using turbidity meter (X INRUI, WGZ-B scattered light turbid meter). Chloride determination was carried out by argentiometric titration while nitrate was detected using colorimetric method.

2.4 Water Quality Index

The WQI of the different drinking water samples was assessed using the weighted arithmetic index method employed by Brown et al. [15] and Soni et al. [16]. This was performed taking into account the nine important parameters which included pH, TDS, turbidity, total hardness, calcium, magnesium, sulphate, chlorides and nitrates. The WAWQI was calculated using the formula below:

WAWQI = /

The quality rating scale (Q_n) for each parameter was calculated by using this expression:

$$Q_n = 100[(V_n\text{-}V_o/S_n\text{-}V_o)]$$

Where,

V_n was estimated concentration of nth parameter in the analyzed water
V_o was the ideal value of this parameter in pure water
V_o = 0 (except pH= 7.0 and DO= 14.6mg/l)
S_n is recommended standard value of nth parameter

The unit weight (W_n) for each water quality parameter is calculated by using the following formula:

$$W_n = K/S_n$$

Where
K = proportionality constant and can also be calculated by using the following equation:

$$K = 1/\sum(1/S_n)$$

3. RESULTS AND DISCUSSION

The mean values of the physico-chemical parameters of the various drinking water samples from Ado-Ekiti and environ are presented in Table 1. The mean pH values of the different drinking water samples ranged from 5.73 in stream to 7.23 in tap. These mean values of the water samples fall within the standard maximum permissible limit set by WHO [17] except for stream samples with slightly acidic mean pH value of 5.73. A similar result was also reported by Chinedu et al. [18]. They recorded pH values between the range of 5.96 and 7.17 for surface water samples collected from Ota, South West, Nigeria. The low pH value observed in stream samples may be attributed to several factors such as percolating carbon-dioxide charged meteoric water that produced weak carbonic acid [19], mineralogical composition as well as differential weathering intensity of the various bed rocks around the study area [20] and discharges or runoff from various sources [13]. The consumption of such acidic water could have adverse effect on health [21] and may also lead to corrosion of water pipes [22].

The mean values recorded for turbidity ranged between 0.86NTU in spring samples and 26.34 NTU in stream samples. The mean value recorded for stream samples is slightly higher than the set standard, 25NTU, by WHO (2011). This may result from suspended matters such as clay, silt, organic and inorganic matter [23] and thus can serve as sources of nutrients for microorganisms in the water samples [24]. Moreover, the high turbidity observed in stream water samples may be possibly due to run off water which carries with it several compounds and bacteria. High turbidity in water bodies can influence the dissolved oxygen level because the suspended particles absorb sunlight and raise the temperature of the water which in turn reduces the oxygen level of such water [18]. In addition, turbidity can interfere with disinfection with ultraviolet light and self-purification of water by reducing photosynthetic activities of aquatic plants [24]. The values recorded for turbidity in this study agree with the findings of an investigation carried out on quality assessment of drinking water in Chandrapur [23]. The authors reported higher turbidity values between 25.64 and 40.3 for two different sampling sites.

Mean total dissolved solids (TDS) values observed in the different water samples were within the limit set by WHO standard with the exception of well water samples which had a higher value of 514.87 mg/l. TDS is a general indicator of the overall water quality and a measure of organic and inorganic materials dissolved in the water [25]. Thus, an increase in TDS value above the permissible limit may impart a bad odour or taste to drinking water and also cause scaling of pipes [26]. Therefore, it reduces the potability of the well water in the study area. Deposition of calcium and magnesium ion in water sources indicates total hardness of the water [22]. The mean values recorded for total hardness, calcium and magnesium ranged from 5.44 mg/l to 27.33 mg/l, 2.18 mg/l to 10.95 mg/l and 0.79 mg/l to 3.96 mg/l respectively. The values for these parameters fell below the WHO specifications. These para-meters reflect the nature of the geographical characteristic of the study area. Water with low magnesium can cause morbidity and mortality for cardiovascular disease, high risk of motor neuronal disease, pregnancy disorders and pre-eclampsia while water with low calcium may be associated with higher risk of fracture in children [1].

The concentration of sulphate and nitrate ranged from 3.28 mg/l in sachet water to 25.13 mg/l in wells and 0.97mg/l in spring to 21.79 mg/l in wells respectively which are still within the WHO specification for these parameters. This corroborates with the previous studies reported by Ramakrishnaiah et al. [6] and [27]. Ingestion of sulphate in large quantity has been found to be responsible for catharsis and gastrointestinal irritation [28]. Nitrate has been implicated in a number of health defects which include cancer, hypertension, increased infant mortality, CNS birth defect, diabetes, respiratory tract infection and changes in the immune system [29].

