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Original Research Article

Assessment of Groundwater Quality in Port Harcourt, Nigeria using Weighted Arithmetic Water Quality Index

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ABSTRACT

Thirty (30) samples of groundwater in Port Harcourt, Nigeria were collected quarterly for a period of one year and analysed for thirteen (13) water quality parameters including pH, total dissolved solids (TDS), electrical conductivity (EC) and chloride (Cl). Other parameters analysed were biochemical oxygen demand (BOD), chemical oxygen demand (COD) nitrate (NO_3), sulphate (SO_4), ammonia (NH_3), potassium (K), sodium (Na), magnesium (Mg) and calcium (Ca), using standard methods. Laboratory results were used to develop weighted arithmetic water quality index (WAWQI) and water quality map of the study area. The analysed results revealed that 93.3% of the samples fell under excellent and good categories of WAWQI as their values ranged from 5.70 to 38.36 while 6.7% of the samples fell under poor and unsuitable categories with values ranging from 66.74 to 415.40. However, it was noted that the groundwater quality improved during the rainy season for the entire study area but deteriorated towards the southern part of the study area irrespective of season. Hence, it was recommended that relevant regulatory bodies should investigate the anthropogenic activities occurring at the southern part of the study area with emphasis on a particular town.

1. INTRODUCTION

One of the fundamental aspects of any environmental monitoring program is the reporting of results to both managers and the general public. However, most water quality researchers report results by comparing the different analyzed parameters with their respective permissible limits set by regulating bodies (local or international). For instance, over the years, several researchers including Ukpaka and Ukpaka (2016), Alex *et al.* (2015) and Ideriah and Ikoro (2015) have reported the groundwater quality of Port Harcourt by describing the trends and compliance with official stated guidelines. However, Carlos and Alejandra (2014) stated that in many cases, managers and the general public rather prefer statements concerning the general health or status of the system concern. One possible solution to this problem is by employing a water quality index (WQI) that will mathematically combine all water quality measures and provide a general and readily understood description of the water (House, 2015). This has been identified earlier by Bordalo *et al.* (2012) who described WQI as a mechanism based on numerical expression for defining the level of water quality by summarizing large amount of complex data into simplified mathematical numbers, which can be interpreted into text classes (excellent, very good, good, moderate, poor, etc.). Thus, WQI inform the regulatory agency covering a specific catchment about water quality status in a very concise and clear manner. Numerous water quality indices have evolved over the years nevertheless, Olayiwola and Olubunmi (2016) recommended that the weighted arithmetic water quality index method is better in the developing countries.

Currently, there are no detailed works on the subject matter. Hence, developing weighted arithmetic water quality index (WAWQI) for the groundwater in Port Harcourt will summarize the various analyzed water parameters and rank the overall quality of the water. This will help the public and the necessary regulatory bodies like the Rivers State Waste Management Agency (RIWAMA).

2. MATERIALS AND METHODS

2.1. Description of Study Area

Port Harcourt is located in Southern Nigeria within Latitude 4^0 42' 00" to 4^0 57' 03" North and Longitude 6^0 53' 11" to 7^0 8' 49" East, occupying an area of approximately 369 km^2 (Ogbozige and Toko, 2020). It is the capital of Rivers State and it comprises two Local Government Areas (LGAs) of the State known as Obio/Akpor and Port Harcourt as could be seen in Figure 1.

