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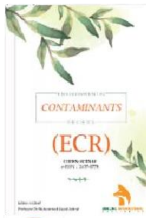

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REVIEW ARTICLE

ASSESSMENT OF GROUNDWATER QUALITY USING WATER QUALITY INDEX (WQI) METHOD IN SOUTHERN IJAW LOCAL GOVERNMENT AREA OF BAYELSA STATE, NIGERIA

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ABSTRACT

This study aims at using Water Quality Index (WQI) method for groundwater assessment in some communities in Southern Ijaw Local Government Area of Bayelsa State, Nigeria. A total of fifteen (15) communities within the LGA were selected and groundwater from hand-dug well (HDW-15 samples) and borehole (BH-15 samples) was sourced during the wet season (July) and dry season (March). The analyses for water quality index was carried out through laboratory APHA standard. The weighted arithmetic water quality method was applied to assess water suitability for drinking purposes. The Quality Index indicated that HDW (67%-good and 33%-poor) and BH (87%-excellent, 13%-very poor) quality during the wet season and HDW (80%- good to excellent, 20%-poor) and BH (100%- good to excellent) during dry season. Spatial variation of water quality index maps for HDW show most deteriorated groundwater quality is centered within hand dug well towards the western part of the area during both wet and dry seasons respectively. Continuous monitoring of the water quality, improvement of environmental quality and sanitation practices is advocated and advised.

KEYWORDS

Groundwater Quality, Water Quality Index, Hand Dug Well, Borehole, Southern Ijaw

1. INTRODUCTION

Groundwater is water that exists in the pore spaces/fractures in rocks and sediments beneath the earth's surface. Groundwater is a hidden but important resource. It originates as rainfall or snow and then makes its way back to surface streams, lakes, or oceans (Han et al., 2010). Groundwater has become an important source of drinking water across the worldwide, especially in developing countries according to (Nwankwoala and Ngah, 2014). The 2006 population census in Nigeria shows that 49.4% of households sampled depend on groundwater as the main source of water for domestic use.

Water quality is defined in perspective of its desired/intended use (s). Thus, the water quality desired for drinking purpose will need to be assessed for a set of parameters in comparison to the agreed standard norm. Similarly, the water quality desired for irrigation purpose will need to be assessed for a different set of parameters in comparison to the agreed standard norm for irrigation water (Ngah and Nwankwoala, 2013). Assessment of the water quality in terms of physical, chemical and bacteriological parameters for different uses is desirable. This is because water quality plays an important role in groundwater protection, quality conservation as well as sustainability. It is very important to assess the quality of water not only for its present use but also from the viewpoint of a potential source (s) of water for future consumption. There is therefore a growing concern about the deterioration of water quality due to geogenic and anthropogenic activities in Bayelsa State, Nigeria (Udom et al., 2012). The quality of water is identified in terms of its physical, chemical, and biological parameters (Ngah and Nwankwoala, 2013; Nwankwoala et al., 2018). Polluted groundwater cannot achieve a balanced ecosystem, in which living things and the environment interact beneficially with one another. Water quality plays a critical/essential role (s) in these relationships, as it is key to the maintenance of a well-balanced environment (Ntengwe, 2006; Ngah and Nwankwoala, 2013).

The water quality index (WQI) is considered a mathematical tool that significantly minimizes the complex water quality data sets and provides a single classifying value that describes the water quality status of water bodies or degree of pollution. WQI is a single dimensionless number that describes the overview of the overall water quality status in a simple way by aggregating the measurements of selected parameters such as pH, nitrate, dissolved oxygen (DO), heavy metal. As early as 1965, this method was introduced through mathematical equations to determine water quality status in the river by (Horton, 1965; Garcia, et al., 2018). The WQI is determined based on various biological, physical, and chemical parameters that define the various purposes of utilization of water bodies for human consumption, such as recreation, drinking, industries, irrigation, and domestic usage (s).

According to after the proposed Water Quality Index (WQI) method by proposed the best-known and most widely used index in the world, i.e. the National Sanitation Foundation's Water Quality Index (WQI-NSF). This index can be used to define water quality for different uses such as irrigation water supply and navigation, as well as for various water bodies (lakes, reservoirs and rivers) (Garcia et al., 2018; Horton,1965; Brown et al., 1970). The WQI-NSF is calculated based on weights assigned to each parameter, according to a statistical survey conducted using the DELPHI technique, elaborated by 142 experts (Garcia et al., 2018). WQI provides a

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single number that expresses the overall water quality at a certain location and time, based on several water quality parameters (Etim, et al., 2013; Emeka et al., 2020). The objective of WQI is to turn complex water quality data into information that is understandable and usable by the public. According to a number of indices have been developed to summarize water quality data in an easily expressible and easily understood format (Etim et al., 2013).

