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Aquifer Vulnerability Assessment in Ekowe, Bayelsa State, Niger Delta Area, Nigeria using GIS-Based on Drastic Method

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Abstract: *This study on aquifer vulnerability assessment in Ekowe town of Southern Ijaw Local Government Area of Bayelsa State, Niger Delta Area, Nigeria, adopted the use of DRASTIC method and geographic information system (GIS) model to delineate areas susceptible to contamination depending on the collective nature of the Seven hydro geologic parameters applied for the aquifer vulnerability evaluations which include depth to water table, net recharge, soil media, impact to vadoze zone, aquifer media, topography, and hydraulic conductivity. Data relating to the seven hydro geologic parameters of the model were obtained and transformed systematically by GIS to develop the DRASTIC vulnerability map which shows the three different forms of aquifer vulnerability namely high, moderate, and low zones. High vulnerable Areas is influenced mainly by high net recharge, shallow depth to water table, porosity of the sandstones in the aquifer media and permeability of the surface soil while the low vulnerability zone is domiciled with Straight slope, high depth to water table, presence of clay and silt in the soil and vadoze zone media, and the distinctive characteristics of the high and low vulnerability zones define the moderate vulnerable Areas.*

Keywords*: Aquifer, vulnerability, DRASTIC, GIS*

I. Introduction

Groundwater plays a major role in Ekowe and its environs because of the unsuitability of the surface waters. Over the years Rapid industrialization growth and agricultural activities have led to both unsustainable groundwater abstractions besides water quality deterioration.

The concerns for the provision of portable water for the people living in the community and its environs have become a challenge to the concerned individual and government.

Aquifers in the communities are prone to contamination by anthropogenic factors such as oil and gas spills, indiscriminate dumping of solid wastes, flooding, open dumps, abandoned borrow pits, poor construction of septic tanks and graveyards, activities of multinational oil companies and agricultural activities, etc. The environmental pollution caused by anthropogenic factors domiciled in the region has affected weather conditions, soil fertility, groundwater, surface water, aquatic and wildlife (AKanaet at., 2002; Olujimi, 2010)

The discharge of untreated waste water, soakaway, pit-latrine as well as agricultural water runoff can lead to deterioration of groundwater in coastal aquifers (Abdel-Satar, 2001; Adams et al., 2008; Amadi and Nwankwoala, 2013; Karbassi et al., 2008; Ngah, 2002; Nwankwoala, 2011; Akoto et al., 2008; Etu–Efeotor, 1981; Etu–Efeotor and Akpokodje, 1990).

The people living in this communities resort to boreholes and drinking river water and that is of a very high risk to the health of the individual. The need to carry out an aquifer vulnerability assessment cannot be over emphasized. The research intends to exploit DRASTIC method based on Geographic Information System (ARC-GIS) Model to map out identified locations, which will purposely delineate areas susceptible to high contamination. The Aquifer vulnerability map generated in this study will be used for the management of water resources in the future and environmental planning.

II. Study Area

The study Area is Ekowe Community, the host community of Federal Polytechnic Ekowe, located in southern Ijaw Local Government area of Bayelsa State. It lies in the Niger Delta Area of Nigeria. it is latitude 5 16 42N and longitude 6 25 00 E. the area is accessible by a network of rivers.

The area has a low-lying plain riddled with an intricate system of water channels through which it flows into the sea. It experiences Tropical climate which encompasses dry and wet seasons. Wet season is accompanied by high rainfall with storms as it varies from one area to another. Relative humidity is high but reduces during rainy season

The study area is characterized by Niger delta sedimentary rocks. It is divided into three formations namely Akata, Agbada and Benin formation. The major aquiferous formation in this study area is the Benin Formation. It is the water bearing zone of the area. It is overlain by Quaternary deposits of about forty to one hundred and fifty metres thick, and generally consists of rapidly alternating sequences of sands and silty clay which later become increasingly prominent seawards. It is about 2100 m thick at the basin center (Short and Stauble, 1967). The Benin Formation is highly permeable, prolific, and productive, and is the most extensively tapped aquifer in the Niger Delta. (Etu-Efeotor and Akpokodje, 1990).Deep boreholes in the area tap water from depths up to about 200meters or more. In terms of water quality, (Udom and Amah, 2006) have noted that groundwater in most parts of the area is high in iron content Rainfall serves as a the principal source of recharge to the aquifer.

