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(Review Article)

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Critical evaluation of groundwater aquifer with 1D resistivity survey and hydraulic parameters in parts of Bayelsa State

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Abstract

In the first place, some previous studies in the study area were looked at. This, consequently, led to the writing of this paper. The paper was made up of carrying out VES and estimation of hydraulic parameters with the help of the Ves results and other related derivations. The electrical resistivity survey was conducted with a resistivity meter called Hero Jat. Schlumberger array was employed in the field work and interpretation of the data was made with ipi2win and Interpex software. The Ves results were used to compute hydraulic parameters with the help of Dar Zarrouck parameters and other related derivations. The results obtained were also presented. The results for the various types of curves were discussed with their hydraulic parameters. It was concluded that there was no noticeable negative impact of the groundwater aquifer in the study area.

Keywords: Dar Zarrouck parameters; Schlumberger array; Hydraulic parameters; Resistivity meter; Related Derivations

1. Introduction

Groundwater is a major source of water supply in Bayelsa State as a greater percentage of the total population relies on it for daily living. It is, therefore, seen that groundwater is very significant in the State.

Some studies have been carried out in the area with conclusions that physico-chemical parameters were within acceptable limit with the exceptionn of iron (Okiongbo et al., 2015, Akpofure et al., 2019). The initial studies were more directed towards the issue of high concentration of iron.

Ground water iron, being a problem in the area, enabled researchers delve into investigation of iron in the area. They investigated the issues of groundwater iron from different perspectives.

Ogini et al., (2021) looked at a way of groundwater iron prediction by means of specification of resistivity values to iron in the area.

Okiongbo et al., (2019) investigated iron concentration from the angle of lithological influence and came up with several conclusions to the issues of groundwater iron. They not only stopped at the lithological influence but went on to investigate the issue of iron from the perspective of sediment colour (okiongbo et al., 2017)

Afolabi *et al*. (2021), carried out a study of influence of seasonal variation of groundwater in Sagbama LGA and opined that there was no effect of seasonal variation on groundwater, though, there were strong correlations among physio-

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chemical parameters. Continuous monitoring of groundwater was recommended for the study area to comprehend groundwater contaminants and provide policy decisions towards them.

The trend of activities of Groundwater iron were examined by means of resistivity and induced polarization in Bayelsa State. Conclusions had been made that resistivity values and induced polarization values were contrasting with the exception of few cases in relative redox potential environment. The redox potential environments were the factors of groundwater iron concentration. In aquifers where the top soil layers were mostly made of clay, the redox potential was not high resulting to mild reducing environment meaning high concentration of groundwater iron. The opposite was the situation where the topsoil layers were mostly made up of sandy material. The redox potential in this case was large indicating mild oxidation environment and low concentration of groundwater iron (Okiongbo *et al.*, 2019).

Okiongbo *et al.* (2012) reported that there was a strong correlation between computed transmissivity and pumping test transmissivity. There was a very high transmissivity in the study area which was in agreement with the coastal plane sand formation. Dar zarrouk parameters were used to compute the transmissivity with the help of established derivations which were proven to be good by other studies such as Niwas *et al*. (1981). Good groundwater potential was noted from the high values of transmissivity (Okiongbo *et al.,* 2012).

It has been noted severally that iron was the major problem in the area. However, in this study, attention is directed to k-curve type of environment and to investigate the situation of the aquifer in these areas whether there would be a negative impact. Not only the areas of less concentration of iron would be looked at but also the areas of high concentration of iron due to environmental changes. Hydraulic parameter estimation is adopted into this study because vulnerability of aquifer has been reckoned to be a function of Dar Zarrouk parameters, Moses et al., (2021) and Yugul et al., (1996) which are viable tools in the estimation of hydraulic parameters and are pointers to the vulnerability status of aquifers.

2. Material and methods

The various sites for the study were selected in the first place and they were mostly chosen partly from Yenagoa Local Government Area and partly from Ogbia Local Government Area. The sites encompassed the regions of high and low concentration of iron because iron is the major issue in the area.. The VES stations are shown by the rectangular shape in figure 1.

