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Assessment of the Vulnerability of Water Supply Aquifers in Parts of Imo River Basin, South-eastern Nigeria: The Case of Imo Shale and Ameki Formations.

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Abstract

Twenty three locations in the study area were investigated to obtain data on the depth to water table, net recharge, aquifer media, soil media, topography, impact of the vadose zone and hydraulic conductivity. These parameters are denoted by the acronym, DRASTIC, an empirical groundwater model that estimates groundwater contamination vulnerability of aquifer systems based on the hydro-geological settings of the area. This was used to develop a groundwater vulnerability map for the study area. The vulnerability map shows that areas within Imo shale and Ameki Formations have generally moderate vulnerability to pollution while locations such as Okwelle, Umuna and Okwe have low vulnerability.

Keywords: Water table, vulnerability, net recharge, aquifer media, soil media, topography. DRASTIC model.

1. Introduction

The Imo River Basin is based on a bedrock of a sequence of sedimentary rocks of about 5480m thick and with ages ranging from Upper Cretaceous to Recent (Uma, 1986). It is known to contain several aquiferous units. The proportion of sandstones to shales varies from formation to formation and sometimes from place to place within the same formation. The interlayering of sandy and shaly units form complex aquifer systems that are respectively localized in the formations,such that it is almost impossible for aquifers to cross formation boundaries. This is because the regional stratigraphy and the general trends of the geologic formations feature sharp changes in lithology which prevent hydraulic continuity (Uma, 1989). The characteristics of these aquifers such as transmissivity, hydraulic conductivity and storage potentials are not clearly understood. Since the mid 1980's, some researchers from the academia have carried out geological/geochemical investigations. Uma (1986) carried out a study on the ground resources of the Imo River Basin using hydro-geological data from existing boreholes. He concluded that three aquifer systems (shallow, middle and deep) exist in the area (Uma,1989). Geophysical investigations on groundwater resources in the Imo River Basin were also carried out in different sections of the basin. While the contributions made by these workers are remarkable, more work still needs to be done, particularly in the area of assessment of vulnerability of the aquifer systems. The present study is aimed at investigating the vulnerability of the hydro-geological settings in Ameki and Imo shale Formations to pollution.

1.1 The Study Area

The study area (Fig. 1) lies between latitudes $5^o42^{\prime}$N and $5^o45^{\prime}$ and longitudes $7^o10^{\prime}$ and $7^o27.^{\prime}$ Some of the towns in the area include Okwelle, Okwe, Umuna, Umuduru, and Ikperejere.

1.1.1 Geology of the Study Area

Two geologic formations are covered in the study area, namely: Imo shale and Ameki formations respectively. Imo shale of Paleocene-Lower Eocene age consists of a thick sequence of blue and dark grey shales with occasional bands of clay-ironstones and subordinate sandstones (Swardt and Casey, 1961). It dips at angles 17° to 25° to the south-west and South (Uma, 1986). It includes three constituent sandstones: the Igbabu, Ebenebe and Umuna Sandstones with the last two outcropping in the Imo River Basin. The Umuna sandstone is composed of thick sandstone units and minor shales and is generally less than 70m thick. The Ebenebe Sandstone occurs as a lens in the northwestern extremity of the Imo River Basin. It is similar in lithology to the Umuna sandstone but is relatively thicker with a maximum thickness of 130m (Uma, 1986). Ameki Formation (Eocene) consists of sand and sandstones. The lithologic units of the Ameki Formation fall into two general groups (Reyment, 1965; Whiteman, 1982 and Arua, 1986); an upper grey-green sandstones and sandy clay and a lower unit with fine to coarse sandstones, and intercalations of calcareous shales and thin shelly limestone.

The Imo River Basin has a large amount of recharge; estimated at 2.5 billion m^3 per annum, coming mainly from direct infiltration of precipitation. Average annual rainfall is about 2000mm (Onwuegbuche, 1993). Shallow unconfined aquifers occur beneath the outcrop areas of the sandstone units of the Imo and Ameki Formations. These shallow unconfined aquifers are limited to the outcrop zone of the various sandstone units of these formations and correspond to the broken ridges and isolated hills common in the upper part of the Imo River Basin (Uma, 1989). They form the recharge zones of the aquifer units within the Imo River Basin, and many of the springs which form the headstreams of the Imo River are sourced from them.

2. Research Methods

The DRASTIC model was developed in USA for the purpose of protecting groundwater resources (Aller et al., 1985; Aller, 1987). DRASTIC is an empirical groundwater model that estimates groundwater contamination vulnerability of aquifer systems based on the hydrogeological settings of the area. A hydrogeological setting is defined as mappable unit with common hydrogeological characteristics (Engel et al., 1996).