The analysis of groundwater quality in some part of Southern Ijaw Local Government Area of Bayelsa State, Nigeria is not only appropriate but timely because there is paucity of baseline data on the quality of groundwater in the area. It can be difficult to ascertain meaningfully, how impaired or degraded the water resources have become over the years. Thus, this study seeks to determine the status of the existing quality of groundwater sourced from unconfined aquifers (hand dug wells) and confined aquifers (boreholes) abstracted largely for domestic purpose (s) in the study area.

2. The Study Area

The study area, Southern Ijaw Local Government Area is in Bayelsa State, South South Nigeria. The area lies within latitudes 4°40′07″ E and 5°5′20″ E and longitudes 6°00′10″ N and 6°25′15″ N (Figure 1). It is bounded by Ekeremor Local Government Area in the West, Sagbama in the North-West, while Yenegoa and Kolokuma/Opokuma Local Government areas are in the north, then in the north-east, it is bounded by Ogbia Local Government area, Brass and Nembe Local Government Areas in the east and in the southern axis by the Atlantic ocean.

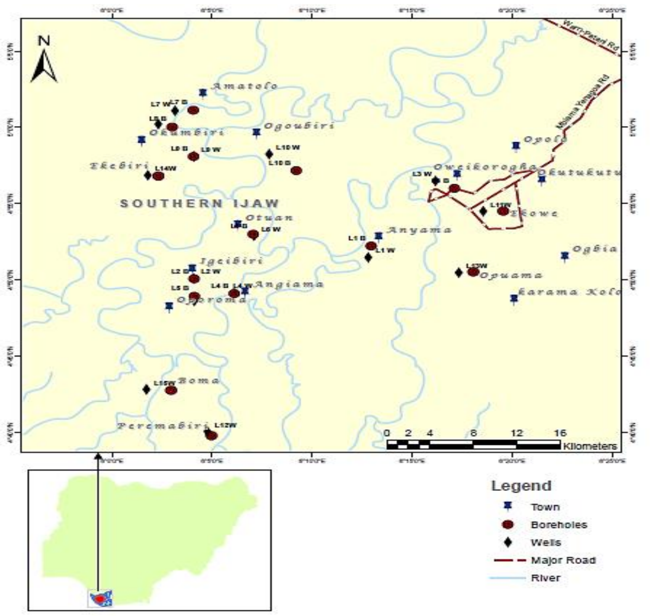

Figure 1: Map of the Study Area Showing Sampling locations

3. Brief Geology and Hydrogeology of The Study Area

The geology of the Niger Delta has been described in details by various authors/researchers, such as (Short and Stauble, I967; Kogbe, I976). The formation of the Delta started during Early Paleocene and resulted mainly from the build-up of fine-grained sediments which were eroded and transported by the River Niger and its tributaries. The Tertiary Niger Delta is a sedimentary structure formed as a complex regressive off-lap sequence of clastic sediments, ranging in thickness from 9,000m - I2,000m (Abam, 1999; Short and Stauble, 1967). Separate depocenters, in the Niger Delta has coalesced to form a single united system (s) since Miocene. The Niger Delta is a large and ecologically sensitive region, in which various water species including surface and sub-surface water bodies exist in a state of dynamic equilibrium (Abam, I999; Abam and Nwankwoala, 2020). The Niger Delta is stratified by three lithologic successions, mainly Benin Formation, Agbada Formation and Akata Formation, respectively.

The Niger Delta has two major aquifers, Deltaic and Benin Formations (Amadi et al., 2012; Ngah and Nwankwoala, 2013). With a regularly dendritic system, this very penetrable sands of the Benin Formation enables simple penetration of water to revive the shallow aquifers. A depicted the aquifers as an arrangement of various aquifer frameworks stacked on one another, with the unconfined upper aquifers as most vulnerable to contamination (Ngerebara and Nwankwoala, 2008; Nwankwoala et al., 2013).

The recharge mechanism of the aquifers is immediate from invasion of precipitation (rainfall), the yearly aggregate of which shifts between 5000mm at the drift to about 2540mm landwards. Groundwater in the zone occurs in shallow aquifer systems, of overwhelmingly mainland deposits experienced at penetrations of somewhere in the range of 45m and 60m .The lithology contains a blend of sand in a fining-up arrangements, rocks and muds. Well yield is phenomenal, with generation rates of 20,000 liters/hour normal and borehole achievement rate is typically high (Amadi et al., 2012; Ngah and Nwankwoala, 2013).