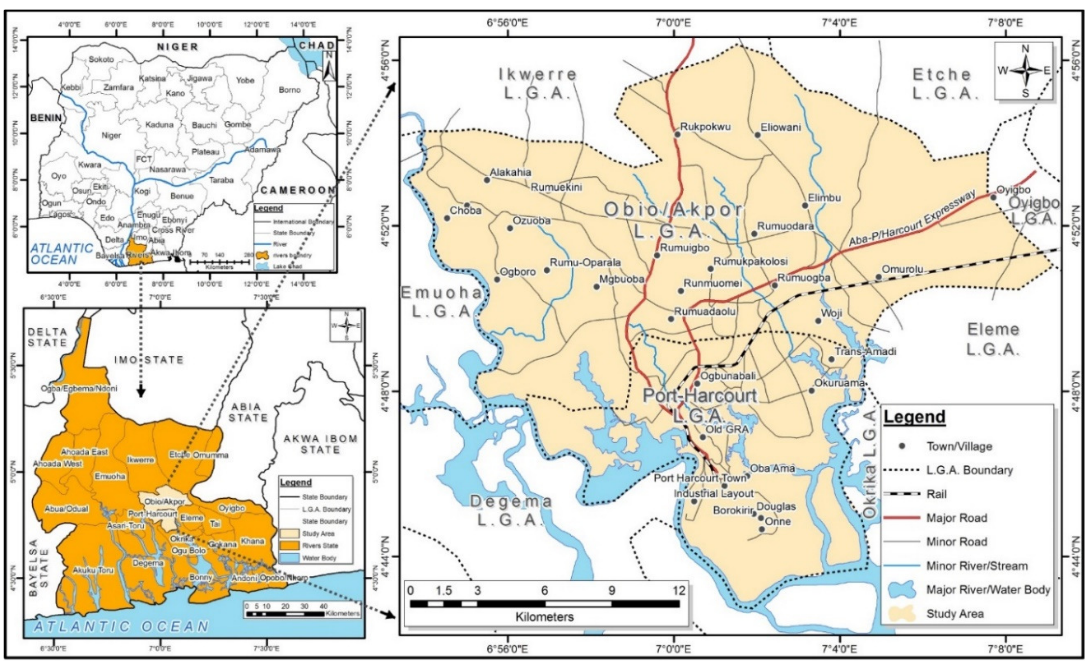

Figure 1: Map of Port Harcourt metropolis (Abio/Akpor and Port Harcourt LGAs)

The main source of aquifer recharge in the study area is rainfall, with an average annual value of 2500 mm. Usually, the rainy season starts in the month of March, get to the peak during the month of September and ends in October. However, the few dry months occasionally records reasonable rainfall especially February and November. The top soil is usually sandy or sandy loam and it is always leached due to the heavy rainfall experienced in the area.

2.2. Samples Collection and Analytical Methods

Water samples were collected quarterly from 30 wells (boreholes and hand-dug wells), evenly distributed within the study area from June, 2017 until March, 2018 and analysed for pH, total dissolved solids (TDS), electrical conductivity (EC), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and chloride (Cl). Other parameters analysed include nitrate (NO_3), sulphate (SO_4), ammonia (NH_3), potassium (K), sodium (Na), magnesium (Mg) and calcium (Ca). Parameters such as pH, TDS and EC were analysed onsite as recommended by Ogbozige *et al.* (2017). Pocket-sized pH meter (pHep®, made by Hanna Ltd, England) was used in determining pH while TDS and EC were determined using a pocket-sized dissolved solids and conductivity meter (TDS & EC hold, ±2% made by Griffin Company, USA). Other parameters were determined in the laboratory using standard methods (APHA, 2012). A hand-held Global Position System (Etrex 20x) was used in recording the geographical coordinates of all the sampling sites as shown in Table 1.