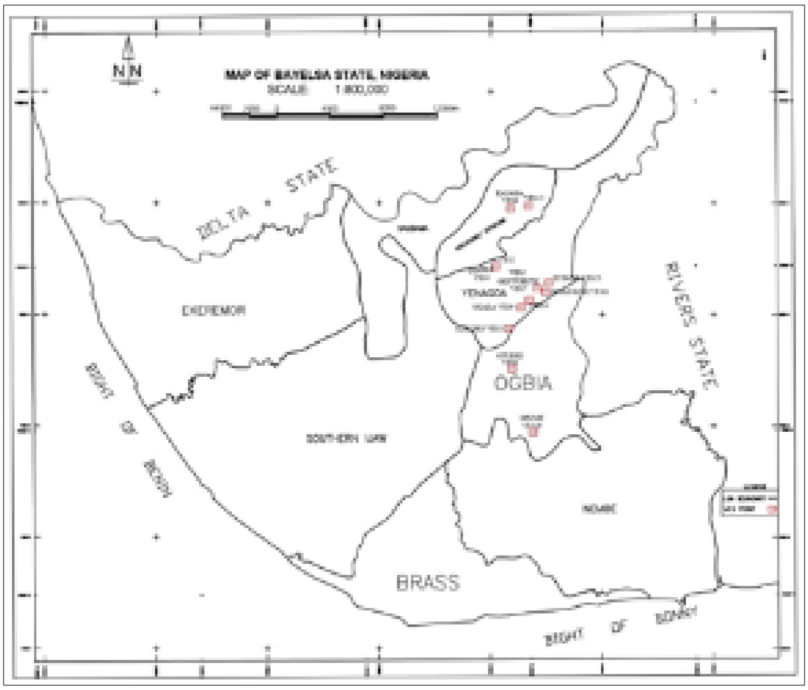

Figure 1 Map Showing the Ves Locations of the Study Area

The instrument for carrying out the resistivity survey was Hero Jat which is a portable equipment and has an inbuilt battery which, off course, enhances its portability. Four steel electrodes were utilized as well as wires or cables for connecting to the current and potential electrodes. The wires were wound round a reel. Hammers were also provided for driving or implanting the electrodes firmly into the ground.

Electrical resistivity method was adopted in the study which involved carrying out resistivity survey. Schlumbergger configuration was used in the field work. In this case, the distance between two current electrode is the same while the distance between potential electrodes is different from that of the current electrodes. The current electrodes were moving forward as the measurement progressed for deeper depth penetration and the potential electrodes moved forward a bit for signal to be captured for evaluation of voltage or potential difference. In essence, resistance was the target while the other parameters (current and potential difference) were obtained in the field. The distance between current electrode is called AB and was divided into two (half AB spacing). The same was applicable to the potential electrodes.

Transmissivity was calculated from Dar Zarrouk parameters and other related derivations as shown subsequently. It is of great convenience to establish a relationship between transitivity and Dar Zarrouk parameters. Transitivity is known to maintain groundwater flow and is given by the expression

$$T= kh$$

Where h = saturated thickness of the aquifer, k = hydraulic conductivity. The Dar Zarrouk parameters are the transverse resistance (T_R) and the longitude conductance (S). They are expressed in the following ways;

$$T_R = h\,\rho \text{ and } S= h/\rho$$

Where h is the saturated thickness of the layer (in meters), ρ is the electrical resistivity of the layer in Ohm –m which is equal to the inverse of conductivity (1/∞), T_R= Transverse Resistance and S= Longitudinal Conductance

Niwas and Singhal (1981**)** set up an analytical relationship between the aquifer transmissivity (T) with transverse resistance T_R and longitude conductance (S).

$$T = (k\,\infty)\,T_R \text{ or } T = (k/\rho)\,T_R$$

And

$$T = (k/\infty)\,S \text{ or } T =(k\rho)S$$

Where T= Transmissivity, T_R= Transverse Resistance, ∞=Conductivity, ρ = Resistivity, S= Longitudinal Conductance, k= Hydraulic conductivity.

It has been noted that in a given geologic location either the product (k ∞) or the quotient (k/∞) showed a good consistence (Niwas and Singhal 1981,1985; Onuoha and Mbazi 1988). The estimation of transmissivity in this paper was based on VES method where the transverse resistance has been noted to be a major parameter in environment of k-shaped curves whereas H-curve has been considered to be influenced by longitudinal conductance (Okiongbo 2014). The reference station for this study had pore water resistivity of 134Ωm while hydraulic conductivity was 28m/day.

$$K=28\text{m/day},\ \infty=1/134=0.0074,\ k\infty=0.21,\ k/\infty=3752$$

The study area was characterized by curves of both K-type and H-type.

3. Results

3.1. Vertical electrical sounding results

The results of the VES have been outlined in the following table1 and table 2 while tables 3 and 4 are showing the various estimations of the hydraulic parameters. Some of the VES curves have also been outlined in the following figures 2 and 3. They showed the behavour of the lithology when currents passed through the earth surface.

