EXTENDED ABSTRACT

Hydrogeochemical-geophysical investigations of groundwater quality and susceptibility potential in Ikot Ekpene-Obot Akara Local Government Areas, southern Nigeria

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ABSTRACT

Groundwater contamination is of global concern. The study area (Ikot Ekpene - Obot Akara Local Government Areas) continues to experience a swift increase in human population and associated economic activities, leading to the generation of more solid wastes. This could result in groundwater contamination, which can put the local pollution in severe danger. The fundamental goal of this work is therefore to weigh up the groundwater standard through hydrogeochemical investigation of groundwater samples and the susceptibility potential of the economically exploited aquifer units in the area. The results of the electrical geo-sounding data acquired at 28 locations in the area reveal three to four lithological successions comprising fine/coarse sands and gravels amid patches of thin clay interbeddings at several places. The primary aquifer in the area is the third layer, which is between 10.5 and 101.5 m deep with resistivity values between 359.4 and 2,472.8 Ωm. The hydrogeochemical evaluation of groundwater samples in the area shows that the measured physicochemical parameters are well within the World Health Organization's acceptable limits except for lead and nickel ions. These metals are shown to be the most significant parameters affecting the groundwater quality in the area. The groundwater quality and susceptibility potential maps generated seem to correlate well and clearly demarcate the poor groundwater quality/high susceptibility potential zones. These maps are useful tools that could aid policymakers in successful groundwater management in the area to meet the needs of the populace.

KEYWORDS: DRASTIC, Groundwater Quality Index (GWQI), Aquifer, Permeability, Susceptibility Potential, Contamination

1.0 INTRODUCTION

One of the problems of the 21st century is the inadequacy of sufficient quantities of fresh water to satisfy human domestic, industrial and agricultural needs. With the world's burgeoning population, groundwater is becoming a more sought-after source of fresh water due to its accessibility and generally higher quality relative to surface sources of water like rivers, streams and lakes (George *et al*., 2017; Thomas *et al*., 2020, Ekanem *et al*., 2022). The dwellers of Ikot Ekpene and Obot Akara Local Government Areas (LGAs) in southern Nigeria depend on groundwater to meet their water needs, in part as a result of insufficient surface water sources in the LGAs and also because of the contamination of the few available ones. In recent times, the study area has witnessed a swift population increase occasioned by the creation of small scale industries in the area coupled with other commercial activities. Consequently, increasing solid wastes (vegetable wastes, waste papers, scrap metals, cans containing different chemicals, plastic containers, old rags, vehicle tyres, scalpels and human wastes) could be seen littering in some streets in the area (Ikpe *et al.*, 2022; Ekanem *et al.*, 2022). Leachates produced by breakdown of these wastes, particularly rainwater have the potential of contaminating the aquifer units (Ikpe *et al.*, 2022).

While a few studies on aquifer vulnerability and groundwater potential assessments have been carried in parts of the LGAs, no hydrogeochemical analyses of borehole water samples have been conducted in these studies to ascertain the groundwater contamination level in the area apart from limited data coverage of the local government areas. Thus, the major thrust of this research work is to utilize the surface electrical resistivity sounding method with borehole lithological data and hydrogeochemical analyses of water samples to appraise the groundwater susceptibility to surface/near surface contaminants and groundwater quality in the entire area to delineate zones that may be prone to contamination. This is especially necessary for formulation of efficient groundwater development, exploration and waste disposal schemes by the policy makers in the research area.

2.0 MATERIALS AND METHOD

The electrical subsurface resistivity variation pattern of the study area was investigated by making use of the vertical electrical sounding (VES) technique. Geosounding measurements were made in the study area using the Schlumberger electrode array at 28 different locations. Three key geoelectric parameters (thickness, resistivity and depth) of the layers identified in the area were derived from the VES data interpretation. These parameters were utilized to determine the different lithological and aquifer units and their properties, in tandem with the available drilling data in the area. Topography data of the survey region was drawn from the digital elevation model (DEM). All these data were integrated in the DRASTIC model to appraise groundwater susceptibility potential using ArcGIS 10.5 in the study area. The DRASTIC model involves the combination of seven environmental variables, namely: Aquifer depth (D), net recharge (R), aquifer media (A), soil media (S), topography (T), impact of vadose zone (I) and aquifer hydraulic conductivity (C), thus forming the acronym 'DRASTIC'. According to how much it affects groundwater susceptibility to contaminants, each of the seven DRASTIC model factors is given a weight (W), which varies between 1 and 5 as stated by Aller et al. (1987). The factors with greatest severity are given a weighting value of 5 while the less severe ones are given a weighting value of 1. Additionally, every one of the seven DRASTIC factors is broken down into groups and categorized as ratings. The DRACTIC index can be computed from the combination of these weightings and ratings from Eq. (1).

$$DRASTIC\ Index = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw \qquad (1)$$

where Dr, Rr, Ar, Sr, Tr, Ir and Cr are the depth, net recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity ratings respectively. On the other hand, Dw , Rw, Aw, Sw, Tw, Iw and Cw are the corresponding depth, net recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity weightings. DRASTIC index (DI) of between 1 and 100 corresponds to low groundwater susceptibility, 101 and 140 corresponds to moderate susceptibility, 140 and 200 corresponds to high susceptibility while values greater than 200 correspond to very high susceptibility respectively (Aller *et al.*, 1987; Ekanem *et al.*, 2022).