Table 1: Description of sampling sites

Site code	Location name	Geographical coordinate	Description
B1	Rukpoku	N 04º 55' 42.9", E 007º 00'	Residential area at Egbelu new road, Rukpoku
B2	UPTH	N 04º 54' 05.8", E 006º 55'	Uniport Teaching Hospital water scheme.
B3	Rumuagholu	N 04º 53' 21.5", E 006º 58'	Residential/school area, off SARS road, Rumuagholo
B4	Rumuodomaya	N 04º 53' 33.4", E 005º 59'	Residential area at Akwaka phase 3, Rumuodomaya.
B5	Eneka	N 04º 53' 40.1", E 007º 02'	Model Health Centre, Eneka.
B6	Rumuokwachi	N 04º 52' 00.6", E 006º 55'	Residential area at 14, Ogbogoro road, Rumuokwachi.
B7	Uzoba	N 04º 52' 04.5", E 006º 56'	Residential area opposite Provil School, Uzoba
B8	Loretha School	N 04º 52' 26.0", E 005º 58'	Staff quarters at Loretha School, Rumuogholu
B9	Eligolo Road	N 04º 51' 58.8", E 007º 00'	Residential/school area at Eligolo road.
B10	Oroigwe	N 04º 52' 21.8", E 007º 02'	Residential area at Oroigwe, Elimgbu.
B11	Rumuokwurushi	N 04º 52' 05.2", E 007º 04'	Residential area before Nzor hotel, Rumuokwurushi.
B12	Iriebe	N 04º 52' 08.7", E 007º 06'	Residential area at Iriebe, off Confidence School Junction.
B13	Elioparanwo	N 04º 50' 07.8", E 006º 57'	Residential area at 27, Royal Avenue, Elioparanwo Town.
B14	Rumuepirikom	N 04º 50' 08.5", E 006º 58'	Commercial area at Rumuepirikom by Ada George Road.
B15	Rumuigbo	N 04º 50' 25.4", E 007º 00'	Residential area behind PHWC, Psychiatric Rd, Rumuigbo
B16	Woji	N 04º 53' 17.2", E 007º 02'	Residential area at Temple Ejekwe Street, Woji Road.
B17	Elelenwo	N 04º 50' 07.3", E 007º 04'	Church premises/residential area at Elelewon.
B18	Rumuolumini	N 04º 48' 40.4", E 006º 57'	Church Premises (St Mark's Ang. Church, Rumuolumini).
B19	Rumuokokwa	N 04º 48' 22.9", E 006º 59'	Commercial area at 4, Nnokam Street (close to RSU gate).
B20	Diobu	N 04º 47' 28.3", E 007º 00'	Church Premises (CKC church, mile 1, Diobu).
B21	T/Amadi	N 04º 48' 10.5", E 007º 02'	School premises (Tago Int'l Sch., off Odili Rd, T/Amadi).
B22	Gbalajam	N 04º 48' 39.5", E 007º 04'	Residential area at Gbalajam, Woji (close to a creek).
B23	Eagle Island	N 04º 47' 00.9", E 006º 58'	Residential area at 38D, Collin Owonda Str., Eagle Island.
B24	Town	N 04º 45' 52.6", E 007º 01'	Residential area at 6, Hospital Road, PH Township.
B25	Abuloma	N 04º 46' 50.9", E 007º 02'	Hotel/residential area at Abuloma.
B26	Borokiri	N 04º 45' 01.6", E 007º 02'	Commercial area at UPE, Borokiri.
C1	Timber	N 04º 56' 06.0", E 007º 01'	Timber market/SPDC flow station, PH/Owerri Rd, Rukpoku.
C2	New Layout	N 04º 53' 11.9", E 007º 05'	New layout (farming activities) along Interlocked Rd, Iriebe
C3	Sand fill	N 04º 44' 07.7", E 007º 01'	Commercial area (petroleum) close to Borokiri Sand Fill.
C4	Iwofe	N 04º 48' 47.7", E 006º 56'	Newly residential area at Erico Street, Iwofe Road.

B1 to B26 = Boreholes, C1 to C4 = Hand-dug wells

2.3. Determination of Water Quality Index

The weighted arithmetic water quality index (WAWQI) was calculated based on the report of Shweta *et al.* (2013) as shown in Equations 1 to 4.

$$WAWQI = \frac{\sum Q_i W_i}{\sum W_i} \tag{1}$$

Where Q_i is the quality of rating scale for each parameter and it was calculated as:

$$Q_i = 100\left[\frac{V_i - V_0}{S_i - V_0}\right] \tag{2}$$

V_i is the estimated concentration of ith parameter in the analyzed water, V_0 is the ideal value of the parameter in pure water which zero (except pH = 7 and DO = 14.6 mg/l), S_i is the recommended standard value for ith parameter.