Table 1 Ves results for k-curve type

Ves no	location	H_1	H_2	H_3	H_4	R1	R2	R3	R4	R5	Error	Curve type
1	Tombia	0.9	2.2	3.6	7.2	894.3	3445.3	2101.3	618.9	710.6	4.4	kh
2	Tombia	0.6	1.3	2.5	9.8	297.6	3449.0	317.5	2301	1658.7	4.7	K
3	Tombia	0.8	0.5	5.9	2.4	158.5	579.3	8337.8	1354.9	282.7	4.8	K
4	Tombia	1.0	0.9	10.2	2.6	294.5	535.2	5445.0	1766.7	317.3	4.8	K
5	kaima	0.5	1.3	19.5	79.5	41.1	/2.0	357.8	584.1	374.4	3.7	K
9	Otuoke	0.4	2.0	5.2	15.1	161.1	147.1	762.7	42.4	939.5	3.8	kh

Table 2 Ves results for H-curve Type

Ves no	location	H_1	H_2	H_3	H_4	R1	R2	R3	R4	R5	Error	Curve type
6	Kaima	0.5	0.6	1.9	9.7	51.1	108.0	47.0	6.2	553.6	4.1	H
8	Otuoke	0.5	7.2	8.0	24.0	565.3	145.5	125.3	190.9	417.6	2.6	H
10	Azikoro	0.5	1.8	3.4	18.5	77.8	18.1	73.7	63.1	62.0	2.3	H
11	Opolo	0.4	0.2	3.1	8.0	174.9	33.0	16.1	62.6	85.0	2.2	H
12	Opolo	0.4	0.6	5.6		113.5	20.8	25.4	1143.1		3.0	H
13	Kaima	0.8	1.2	2.6	12.9	148.5	34.8	15.4	13.5	128.5	3.2	H
14	Opolo	0.3	2.6	22.7		402.6	48.3	55.9	330.0		3.6	H
15	Opolo	0.5	0.4	4.7		94.0	16.2	19.1	450.5		3.9	H

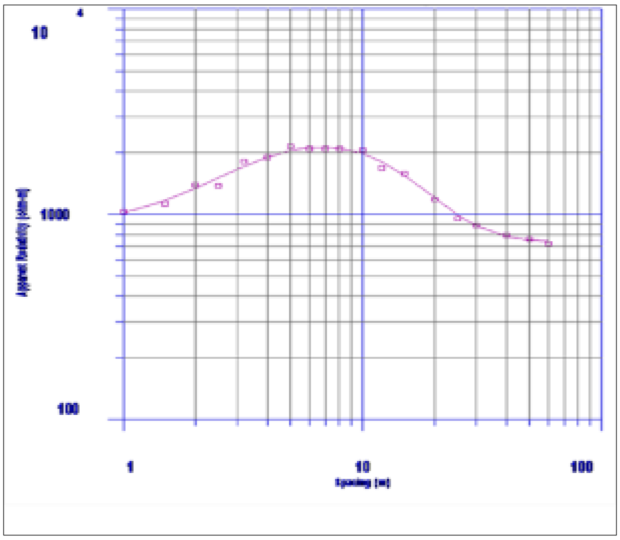

Figure 2 Ves 1

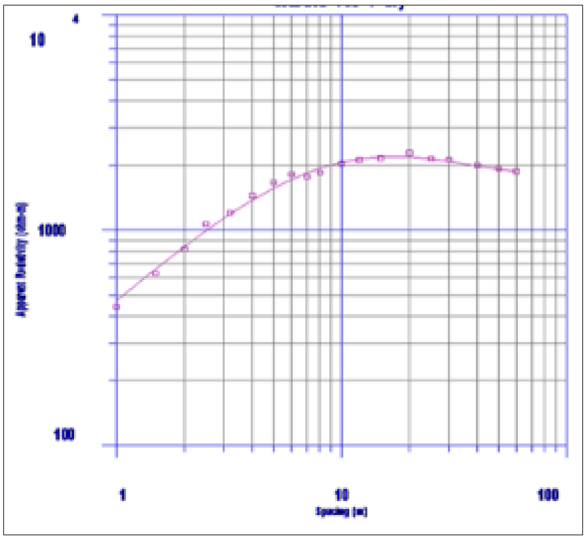

Figure 3 Ves 2

3.2. Estimation of hydraulic parameters from Dar Zarouk Parameters

Table 3 Estimation of hydraulic parameters from Dar Zarouk parameters for k curves