Borehole water samples were obtained from 12 locations in the neighbourhood of the VES stations and dispatched out to the laboratory for geochemical analysis for major cations (sodium (Na), copper (Cu), iron (Fe), , manganese (Mn), calcium (Ca), potassium (K), cadmium (Cd), nickel (Ni), chromium (Cr), lead (Pb) and magnesium (Mg)) and anions (bicarbonates, sulphates, chloride and sulphides). Measurement of physical properties like TDS, pH and temperature were made on site by the use of a Waterproof pH/TDS/ EC/Temperature meter while that of DO were made also on site by the use of Jenway Model 1970 water proof DO meter.

Evaluation of the groundwater quality was carried out by the use of the Groundwater Quality Index (GWQI) parameter based on the World Health Organization's recommended standards (WHO, 2017). This was achieved by the use of Horton's weighted arithmetic technique introduced in 1965 and further refined by Brown *et al*. (1972). Mathematically, GWQI can be computed from Eq. 2.

$$GWQI = \frac{\sum_{i=1}^{n} W_i \times Q_i}{\sum_{i=1}^{n} W_i} \qquad (2)$$

where n is the number of parameters, i denotes an index that runs from 1 to n, W_i is the unit weight and Q_i denotes the quality rating value of the i^{th} parameter respectively.

3.0 RESULTS AND DISCUSSION

3.1 VES Interpretation Results

Three to four earth strata have been identified in the research area with their corresponding primary parameters (thicknesses, depths and resistivities). The lithological entities that were identified based on their patterns of resistivity variations were further interpreted using the geological drilling data from the survey region. The layers respectively have resistivity ranges of 64.6 to 1131.8 Ωm, 40.6 to 2648.1 Ωm, 354.2 to 2478.6 Ωm and 75.6 to 2658.3 Ωm. The identified layers were generally taken to be made up of poorly sorted sands of varying granule sizes ranging from clayey sand, sandy clay, fine and coarse sands to gravelly sands. Groundwater extraction in the research area is carried out mainly in the third layer, which lacks impervious confining layers at most locations occupied except VES 2, 6 12, 13, 20, 23 and 24. This aquifer layer lies between 10.5 and 101.5 m deep.

3.2 Groundwater susceptibility potential (GSP) and DRASTIC index (DI)

The computed DI values range between 111 and 173 in the study area. These values were employed to grade the aquifer susceptibility potential in the study region into two classes. These classes are moderate (DI = 111 - 134) and high (DI = 142 - 173). Analysis of the susceptibility ratings reveals that 75 % of the study area has moderate rating whilst the remaining 25 % has high rating. This result may be caused by the relatively flat topography in the research area together with the enormous pervious geomaterials of the strata above the aquifer system, which aid swift infiltration of any contaminants to the water table.

3.4 Water sample geochemical analyses results

The measured values of a greater number of the water sample parameters are well below the acceptable WHO's standards except parameters like pH at some locations (boreholes 1, 2, 3, 4, 5, 6, 8, 9 and 10), BOD at nearly all the borehole locations, chromium ions (boreholes 11 and 12) and nickel ions (boreholes 1, 8, 10, 11 and 12). The pH values measured vary between 5.6 and 9.8 with 6.6 mean. Underground water temperature ranges between 27.1 and 28.4 °C. DO concentration (in mg/L) varies between 4.5 and 5.8 with 5.22 average 0.43 standard deviation values respectively. TDS and COD both in parts per million (ppm) range from 1.0 to 56 and 0.48 to 6.67 with mean values of 7.95 and 1.67 respectively. The biochemical oxygen demand (BOD) in mg/L varies between 2.1 and 5.3 with a 2.99 mean value. The concentrations of all the anions (Cl^-, CO_3^-, SO_4^{2-} and SO_3^{2-}) in mg/L measured from the water samples are all well below the allowable limits of

WHO (2017). Similarly, the concentrations of the cations (Na^+, K^+, Mg^{2+}, Ca^{2+}, Fe^{2+}, Cu^{2+}, Pb^{2+}, Cd^{2+}, Mn^{2+} and Zn^{2+}) in mg/L are all well below the allowable limits of WHO (2017) except for Cr^{2+} (boreholes 11 and 12) and Ni^{2+} (boreholes 1, 8, 10, 11 and 12). By implication, these variables do not pose significant contamination risk except for Cr^{2+} and Ni^{2+} at the borehole locations indicated above.