The DRASTIC model was used to develop the groundwater vulnerability map for the study area. The generic model was used to determine the weights and the ratings. The The model employs a numerical ranking system that assigns relative weights to various parameters. The acronym DRASTIC is derived from the seven factors considered in the method, which are **D**epth to water table [**D**], net **R**echarge [**R**], **A**quifer media [**A**], **S**oil media [**S**], **T**opography [**T**], **I**mpact of the vadose [**I**] and hydraulic **C**onductivity [**C**]. Each DRASTIC factor is assigned a weight based on its relative significance in affecting pollution potential. The ratings range from 1 – 10 and weights from 1-5. The DRASTIC Index [**DI**], a measure of pollution potential, is computed by summation of the products of ratings and weights of each factor . The final results for each hydrogeological setting is a numerical value, called DRASTIC index. The higher the value is, the more susceptible the area is to groundwater pollution.

Twenty three vertical electrical sounding results coupled with the geology of the study area were used to determine such parameters as the depth to the water table, the aquifer media, the soil media and the impact of the vadose zone. The topography was estimated from a topographic contour map . The hydraulic conductivities were derived from the Dar Zarrouk parameters (transverse unit resistance and longitudinal conductance in porous media) obtained from the VES data . The recharge rate was estimated from annual rainfall records for Umuahia (NRCRI)** and Owerri (UNICEF)***, and extrapolated for the rest of the study area.

The GIS software, ArchView 3.2a, was used to generate the Groundwater Vulnerability Map. The VES sounding locations, as represented by northings and eastings, were used in geo-referencing. Estimates for the vulnerability indices spatial distribution were determined by applying appropriate GIS overlay functions.

3. Results and Discussions

The deduced DRASTIC parameters were used to compute the DRASTIC Index at the various VES points and these are given in Table 1. This was then used to generate the Groundwater Vulnerability Map (GVM) for the study area. Figure 2 shows the vulnerability map of the study area, while Figure 3 shows the vulnerability contour map of the study area. The map shows that much of the study area has generally moderate vulnerability, while such locations as KS1 (Okwelle 1), KS2 (Okwelle 2), KS3 (Umuna 1), KS6 (Okwe 3), KS10 (Umuna 3), KS13 (Orji), KS15 (Umudike Eluama), KS16 (Umudibia Eluama) and KS22 (Ezuiama Osuama) have low vulnerability. This may be due to lower porosity in areas underlain by clay and shale.

4. Conclusion

The study area consists of intercalations of clay and shale which have generally low permeability. This may have accounted for the low and moderate vulnerability of the aquifers located there. The DRASTIC model proved to be useful in the assessment of the vulnerability of the formations studied.

5. Acknowledgements.

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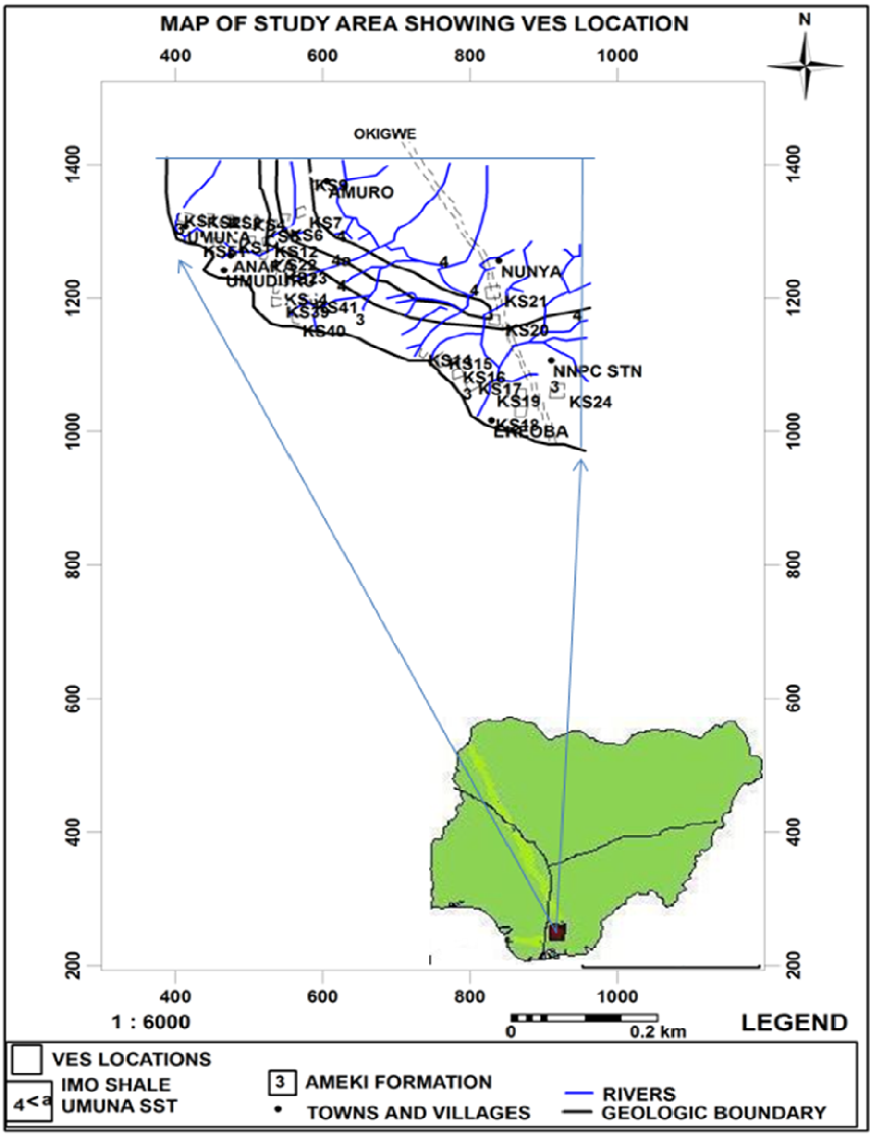