It has been documented that presence of chloride in potable water is attributed to both natural and anthropogenic source such as dissolution of salt deposits, the use of inorganic fertilizers, animal feeds, landfills, chemical effluent from industries, sewage, refuse leachates and oil-well operations [30]. In this study, the chloride concentration was in the range of 10.9mg/l in spring to 206.79 mg/l in pipe-borne water which is still below WHO set standard.

Table 1. Mean physicochemical parameters of water samples from different drinking water sources in Ado-Ekiti and environs

Parameters/ samples	Boreholes	Streams	Pipe-borne	Wells	Springs	Sachets	WHO standard (Sn)
Chlorides (mg/l)	119.60	94.90	206.79	138.34	10.90	57.90	250
Nitrate (mg/l)	14.71	11.75	15.32	21.79	0.97	5.40	100
Sulphate (mg/l)	20.18	18.65	9.08	25.13	9.03	3.28	400
Total hardness (mg/l)	25.35	17.27	26.63	20.13	5.44	9.85	200
Calcium (mg/l)	10.16	6.92	10.65	8.15	2.18	3.95	200
Magnesium (mg/l)	3.67	2.500	3.88	2.97	0,79	1.43	150
TDS (mg/l)	83.29	146.38	43.11	514.87	60.5	66.75	500
Turbidity (NTU)	1.05	26.34	14.90	0.97	0.86	2.18	25
pH	7.07	5.73	7.23	7.19	6.2	6.5	6.5-8.5
%difference between ca+ and anions	66.5	71.0	76.1	76.0	49.2	70.0	13.6

Table 1 also revealed the percentage differences between the cations and the anions in the water samples. This was calculated based on the principle of electro-neutrality. The principle of electro-neutrality requires that the sum in eq/L or meq/L of positive ions (cations) must equal the sum of negative ions (anions) in solution (http://www.lenntech.com/calculators/accuracy/accuracy-water-analysis.htm) [31]. Theoretically, a perfect analysis will lead to a charge balance error of 0%. Obviously, when using multiple instruments for analyses of ions, analytical error accrues, and a charge balance of 0% is rare and this was revealed in the percentage differences of the water samples.

The results in Tables 2 and 3 express the details involved in the calculation of WAWOI of the different water samples collected from different sources in Ado-Ekiti and environs. The calculation of WQI is also reflected in Table 3 using the formula given above. This has been applied to the evaluation of water quality in the study area. The WQI summarizes all the water quality parameters into simple terms. Thus, it indicates the quality of each water samples in the study area in terms of index number which represents overall quality of water for any intended use [5]. Table 4 shows the calculated values and WQI rating for each water sample in the study area.

The results indicate that water samples from spring and packaged (sachet) water are of good quality. This implies that they are safe for human consumption and other domestic purposes.

Table 2. The quality rating scale (Qn) for each parameter of the water samples

Qn=100(Vn/Sn)	Boreholes	Streams	Pipe-borne	Wells	Springs	Sachets
Chlorides (mg/l)	47.664	37.96	82.72	55.34	4.36	23.16
Nitrate (mg/l)	147.1	117.5	153.2	217.9	9.7	54.0
Sulphate (mg/l)	5.045	4.6625	2.27	6.28	2.26	0.82
Total hardness (mg/l)	12.67	8.64	13.32	10.07	2.72	4.93
Calcium (mg/l)	5.08	3.46	5.33	4.08	1.09	1.98
Magnesium (mg/l)	2.45	1.67	2.59	1.98	0.53	0.95
Total dissolved solids (mg/l)	16.66	29.28	8.62	102.97	12.10	13.35
Turbidity (NTU)	4.20	105.36	59.6	3.91	3.44	8.72
pH	83.18	67.41	85.06	84.59	78.82	76.47