Similarly, W_i in Equation (1) is the unit weight for each water quality parameter, calculated as:

$$W_i = \frac{K}{S_i} \tag{3}$$

K is a proportionality constant, calculated as:

$$K = \frac{1}{\Sigma\left(1/S_i\right)} \tag{4}$$

Equation (1) to (4) were employed in all the sampling sites and their respective results were interpreted based on the report of Shweta *et al.* (2013) as follows; 0 – 25 (excellent), 26 – 50 (good), 51 – 75 (poor), 76 – 100 (very poor) and above 100 (unsuitable for drinking purpose). Since the water sampling was done quarterly (March, June, September, December) as earlier stated, the months of March and December were considered as Dry Season while June and September were considered as Rainy Season. The water quality indices determined for these two seasons (dry and rainy) were mapped using inverse distance weighted interpolation (IDW) tool of ArcGIS 10.5 as reported in Ogbozige *et al.* (2018).

3. RESULTS AND DISCUSSION

The determined water quality indices for the various sampling sites are shown in Table 2. It clearly revealed that the study area has groundwater suitable for drinking (excellent and good) during both seasons apart from the boreholes situated in Borokiri town (B26 and C3) which are of poor water quality and unsuitable for drinking. This is because the water quality indices for B26 and C3 during both seasons ranged from 66.74 to 415.40 while the values for the remaining 28 boreholes ranged from 5.70 to 38.36, with majority of them falling on excellent water category during both seasons. This affirms the report of Bolaji and Tse (2009) which recorded that higher percentage of Port Harcourt groundwater fell under excellent water category. Boreholes within Borokiri had earlier been recorded by Ogbozige and Toko (2020) of having poor water quality especially chloride ion and TDS, and it was accredited to seawater intrusion due to the nearness of these boreholes to the sea. Besides, the position of the wells B26 and C3 were within commercial areas dealing on petroleum products in Borokiri town hence, the petroleum products might have leached to contaminate the groundwater in these boreholes. Table 2 also revealed that the groundwater quality of the study area improved during the rainy season as lower values of water quality indices were recorded compared

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to values recorded during dry season and could be attributed to the dilution effect of precipitation (Ibrahim *et al.,* 2019).

Table 2: Weighted arithmetic water quality index of sampled water

Site code	Water quality index (Dry season)	Interpretations	Water quality index (Rainy season)	Interpretation
B1	8.49	Excellent water	7.32	Excellent water
B2	7.39	Excellent water	6.01	Excellent water
B3	10.05	Excellent water	7.57	Excellent water
B4	8.54	Excellent water	6.75	Excellent water
B5	10.30	Excellent water	9.69	Excellent water
B6	10.71	Excellent water	8.59	Excellent water
B7	9.66	Excellent water	6.00	Excellent water
B8	38.36	Good water	17.19	Excellent water
B9	9.08	Excellent water	7.29	Excellent water
B10	8.59	Excellent water	6.62	Excellent water
B11	7.07	Excellent water	7.13	Excellent water
B12	8.94	Excellent water	8.08	Excellent water
B13	7.97	Excellent water	7.67	Excellent water
B14	12.11	Excellent water	13.75	Excellent water
B15	8.75	Excellent water	7.92	Excellent water
B16	8.76	Excellent water	7.67	Excellent water
B17	7.66	Excellent water	6.67	Excellent water
B18	10.09	Excellent water	8.30	Excellent water
B19	13.36	Excellent water	14.91	Excellent water
B20	9.98	Excellent water	8.83	Excellent water
B21	10.03	Excellent water	9.33	Excellent water
B22	17.51	Excellent water	11.87	Excellent water
B23	9.55	Excellent water	6.87	Excellent water
B24	26.77	Good water	26.32	Good water
B25	7.55	Excellent water	6.48	Excellent water
B26	415.40	Unsuitable for	304.27	Unsuitable for
C1	8.36	Excellent water	6.90	Excellent water
C2	7.80	Excellent water	5.70	Excellent water
C3	109.17	Unsuitable for	66.74	Poor water
C4	7.62	Excellent water	8.15	Excellent water

The water quality maps of the entire study area during dry and rainy seasons are presented in Figures 2 and 3 respectively and it is revealed that the water quality deteriorate towards the southern part of the study area irrespective of the meteorological seasons. This might be as a result of seawater intrusion from the nearby seas at the southern part of the study area as earlier identified by Ogbozige and Toko (2020).