Figure 1: Map of the Study Area showing VES locations.

Table 1: Calculated DRASTIC Index for the Study Area.

VES #	LOCATION	NORTHINGS	EASTINGS	D_r	D_w	R_r	R_w	A_r	A_w	S_r	S_w	T_r	T_w	I_r	I_w	C_r	C_w	DI
KS1	OKWELLE 1	192328	524631	1	5	9	4	8	3	3	2	7	1	2	5	1	3	**91**
KS2	OKWELLE 2	192101	525385	9	5	9	4	8	3	3	2	7	1	3	5	1	3	**136**
KS3	UMUNA 1	193625	527164	1	5	9	4	1	3	3	2	8	1	1	5	1	3	**66**
KS4	OKWE 1	194011	528398	5	5	9	4	3	3	3	2	9	1	2	5	1	3	**98**
KS5	OKWE 2	194534	529866	7	5	9	4	3	3	3	2	9	1	3	5	1	3	**113**
KS6	OKWE 3	194887	531171	5	5	9	4	3	3	3	2	9	1	2	5	1	3	**98**
KS7	UMUNA 2	195957	532768	3	5	9	4	3	3	3	2	10	1	2	5	1	3	**89**
KS8	AMURO 1	196535	533894	7	5	9	4	2	3	3	2	9	1	3	5	1	3	**110**
KS9	AMURO 2	197628	535422	1	5	9	4	1	3	3	2	10	1	2	5	1	3	**73**
KS10	UMUNA 3	194590	532056	7	5	9	4	1	3	3	2	9	1	2	5	2	3	**105**
KS11	OBIOHURU 1	193434	530967	3	5	9	4	8	3	3	2	9	1	5	5	1	3	**118**
KS12	OBIOHURU 2	192063	530712	3	5	9	4	8	3	3	2	9	1	5	5	1	3	**118**
KS13	ORJI	190453	530273	1	5	9	4	8	3	3	2	8	1	5	5	1	3	**107**
KS14	IKPEREJERE	178912	545625	1	5	9	4	8	3	3	2	7	1	5	5	1	3	**106**
KS15	UMUDIKE ELUAMA	178516	547311	1	5	9	4	5	3	3	2	8	1	5	5	1	3	**98**
KS16	UMUDIBIA ELUAMA	178555	548770	2	5	9	4	8	3	3	2	10	1	5	5	1	3	**99**

KS17	ABUEKE	178411	550335	5	5	9	4	8	3	3	2	7	1	8	5	1	3	**141**
KS18	EKEOBA	174718	554389	7	5	9	4	3	3	9	2	10	1	5	5	1	3	**136**
KS19	AMAOGW UGW-U	176000	553668	7	5	9	4	1	3	6	2	10	1	2	5	1	3	**109**
KS20	NUNYA 1	186622	550846	5	5	9	4	3	3	6	2	10	1	3	5	1	3	**110**
KS21	NUNYA 2	187804	549394	7	5	9	4	8	3	6	2	9	1	2	5	1	3	**129**
KS22	EZIAMA OSUAMA	189225	530008	3	5	9	4	6	3	3	2	7	1	3	5	1	3	**100**
KS23	**UMUEZEALA-EGBE UMUDURU**	**187779**	**522952**	**3**	**5**	**9**	**4**	**8**	**3**	**3**	**2**	**7**	**1**	**5**	**5**	**1**	**3**	**116**