4. Methodology

4.1 Sampling Procedure

Water samples for the study were collected during the dry season (March) and wet season (July) from borehole (s) and hand-dug well (s) groundwater sources around the study area. Water samples were collected from 15 boreholes and 15 groundwater sources during the dry season. The process was repeated during wet season which implies that a total of sixty (60) samples were collected for the study during both seasons. In order to prevent confusion and mixed up of the water samples, each sample was tagged according to their sources, and the season they represent and with Roman figure (s) to represent the position of the sample (s) as presented;

- Borehole (BH) Water during Wet Season (WS) = BHWS I-XIV
- Borehole (BH) Water during Dry Season (DS) = BHDS I-XIV
- Hand-dug well (HDW) Water during Wet Season (WS) = HDWWS I-XIV
- Hand-dug well (HDW) Water during Dry Season (DS) = HDWDS I-XIV

With the aid of labeled lucid bottle, water samples were collected from various designated water source. Prior to the water collection, the lucid bottles were cleaned with 70% sterilizer in order prevent impurities and other forms of contamination. Thereafter, the water samples were collected from each designated point and the bottles were fully filled. The filled bottles were immediately placed in the ice-parked cooling medium to arrest continuous microbial activities and to preserve the water before been taken to the laboratory for analyses.

4.2 Weighted Arithmetic Water Quality Index (WQI) Analysis

The weighted arithmetic WQI method was applied to ascertain water suitability for drinking purposes (Akter et al., 2016). In this method, water quality rating scale, relative weight, and overall WQI were calculated by the following formulae:

$$q_i = (C_i / S_i) \times 100 \qquad (1)$$

Where;

q_i = Quality rating scale

C_i = Concentration of i parameter

S_i= Standard value of i parameter,

Relative weight was calculated by

$$w_i = 1/S_i \qquad (2)$$

Where the standard value of the i parameter is inversely proportional to the relative weight.

Thereafter, the overall WQI was calculated according to the following expression:

$$WQI = \sum q_i w_i \Big/ \sum w_i \qquad (3)$$

5. Results and Discussion

5.1 Water Quality Index (WQI) for Groundwater from Various Sources

Water Quality Index (WQI) results for groundwater obtained from Hand Dug Wells (HDW) ranged from 34.97 - 58.77 during wet season and from 24.91 to 65.48 during dry season. According to classification scheme, the result showed that over 67% of groundwater sourced from HDW's are of good quality while 33% are of poor quality during the wet season. Similarly, in the dry season, 80% of groundwater sourced from HDWs are of good to excellent quality while 20% are of poor quality (Vasanthavigar et al., 2010). For groundwater obtained from boreholes (BH), WQI ranged from 18.51 to 78.61 during wet season and from 18.12 to 25.97 during dry season. Based on classification scheme, this result shows over 87% of groundwater sourced from boreholes are of good to excellent quality while 13% are of very poor quality during the wet season (Vasanthavigar et al., 2010). Meanwhile, in the dry season, 100% of groundwater sourced from BH are of good to excellent quality, suggesting much improvement in groundwater quality during dry season. Spatial variation water quality index maps for HDW show most deteriorated groundwater quality is centered around hand dug well L8W towards the western part of the area during both wet and dry seasons, respectively. Spatial variation water quality index maps for boreholes during the wet season showed that most deteriorated groundwater quality is centered around the southeastern part of the study area.

From Table 2 and Figures 2 - 5, based on the WQI rating proposed by the sampled groundwater from various communities of study were categorized into "Excellent (0-25)", "Good (>25-50)", "Poor (>50-75)" and "Very Poor (>75-100)" according to their obtained rating (Akter et al., 2016). The WQI rating of HDW during the wet season showed that water from L1W, L2W, L5W, L6W, L7W and L12W-L15W were rated *Good* having index ranged from 34.95-44.18 while water from L3W, L4W, L8W, L10W and L11W were rated *Poor* having index ranged from 53.59-58.77. The WQI rating of HDW during the dry season showed that water from L2W was rated *Excellent* having index of 24.91, water from L1W, L5W, L6W, L7W, L9W-L15W were rated *Good* having index ranged from 34.17-48.54 while water from L3W, L4W and L8W were rated *Poor* having index ranged from 53.50-65.48. The WQI rating of BH during the wet season showed that water from L2B, L5B-L10B, L12B, L14B and L15B were rated *Excellent* having index ranged from 19.58-23.92. Water from L1B, L4B and L11B were rated *Good* having index ranging from 24.83-25.97 while L3B and L13B were rated *Very Poor* having index 78.61 and 77.74 respectively. The WQI rating of BH during the dry season showed that water from L2B-L10B, L13B, L14B and L15B were rated *Excellent* having index ranged from 18.12-24.83 while water from L1B, L11B and L12B were rated *Good* having index of 25.14, 25.97.