Table 3. Determination of water quality index

Parameters	Unit weight factor (Wn)	QnWn					
		Borehole	Stream	Tap	Well	Spring	Sachet
pH	0.0207	50.648	41.0459	51.793	51.506	44.4132	46.562
Turbidity (NTU)	0.0518	0.8694	21.8095	12.340	0.8089	0.71208	1.8050
Total dissolved solids (mg/l)	0.0129	0.1733	0.3045	0.0897	1.0709	0.1258	0.1388
Magnesium (mg/l)	0.0259	0.0845	0.0576	0.0893	0.0683	0.0183	0.0329
Calcium (mg/l)	0.0259	0.1316	0.0895	0.1378	0.1055	0.0282	0.0511
Total hardness (mg/l)	0.0345	0.3282	0.2235	0.3446	0.2605	0.0704	0.1275
Sulphate (mg/l)	0.0104	0.0651	0.0603	0.0294	0.0813	0.0292	0.0106
Nitrate (mg/l)	0.2070	0.7619	0.6082	0.7930	1.1279	0.0502	0.2795
Chloride (mg/l)	0.6089	0.9866	0.7858	1.7122	1.1455	0.0903	0.4794
∑QnWn	∑Wn 0.998	54.0486	64.9848	67.329	56.1756	45.9890	49.4874
WQI=∑Qn/Wn -----------∑Wn		54.16	65.12	67.46	56.29	46.08	49.59

Table 4. The water quality rating of each water source in Ado-Ekiti and environs

WQI level	Water quality status	Borehole	Stream	Pipe-borne	Well	Spring	Sachets
0 - 25	Excellent water quality						
26 - 50	Good water quality					46.08	49.59
51 - 75	Poor water quality	54.16	65.12	67.46	56.29		
76- 100	Very poor water quality						
Above 100	Unsuitable for drinking purpose						

Generally, spring water is safe for drinking purpose due to its excellent quality while packaged (sachet) water has undergone some treatment and tested for good quality before being packaged and sold to the populace. Water samples from boreholes, wells, streams and pipe-borne water have their index within the poor water quality rating which implies that they are not safe for human consumption. Generally, in the study area, majority of the wells are shallow. This is because the water table level is high and thus does not allow further digging into the ground. Besides this, all the wells sampled were constructed with rings which are not cemented together. Therefore, allowing percolation into the wells. The same condition applies to most constructed boreholes in the study area. In some of the areas, underlying bed rock hinders further sinking of boreholes which consequently affect the physico-chemical properties of the water. Stream water is known to be exposed to so many factors such as weathering, runoff, discharges, among others. All these affect its quality for human consumption. The poor quality rating for pipe-borne water may probably be as a result of the quality of water distributed into the community, rusted pipes used for distribution, percolation of drainage water into perforated pipes, among others. This is contradictory to the findings of Etim et al. [5] who reported that pipe-borne and borehole water samples examined in the Niger Delta region of Nigeria are of good water quality. While they reported stream water to be unfit for human consumption which is similar to the result obtained in this study.

4. CONCLUSION

The objective of using an index, WQI, is to give a single value to water quality of a particular source and reducing number of different parameters into a simple expression. The results of this study revealed that spring and sachet water in the study area were of good water quality in terms of purity and are fit for human consumption while the other samples were not suitable for consumption. Therefore, the indices selected will serve as useful tools for communicating water quality information to the public and the appropriate agencies and policy makers in the State.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Balan IN, Shivakumar M, Kumar PDM. An assessment of ground water quality using water quality index in Chennai, Tamil Nadu, India. Chronicles Young Scientists. 2012;3(2):146-150.
2. Tyagi S, Sharma B, Singh P, Dobhal R. Water quality assessment in terms of water quality index. American Journal of Water Resources. 2013;1(3):34-38.
3. Khalil B, Ouarda TBMJ, St-Hilaire A. Estimation of water quality characteristics at ungauged sites using artificial neural networks and canonical correlation analysis. J. Hydrology. 2011;405:277–287.
4. Deepika, Singh SK. Water quality index assessment of Bhalswa Lake, New Delhi. Int. J. Adv. Res. 2015;3(5):1052-1059.
5. Etim EE, Odoh R, Itodo AU, Umoh SD, Lawal U. Water quality index for the assessment of water quality from different sources in Niger Delta Region of Nigeria. Frontiers in Science. 2013;3(3):89-95.
6. Ramakrishnaiah CR, Sadashivaiah C, Ranganna G. Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State India. European J. Chem. 2009;6(2):523-530.
7. Boah DK, Twum SB, Pelig-Ba KB. Mathematical computation of water quality index of Vea Dam in upper East Region of Ghana. Env. Sci. 2015;3(1):1-16.
8. Chaturvedi MK, Bassin JK. Assessing the water quality index of water treatment plant and bore wells, in Delhi, India. Environ. Monit. Assess. 2010;163:449-453.
9. Rao CS, Rao BS, Hariharan AVL, Bharathi NM. Determination of water quality index of some areas in Guntur district, Andhra Pradesh. Int. J. Appl. Bio. Pharm. Tech. 2010;1(1):79-86.
10. Chowdhury RM, Muntasir SY, Hossain MM. Study on ground water quality and its suitability or drinking purpose in Alathur block-Perambalur district. Archiv. Appl. Sci. Res. 2012;4(3):1332-1338.
11. Fadaei A, Gafari M. Physico-chemical assessment of the ZayandehRud River, Iran, using water quality index. J. Applied Sci. in Environ. Sanitation. 2015;9(3):199-204.
12. Oriye O. Urban expansion and urban land use in Ado Ekiti, Nigeria. American J. Res. Comm. 2013;1(2):128-139. ISSN: 2325-4076.