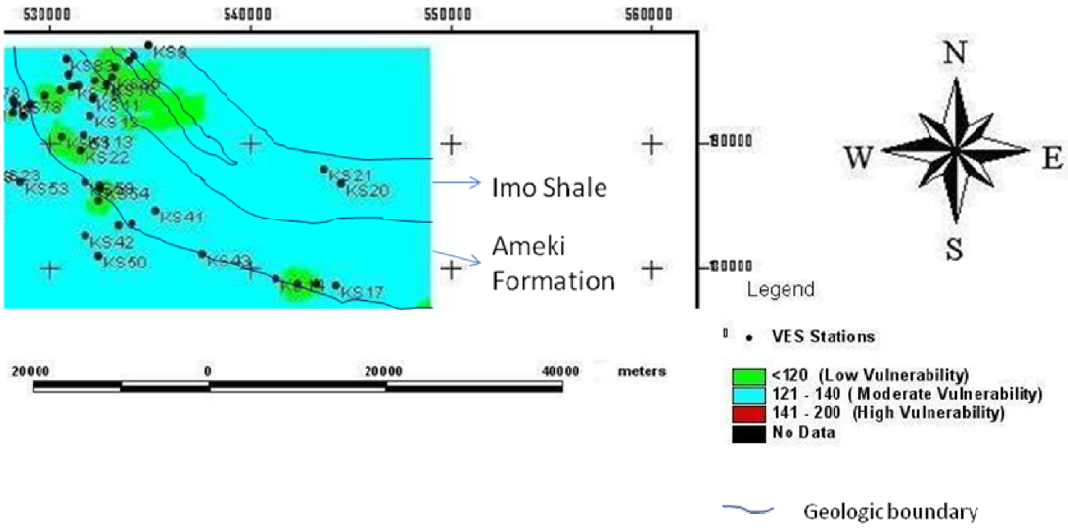

Figure 2 : The Vulnerability Map of Imo Shale and Ameki Formations

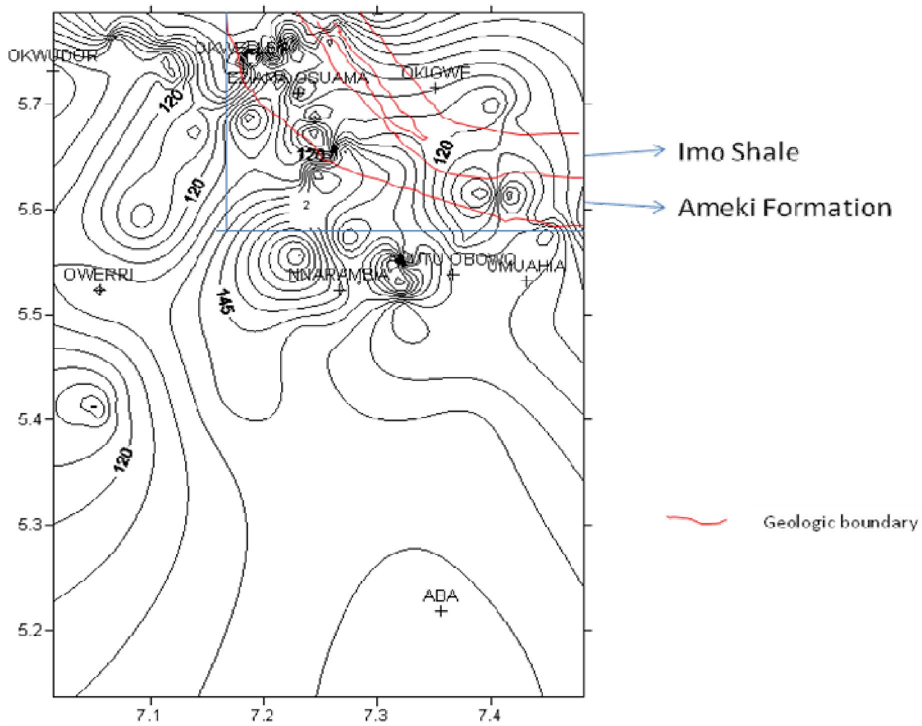

Figure 3 : Vulnerability Contour Map for the Study Area