Table 2: Weight and Relative Weight for Each Water Quality Index Parameter

No.	Chemical Parameter	Standard	Weight (Wi)	Relative Weight (Wi)
1	Ph	8.5	4	0.129
2	EC	750	4	0.129
3	Total Hardness	300	2	0.065
4	TDS	500	4	0.129
5	Bicarbonate	250	3	0.097
6	Chloride	250	3	0.097
7	Sulphate	200	4	0.129
8	Calcium	75	2	0.065
9	Magnesium	30	2	0.065
10	Sodium	200	3	0.097
			∑ wi = 31	∑ Wi = 1.002

Table 3: Water Quality Index (WQI) for Groundwater Across the Study Area

Hand Dug Well	Wet Season		Dry Season		Boreholes	Wet Season		Dry Season	
	WQI	Rating	WQI	Rating		WQI	Rating	WQI	Rating
L1W	34.97	Good	36.55	Good	**L1B**	28.35	Good	25.14	Good
L2W	37.72	Good	24.91	Excellent	**L2B**	19.99	Excellent	18.90	Excellent
L3W	54.78	Poor	53.50	Poor	**L3B**	78.61	Very Poor	22.15	Excellent
L4W	58.77	Poor	62.04	Poor	**L4B**	25.80	Good	24.83	Excellent
L5W	34.95	Good	31.45	Good	**L5B**	23.58	Excellent	22.27	Excellent
L6W	32.08	Good	34.17	Good	**L6B**	21.82	Excellent	19.00	Excellent
L7W	36.32	Good	25.96	Good	**L7B**	18.51	Excellent	18.42	Excellent
L8W	58.33	Poor	65.48	Poor	**L8B**	19.58	Excellent	18.96	Excellent
L9W	44.18	Good	37.42	Good	**L9B**	23.39	Excellent	23.04	Excellent
L10W	53.59	Poor	48.54	Good	**L10B**	19.62	Excellent	18.12	Excellent
L11W	56.76	Poor	38.48	Good	**L11B**	25.27	Good	25.97	Good
L12W	43.32	Good	48.39	Good	**L12B**	22.68	Excellent	25.40	Good
L13W	39.31	Good	40.40	Good	**L13B**	77.74	Very Poor	22.21	Excellent
L14W	39.19	Good	44.57	Good	**L14B**	23.92	Excellent	21.20	Excellent
L15W	35.51	Good	31.48	Good	**L15B**	21.35	Excellent	22.33	Excellent

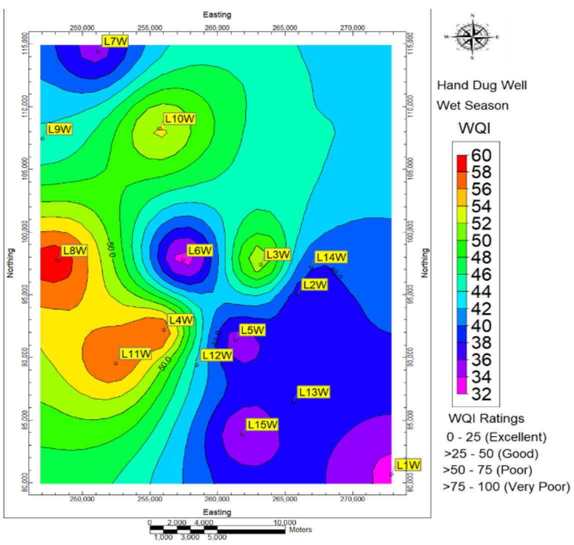

Figure 2: WQI Variations in Groundwater Quality obtained from HDW during the Wet Season

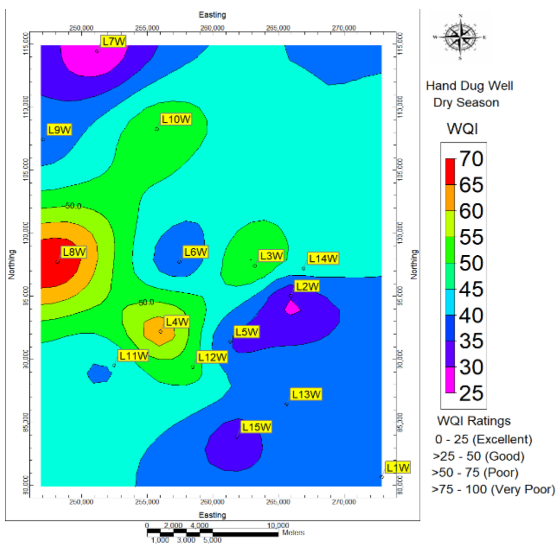

Figure 3: WQI Variations in Groundwater Quality obtained from HDW during the Dry Season