13. Daramola SO. Groundwater quality assessment of some boreholes from Odo-Oro Ekiti, South Western Nigeria. J. Environ. Sci., Toxico. and Food Techn. 2013;7(2):58-62.
14. Maushkar JM. Guidelines for water quality monitoring. Central pollution control board (A government of India organization), Delhi, 2007.
15. Brown RM, Mccleiland NJ, Deiniger RA, O' Connor MFA. Water quality index – crossing the physical barrier (Jenkis SH, ed) Proc. Intl. Conf. on Water Poll. Res. Jerusalem. 1972;6:787–797.
16. Soni VK, Visavadia M, Gosai C, Hussain MD, Mewada MS, Gor S, et al. Evaluation of physico-chemical and microbial parameters on water quality of Narmada River, India. Afri. J. Environ. Sci. Techn. 2013;7(6):496-503.
17. World Health Organisation. Guidelines for drinking-water quality. 4th Edition, W.H.O Press, Geneva, Switzerland. 2011;223-230.
18. Chinedu SN, Nwinyi OC, Adetayo YO, Eze VN. Assessment of water quality in Canaanland, Ota, Southwest, Nigeria. Agric. Bio. J. North America. 2011;2(4): 577-583.
19. Napacho ZA, Manyele SV. Quality assessment of drinking water in Temeke District (part II): Characterization of chemical parameters. Afri. J. Environ. Sci. Tech. 2010;4(11):775-789.
20. Talabi AO, Ogundana AK. Preliminary quality and potential assessment of groundwater in the basement complex terrain of Ijero-Ekiti, Southwestern, Nigeria. Inter. J. Innovative Res. Sci., Eng. Tech. 2014;3(8):15100-15107.
21. Orewole MO, Makinde OW, Adekalu K, Shittu KA. Chemical examination of piped water supply of Ile –Ife in South West Nigeria. Iran J. Environ. Hlth. Sci. Eng. 2007;4(1):51-56.
22. Bernard E, Ayeni N. Physicochemical analysis of groundwater samples of Bichi local government area of Kano State, Nigeria. ARPN J. Sci. Tech. 2012;2:325-332.
23. Tambekar P, Morey P, Batra RJ, Weginwar RG. Quality assessment of drinking water: A case study of Chandrapur District. J. Chem. Pharm. Res. 2012;4(5):2564-2570.
24. Gideon YB, Fatoye FB, Omada JI. Quality assessment of physico-chemical characteristics of Okura River, Kogi State, Nigeria. Int. J. Sci. Tech. 2013;2(12):891-899.
25. Mandal NS, Nand D. Study of some physicochemical water quality parameters of karola river, West Bengal – An attempt to estimate pollution status. International Journal of Environmental Protection. 2014;2(8):16-22.
26. Ackah M, Agyemang O, Anim AK, Osei J, Bentil, NO, Kpattah L, et al. Assessment of groundwater quality for drinking and irrigation: The case study of Teiman-Oyarifa Community, Ga East Municipality. Ghana Proceedings of the International Academy of Ecology and Environmental Sciences. 2011;1(3-4):186-194.
27. Paul DR, Bryan RS. Nitrates in drinking water, College of Agricultural Sciences, U.S. Department of Agriculture and Pennsylvania Cooperative. 2008;203.
28. Park K. Textbook of preventive and social medicine, 20th edition, BanarsidasBhanot publishers, Jabalpur, India; 2009.
29. Villaueva CM, Kogevines M, Cordier S, Templeton MR, Vermeulen R, Nuckols JR, et al. Assessing exposure and health consequences of chemicals in drinking water; current state of knowledge and research needs. Environ. Hlth Perspectives 2014;122(3):1-10.
30. Lathamani R, Janardhana MR, Suresha S. Application of water quality index method to assess groundwater quality in Mysore city, Karnataka, India. Inter. J. Innovative Res. Sci., Eng.Tech. 2014;3(5):501-508.
31. Available:http://www.lenntech.com/calculators/accuracy/accuracy-water-analysis.htm

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