3.5 Groundwater quality investigation results

The value of the computed GWQI varies between 18.2 at Ikot Abia Idem community and 70.7 at Library Avenue, which is close to the location of the old and abandoned dumpsite in the study area. The quality of groundwater was categorized into three ratings. These ratings are accordingly excellent (25 %) with GWQI values of 18.2 – 22.2, good (50%) with GWQI values of 27.5 – 47.5) and poor (25 %) with GWQI values of 50.5 – 70.7. The groundwater quality map indicates clearly that a greater part of the survey region belongs to the good/excellent groundwater standard zone. The southern section of the survey region, including the neighbourhoods of Utu Ikpe, Library Avenue, and Ikot Osurua, has poor groundwater quality. The red circle in Figure 2 indicates the abandoned old dumpsite while the blue one indicates the new one sited in the ravine area. Rainwater flows generally towards the south-eastern part, where there is a ravine carrying debris and other dissolved chemicals/contaminated fluid into the ravine area.

4.0 SUMMARY AND CONCLUSION

In this work, groundwater susceptibility potential and quality have been investigated using integrated hydrogeochemical and geophysical techniques. The research area is shown to be made up of three to four strata with the third stratum constituting the economically exploited aquifer. The aquifer depth varies between 10.5 to 101.5 m. Groundwater susceptibility potential was investigated by the use of the DRASTIC model whose index varies from 111 – 173. Accordingly, the study area grouped into two classes: moderate (75%) and high (25%) susceptibility potential ratings respectively. The results of the geochemical analyses of borehole water samples in the area show that the physiochemical parameters are below the allowable standards provided by the World Health Organization except for parameters like pH at some locations, BOD at nearly all the borehole locations, chromium ions and nickel ions respectively. The groundwater quality index (GWQI) is shown to vary from 18.2 to 70.7. Based on these GWQI values, three classes of quality ratings have been established for the study area: poor (25%), good (50%) and excellent (25%). Most of the exploitable aquifers in the area belong to the region with good to excellent water quality rating. Zones of high groundwater susceptibility potential and poor groundwater quality have been clearly demarcated by the generated groundwater susceptibility potential and water quality maps respectively. The groundwater susceptibility potential and water quality maps seem to correlate well and therefore constitute effective tools that could be employed by government and other policy makers for efficient planning and exploitation of groundwater in the research region.

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References

Aller, L., Bennett, T., Lehr, J. H., Petty, R. J. & Hackett, G. (1987). DRASTIC: A Standardised System for Evaluating Groundwater Pollution Potential Using Hydrogeologic Settings. US-EPA Report 600/2-87-035.

Brown, R. M., Mccleiland, N. J., Deiniger, R.A. & O'Connor, M. F. (1972). Water quality index-crossing the physical barrier. *Res. Jerusalem*, 6:787–797.

Ekanem, A. M., Ikpe, E. O., George, N. J. & Thomas, J. E. (2022). Integrating geoelectrical and geological techniques in GIS-based DRASTIC model of groundwater vulnerability potential in the raffia city of Ikot Ekpene and its environs, southern Nigeria. *International Journal of Energy and Water Resources*. https://doi.org/10.1007/s42108-022-00202-3.

George, N. J., Ekanem, A. M., Ibanga, J. I. & Udosen, N. I. (2017). Hydrodynamic Implications of Aquifer Quality Index (AQI) and Flow Zone Indicator (FZI) in groundwater abstraction: a case study of coastal hydro-lithofacies in South-eastern Nigeria. J. *Coast. Conserv.*, 21**:** 759 – 776. https://doi.org/10.1007/s11852-017-0535-3.

Ikpe, E. O., Ekanem, A. M. & George, N. J. (2022). Modelling and assessing the protectivity of hydrogeological units using primary and secondary geoelectric indices: a case study of Ikot Ekpene Urban and its environs, southern Nigeria. *Model. Earth Syst. Environ*., 8: 4373 – 4387. https://doi.org/10.1007/s40808-022-01366-x.

Thomas, J. E., George, N. J., Ekanem, A. M. & Nsikak, E. E. (2020). Electrostratigraphy and hydrogeochemistry of hyporheic zone and water-bearing caches in the littoral shorefront of Akwa Ibom State University, Southern Nigeria. *Environ Monit Assess*, 192:505. https://doi.org/10.1007/s10661-020-08436-6.

WHO, (2017). *Guideline for drinking water quality, 4th edition*. World Health Organization, Geneva.