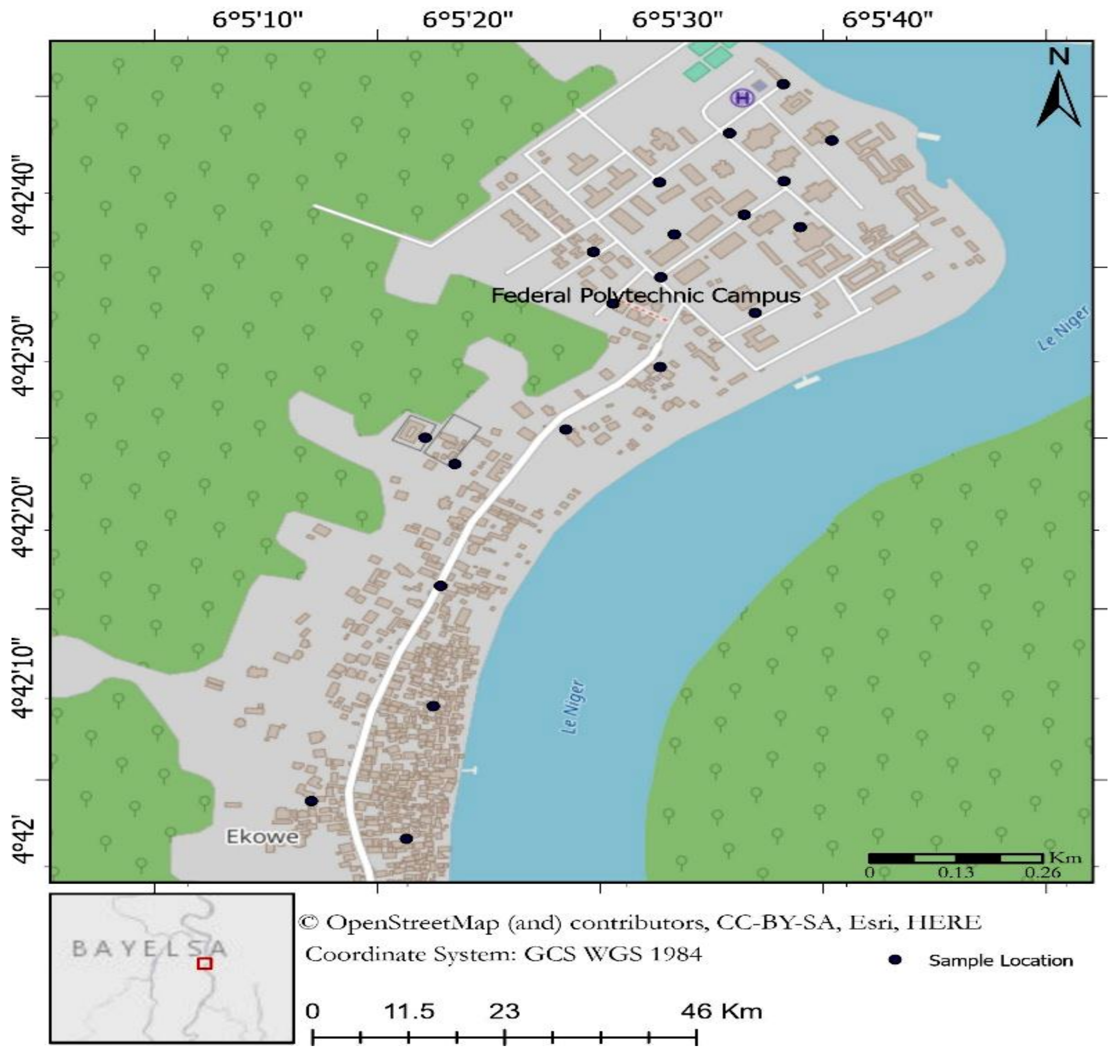

Figure no 1: Map of Study Area

III. DRASTIC METHOD

The DRASTIC method was developed by the agency of environmental protection of United States of America by (Alleret al.1987) in collaboration with National Well Association to be a standardized model for evaluating vulnerability of groundwater to pollution. This model was applied in the study Area (Ekowe) to delineate areas that are more susceptible or vulnerable to pollution in difference to low vulnerable areas, The method was derived from weight, ratings, with respect to the seven parameter and the acronym for DRASTIC are; D-depth to water table, R-net recharge, A-aquifer media, S-soil media, T-topography, I-impact to vadoze zone media and C-hydraulic conductivity

Each DRASTIC parameter is divided into ranges and is allotted different ratings in a scale of 1 (least contamination potential) to 10 (highest contamination potential) based on significance of the parameter. The weighting factors ranges from 1 (least significant) to the 5 (most significant) as Shown in Table no. 1.

The addition and combination of the above DRASTIC parameter with the ratings and weights was used to calculate the DRASTICA Vulnerability Index Scores

Drastic Index Scores deducibility: The DRASTIC vulnerability index was solved by equation below

$$DVI = D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w$$

Where

Dr = Ratings to the depth to water table

Dw = Weights assigned to the depth to water table.