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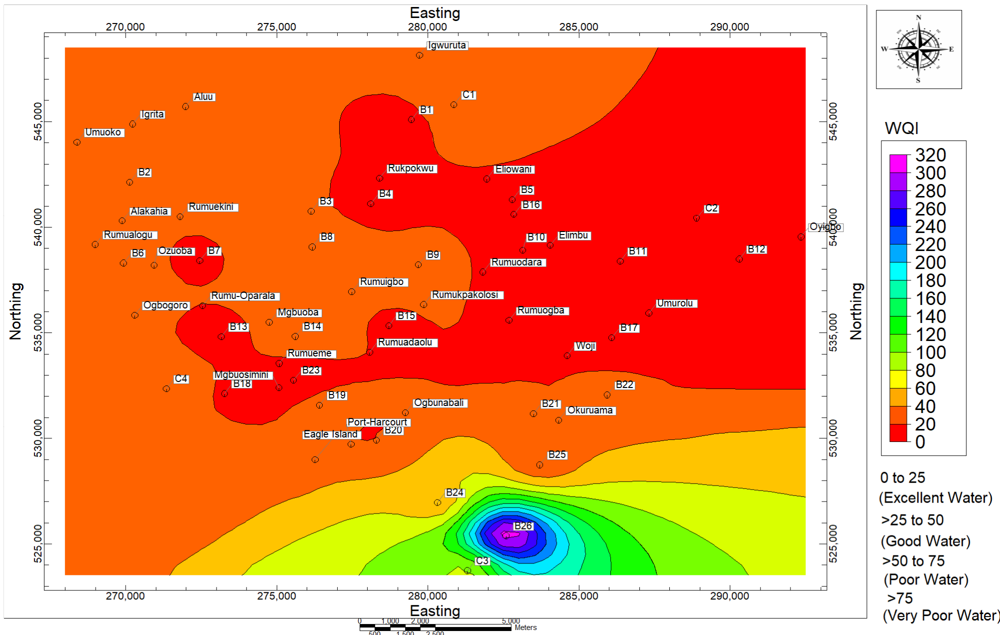