Ves	H	ρ	RT	k∞=0.21	T	K
1	3.5517	2101.3	5361.9		1126.0	317.0
2	2.7663	3171.5	7821.9		1642.6	666.0
3	5.9076	8337.8	4925.6		1034.3.	1750.9
4	10.178	5445.0	5541.9		1163.8	1143.5
5	19.445	357.73	6955.9		1460.7	76.7
7	4.4515	35.738	159.1		33.4	7.5
9	5.1988	752.70	3965.1		832.7	160.2

Table 4 Estimation of hydraulic parameters from Dar Zarouk parameters for h curves

Ves	H	ρ	S	k/∞=3752	T	K
6	1.9095	46.991	0.041		152.4	79.8
8	7.9819	125.29	0.064		239.0	30.0
10	3.4280	73.737	0.046		174.0	50.8
11	3.08114	16.080	0.192		718.9	233.3
12	5.6122	25.387	0.221		829.4	147.8
13	2.5446	15.442	0.165		618.3	243.0
14	22.729	55.880	0.407		1527.1	67.2
15	4.6766	19.053	0.245		920.9	196.9

4. Discussion

4.1. Transmissivity under K-curves Location

Transmissivity is known to be a function of aquifer thickness and resistivity. According to Moses, et al., (2021), high values of transverse resistance means high transmissivities. In Ves 1 and 2, transmissivity was a bit high. The transmissivity, was noted to be high which is also an indicator of high groundwater potential in the aera. These transmissivity values also mean high permeability, porosity and contaminant flow. Iron is the major undesirable element in this study area which is limited in this environment of k-type of curves as supported by pre-existing boreholes and previous study conducted in the area. In essence, the movement of the iron would also be limited. There would be no migration of iron and within the wet season, there would be dissolution of concentration of geochemical parameters. For VES 3 and 4, the transmissivity values were also high. This could be due to the high resistivity values as transmissivity is a function of resistivity and aquifer thickness as increase in resistivity would lead to increase in transverse resistance which, in turn, gives high transmissivity bearing in mind the constant of multiplication. In general, there would be no impact of iron.

4.2. Hydraulic Conductivity under K-type of Curves

Hydraulic conductivity is high as noted previously as the transverse resistance is high. Generally, the hydraulic conductivity is high in this area of the study area.

4.3. Transmissivity under H-curve type

The longitudinal conductance under the H-curve type is not high and the highest values are seen between Ves 14 and 15. The transmissivity values are not so high as those in K-type of curves which are higher in the area of k-type of curves. According to Moses et al (2021), low longitudinal conductance means poor aquifer protection. However, the transmissivity values are low and the problematic element is iron whose transmission would be low. In this area, the iron concentration is more from preexisting boreholes and previous studies in the area. The transmissivity values are low meaning lesser permeability, porosity and movement of fluid contaminants while in this case is iron. From the Ves resistivity values, the greater the depth the greater the resistivity values meaning higher transmissivity and greater groundwater potential with depth in the area of H-type of curves. The sandy layer in most of these curves tend to extend to greater depth.

4.4. Hydraulic Conductivity under H-type of curves

Comparatively, the hydraulic conductivity values are less in this area than the K-type of curves. . The hydraulic conductivity also increases with depth.

4.5. Critical Evaluation of Groundwater Aquifer

There is no perceived negative impact of groundwater aquifer in both areas of high concentration and low concentration of iron. In the areas of low concentration of iron (k-curve type of environment), the transmissivity and hydraulic conductivity values are high which means that there would be high flow of contaminant and in this case, iron. However, it is less concentrated and therefore, its vulnerability impact would be less as its transportation in the area would be insignificant. There is an appreciable groundwater potential in this area. In the areas of high concentration of iron, the transmissivity and hydraulic conductivity values are low meaning less transportation of contaminants. Therefore, in the H-curve type of environment (high concentration of iron), there would be no significant vulnerability impact of the groundwater aquifer. In this type of environment (in most cases) the deeper the aquifer the greater the resistivity values and the greater the groundwater potential.

5. Conclusion

There was no noticeable negative impact in the aquifers of the study area as noted from the hydraulic parameters. The same situations were applicable to the areas of high concentration of groundwater iron as well as those of low concentration.

Recommendation

It is always necessary to know the events of activities in the subsurface through geophysical survey such as ground water which is fundamental to the well-being of mankind. It is, therefore, important to carry out this kind of study continuously in order to be aware of the activities going on in the subsurface. Not only ground water but also other activities which might be taking place in the subsurface. Governmental organizations should try to give more attention to the issue of groundwater in Bayelsa State.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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