Rr = Ratings for ranges of aquifer recharge

Rw = Weights for the aquifer recharge

Ar = Ratings assigned to aquifer media

Aw = Weights assigned to aquifer media

Sr = Ratings for the soil media

Sw = Weights for soil media

Tr = Ratings for topography (slope)

Tw = Weights assigned to topography

Ir = Ratings assigned to vadose zone

Iw = Weights assigned to vadose zone

Cr = Ratings for rates of hydraulic conductivity

Cw = Weights given to hydraulic conductivity

Table no 1: Weights of the different components in DRASTIC Model

Components	Weight
Depth to water Table	5
Net recharge	4
Aquifer media	3
Soil media	2
Topography	1
vadoze zone media	5
Hydraulic conductivity	3

Mapping of Aquifer Vulnerability: The DRASTIC vulnerability Index scores was first sorted out in a descending form and categorized into scale and range using quantile classification method to obtain three different range group of low, moderate and high aquifer vulnerability.(Rahman, 2008; Lee, 2003; Al-Adamat et al., 2003; Baalousha, 2003).

Depth to Water Table:

Water table depth is the distance a contaminant will travel before getting to the aquifer. The water table for the study area increases during rainy seasons and decreases at dry season. The water table depth and the ratings are shown below in Table 2.

Table no 2: Ratings of water table depth

Water Table Depth (m)	DRASTIC Rating
0.00 – 1.23	10
1.23 – 4.58	9
4.58 – 9.15	7
9.15 – 15.25	5
15.25 – 22.88	3
22.88 – 30.50	2
>30.50	1

(Aller et al. 1987)

Soil Media:

This is the part of the soil that is topmost, that falls between two meter or less in thickness below the ground. It is the uppermost portion of the vadoze zone that is weathered and depicted by notable biologic activity. The nature of the soil affects the amount of recharge and contaminant that can enter into the ground. The results from the particle size analyses(PSD) from the study area were used as the source data for soil media and the ratings are given below in Table 3.

Table no 3: Ratings of soil material

Soil Material	DRASTIC Rating
Thin or absent	10
Gravel	10
Sand	9
Peat	8
Shrinking and or aggregated clay	7
Sandy loam	6
Loam	5
Silt loam	4
Clay loam	3
Muck	2
Non-shrinking and non-aggregated clay	3

(Aller et al. 1987)

Aquifer Media:

Aquifer media is defined as the unconsolidated or consolidated rock that serves as an aquifer. It considers the saturated zone properties and controls contaminant processes of attenuation. The contaminant way and flow pattern is dependent on the aquifer flow system. Geological map of the study area and Results from the borehole data in the study area was used as the source for specifying the aquifer media range and ratings in Table 4 below.

Table no 4: Ratings of the aquifer material

Aquifer Material	DRASTIC Rating
Massive shale	2
Metamorphic/igneous	3
Weathered metamorphic/igneous	4
Glacial till	5
Bedded sandstone, limestone, shale sequences	6
Massive sandstone	6

Massive limestone	6
Sand and gravel	8
Basalt	9
Karst limestone	10

Impact to Vadoze Zone:

This involves the zone that is unsaturated above the water table. The vadoze zone media type controls the passage of contaminant and determines attenuation activities such as chemical reactions, biodegradation, dispersion, neutralization and mechanical straining that affects path length, rout, and contaminant time of arrival to the aquifer. The unsaturated zone is imperative and vital to protecting for contaminants from reaching the water table. The geological map of the study area as well as the borehole data for the study area were used in outlining the different sub-zones and the special rating given to them are given below in Table 5.

Table no 5: Ratings of the vadoze zone material

Unsaturated Zone Material	DRASTIC Rating
Confining layer	1
Silt/clay	3
Shale	3
Limestone	6
Sandstone	6
Bedded limestone, sandstone shale	6
Sand and gravel with significant silt and clay	6
Metamorphic/igneous	4
Sand and gravel	8
Basalt	9
Karst limestone	10

Net Recharge:

The main source of groundwater is precipitation. This involves the total amount of infiltration that enters the ground and reaches the water table. This recharge water serves as the main media for transporting contaminants to the water table and within the aquifer. The higher the net recharge the greater chance for contamination.

The source data for net recharge was obtained from Nigeria Metrological Agency. This data entails evaporation, and rainfall data for all the study areas, in view of that soil and slope values were taken into consideration to deduce the recharge rates taken from the aquifer recharge rates and the ratings given below.

Table no 6: Ratings of groundwater recharge

Recharge (mm/year)	DRASTIC Rating
0.00 – 50.8	1
50.8 – 101.6	3
101.6 – 177.8	6
177.8 – 254.0	8
>254.0	9

Hydraulic Conductivity:

This is defined as the ability of an aquifer to transmit water. It governs the rate at which groundwater will flow under a given hydraulic gradient and controls the movement of contaminant to and away from the aquifer. The higher the hydraulic conductivity, the higher the vulnerability of the aquifer.