Figure 2: Weighted arithmetic WQI map of study area during dry season

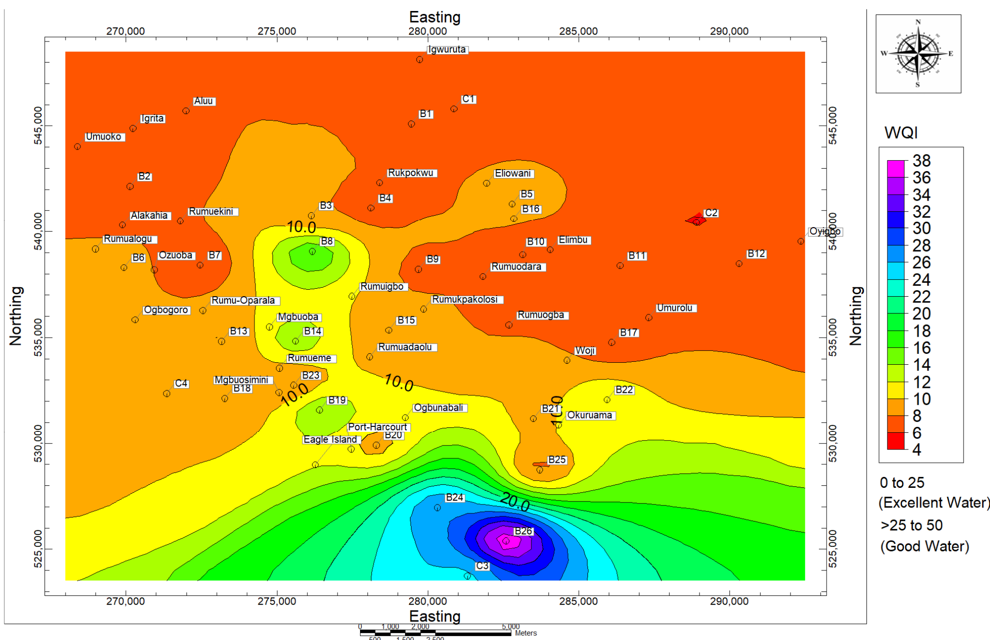

Figure 3: Weighted arithmetic WQI map of study area during rainy season

4. CONCLUSION

Based on the analyses results obtained from this research, it could be concluded that the groundwater quality of Port Harcourt is suitable for drinking as 93.3% of the samples fell under excellent and good categories of weighted arithmetic water quality index during both seasons. However, the remaining 6.7% which fell under poor and unsuitable categories are from boreholes located within Borokiri town. Also, the groundwater quality improved during rainy season for the entire study area but deteriorated towards the southern part regardless of the meteorological season. Hence, it is recommended that relevant regulatory bodies such Rivers State Waste Management Agency (RIWAMA), should investigate the anthropogenic activities occurring within the southern part of the study area especially Borokiri town.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Alex, A.A., Chinedu, N.V., Olatunde, A.M., Longinus, N.K. and Omosileleola, J.A. (2015). Groundwater Quality Assessment in Eliozu Community, Port Harcourt, Niger Delta, Nigeria. *International Journal of Scientific & Technology Research,* 4(12), pp. 149-156.

American Public Health Association (APHA) (2012). Standard Methods for Examination of Water and Wastewater (22nd Edition). American Public Health Association (APHA), American Water Works Association (AWWA), Water Pollution Control Federation (WPCF), Washington DC.

Bolaji, T.A. and Tse, A.C. (2009). Spatial Variation in Groundwater Geochemistry and Water Quality Index in Port Harcourt. *Scientia Africana,* 8(1), pp. 134-155.

Bordalo, A.A., Teixeira, R. and Wiebe, W.J. (2012). A Water Quality Index Applied to an International Shared River Basin: The Case of the Douro River. *Environmental Management,* 38(2), pp. 910-920.

Carlos, M. and Alejandra V. V. (2014). Comparative Study of Surface Water Quality Using Different Water Quality Index Methods. *Journal of Urban and Environmental Engineering,* 1(1), pp. 56–64.

House, M.A. (2015). Water Quality Indices as Indicators of Ecosystem Change. *Environmental Monitoring and Assessment*, 15(3), pp. 255 - 263.

Ibrahim, F.B., Ogbozige, F.J and Jimoh, A.M. (2019). Variation in Some Water Quality Parameters in Vended Water from Source to Consumption: A Case of Anguwar Liman Area of Samaru-Zaria, Nigeria. *Calabar Journal of Health Sciences,* 3(2), pp. 46-53.

Ideriah, T.J. and Ikoro, U.J. (2015). Hydrogeochemical Characteristics and Quality Assessment of Groundwater in University of Science and Technology, Port Harcourt. *International Journal of Environmental Monitoring and Analysis,* 3(4), pp. 221-232.

Ogbozige, F.J. and Toko, M.A. (2020). Piper Trilinear and Gibbs Description of Groundwater Chemistry in Port Harcourt, Nigeria. *Applied Science and Engineering Progress,*13(4), pp. 362-369.

Ogbozige, F.J., Adie, D.B. and Abubakar, U.A. (2018). Water Quality Assessment and Mapping Using Inverse Distance Weighted Interpolation: A Case of River Kaduna, Nigeria. *Nigerian Journal of Technology,* 37(1), pp. 249-261.

Ogbozige, F.J., Adie, D.B., Igboro, S.B. and Giwa, A. (2017). Identification of Critical Influential Parameters Responsible for Inconsistency of River Water Quality. *Nigerian Research Journal of Engineering and Environmental Sciences,* 2(2), pp. 315-321.

Olayiwola, O. and Olubunmi, F. (2016). The Use of Water Quality Index Method to Determine the Potability of Surface water and Groundwater in the Vicinity of a Municipal Solid Waste Dump Site in Nigeria. *American Journal of Engineering Research,* 5(10), pp. 96-101.

Shweta, T., Bhavtosh, S., Prashant, S. and Rajendra, D. (2013). Water Quality Assessment in Terms of Water Quality Index. *American Journal of Water Resources,* 1(3), pp. 34-38.

Ukpaka, C.P. and Ukpaka, C. (2016). Characteristics of Groundwater in Port-Harcourt Local Government Area. *Journal of Advances in Environmental Sciences,* 1(2), pp. 59-71.