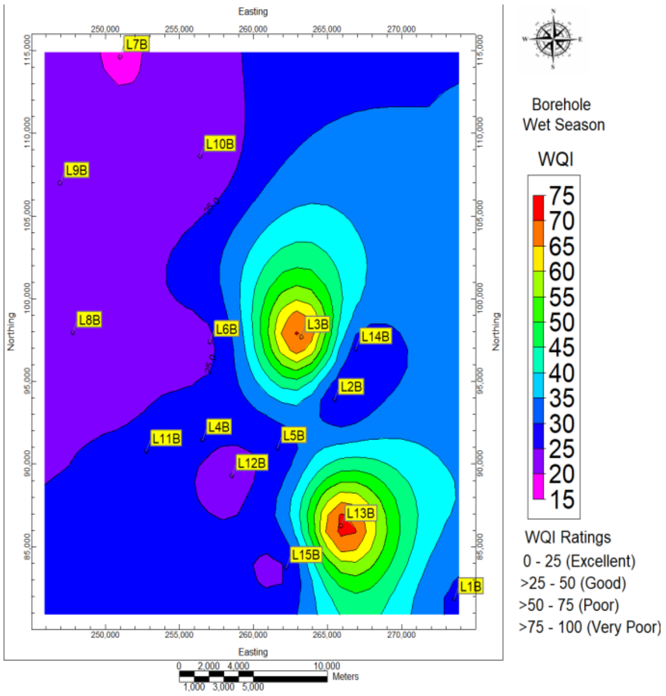

Figure 4: WQI Variations in Groundwater Quality obtained from BH during the Wet Season

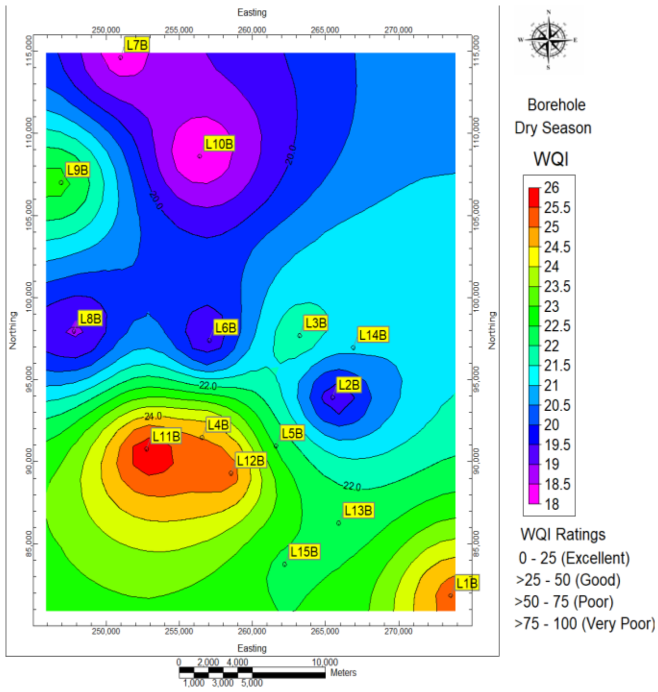

Figure 5: WQI Variations in Groundwater Quality obtained from BH during the Dry Season

6. Conclusion

i. The result showed that over 67% of groundwater sourced from hand dug wells (HDW) are of good quality while 33% are of poor quality during the wet season. Similarly, in the dry season, 80% of groundwater sourced from HDW is of good to excellent quality while 20% are of poor quality.

ii. The result showed that over 87% of groundwater sourced from boreholes (BH) are of good to excellent quality while 13% are of very poor quality during the wet season. Meanwhile, in the dry season, 100% of groundwater sourced from BH are of good to excellent quality, suggesting much improvement in groundwater quality during dry season.

iii. Spatial variation of water quality index maps for HDW show most deteriorated groundwater quality is centered around hand dug well L8W towards the western part of the area during both wet and dry seasons respectively.

iv. Spatial variation of water quality index maps for BH during the wet season shows most deteriorated groundwater quality is centered around the southeastern part of the study area.

v. Water quality monitoring and assessment in the study area is invariably made apparent in this study and further elaborations of the significance of water quality in sustainable development are presented.

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