The source data for hydraulic conductivity was obtained from the pumping test values calculated and ratings for each range of hydraulic conductivity are given below in Table 7

Table no 7: Ratings of hydraulic conductivity

Hydraulic Conductivity (m)	DRASTIC Rating
0.50*10-6 – 0.50*10-4	1
0.50*10-4 – 0.15*10-3	2
0.15*10-3 – 0.36*10-3	4
0.36*10-3 – 0.51*10-3	6
0.51*10-3 – 0.10*10-2	8
>0.10*10-2	10

Topography:

It is defined as the slope variability of the surface of the land. It determines whether a contaminant will settle sufficiently enough to enter the ground or run off. Topography influences the drainage characteristics, gradient and direction of flow path of contaminant. Data for the study area was derived from digital elevation model to obtain the slope. IDRISI (2000) was used in modeling the percent slope of the study area. The results put in an increasing order in reference to the Table 8 below.

Table no 8: Ratings of slope percent

Slope (%)	DRASTIC Rating
0-2	10
2-6	9
2-12	5
12-18	3
>18	1

IV. Aquifer Vulnerability Map of Ekowe

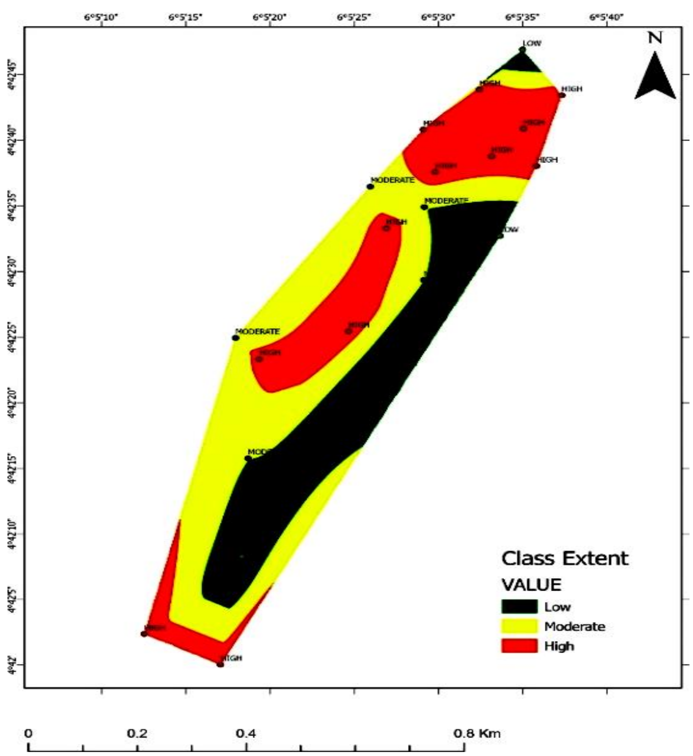

Figure no 2: Aquifer Vulnerability Map of Ekowe

The Aquifer vulnerability map for the Ekowe community was developed from the results analyzed based on the information derived through borehole logging, geophysical survey, particle size distribution analysis, laboratory analysis, pumping and permeability test as well as the information on the hydrogeology and geology of the area . The result of this study has led to the delineation of aquifers in Ekowe into high, medium and low vulnerability using DRASTIC Method. The aquifer vulnerability map is subdivided into zones of differing vulnerability namely highvulnerability is influenced mainly by high net recharge, shallow depth to water table, porosity of the sandstones in the aquifer media and permeability of the surface soil while the low vulnerability zone is domiciled with presence of clay and silt in the soil and vadoze zone media, level slope, high depth to water table and the distinctive characteristics of the high and low vulnerability zones define the moderately vulnerable Areas.

V. Conclusion

The evaluation of aquifer DRASTIC vulnerability index for Ekowe in Southern Ijaw Nigeria was done using DRASTIC method based on Geographic Information System (GIS) based dependent upon the collective nature of the seven hydrogeologic parameters. The DRASTIC vulnerability map classified the area into low, moderate, and very high vulnerability zones. The results showed that the aquifers in parts of the north east, south-south westis highly vulnerable to contamination.

RECOMMENDATION

The drilling of boreholes/well near refuse dump sites or locations should be discontinued and the community informed on the health implications of drinking contaminated water.

Indiscriminate dumping of solid wastes should be discouraged and controlled by government sanitation authorities.

Seminars and sensitization workshops should be organized to inform and create awareness on the danger of groundwater contamination and how to minimized it.

Areas where there is pollution, government agency should employ aremedial action approach to clean up the polluted top soil,surface water of host communities with hydrocarbon without delay.

Septic tank, open dump sites, graveyards, oil pipe lines should be properly constructed to avoid leakage.

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