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Ground water vulnerability in Parts of Yenagoa, Southern Niger Delta, Nigeria

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Abstract: *This study on aquifer vulnerability assessment in certain parts of Yenagoa, Bayelsa State, Southern Niger Delta, Nigeria, adopted the use of DRASTIC method based on geographic information system (GIS)model to delineate areas susceptible to contamination. Seven hydrogeologic parameters were 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 hydrogeologic parameters of the model were obtained and transformed in the model into seven maps by GIS to develop the DRASTIC vulnerability map which shows the three different forms of aquifer vulnerability namely high, moderate, and low zones. The communities within the high vulnerable zonesincludeSwali, Agudama, Ovum, Igbogene, Okutukutu, Onopa and Okolobiri. Those within the moderate vulnerability zones are Kpansia, Etegwe, Yenezue, Azikoro, Opolo, Tombia, Biogbolo and Akenfa and in the low vulnerability zones, we have Amarata, Yenezuegene, Edepie, Azikoro, Akenfa and Okaka.The high vulnerability zones ranking was attributed to very high depth to water table, high net recharge, high hydraulic conductivity and permeability of gravelly sand in the aquifer media. The moderate vulnerability zones were due to high net recharge, low porosity of silt/clay in vadoze zone, siltyloam in soil media and high hydraulic conductivity. The low vulnerable zones were influenced by impermeability of clayloam in the soil media, low porosity of siltyclay in the vadoze zone and low topographic slope percent.*

Key Words: Aquifer, GIS, Vulnerability, DRASTIC.

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I. Introduction

Groundwater plays a significant role in meeting the demand of water availability because of unsuitability of surface waters in Bayelsa State for domestic uses. In general, contamination of groundwater is a serious issue of concern because aquifers and the contained groundwater are prone to contamination from land use and human activities.

Yenagoa and its environs have witnessed a substantial industrial and population growth since the creation of Bayelsa State in 1996. This has led to various activities that have the potential of polluting groundwater such as crude oil exploration and exploitation, Waste deposited in open dumps, indiscriminate dumping of waste materials, abandoned borrow pits, industrial effluents, agricultural runoff etc. and There is no enforement of laws to check and control these activities that have constantly threatened groundwater quality in Yenagoa.

Therefore, the need to carry out vulnerability assessment to delineate areas prone to contamination by DRASTIC method cannot be overemphasized. The DRASTIC method was developed by the agency of environmental protection of United States of America by (Aller et al.,1987) in collaboration with National Well Association to be a standardized model for evaluating vulnerability of groundwater to pollution..

This study will provide information for government in all levels in Bayelsa state of Nigeria and stake holders to be anticipatory in groundwater management and preventing of the aquifer environment in Yenagoa from getting worse.

II. Study Area

The study area lies between Latitudes 4° 48′ 00″and 5° 24′ 10″North; and Longitudes 6° 12′ 00″E and 6° 39′ 30″E. It is bounded by Rivers State to the North and East, Kolokuma/Opokuma LGA to the North West and West, Ogbia LGA to the South East and Southern Ijaw on the South west. The study area is accessible by road and a network of rivers and creeks

Yenagoa(study area) has a common climatic conditions namely dry and wet seasons. It is located in the southern Niger delta area of Nigeria. The stratigraphy is divided into Akata, Agbada and Benin formation. (Etu-Efeotor and Akpokodje, 1990). The water bearing formation is the Benin formation and its main source of groundwater recharge is rainfall (Amajor and Ofoegbu, 1988). It consist of alternating sandand silt which increase towards seaward. (etu –effeotor 1981)

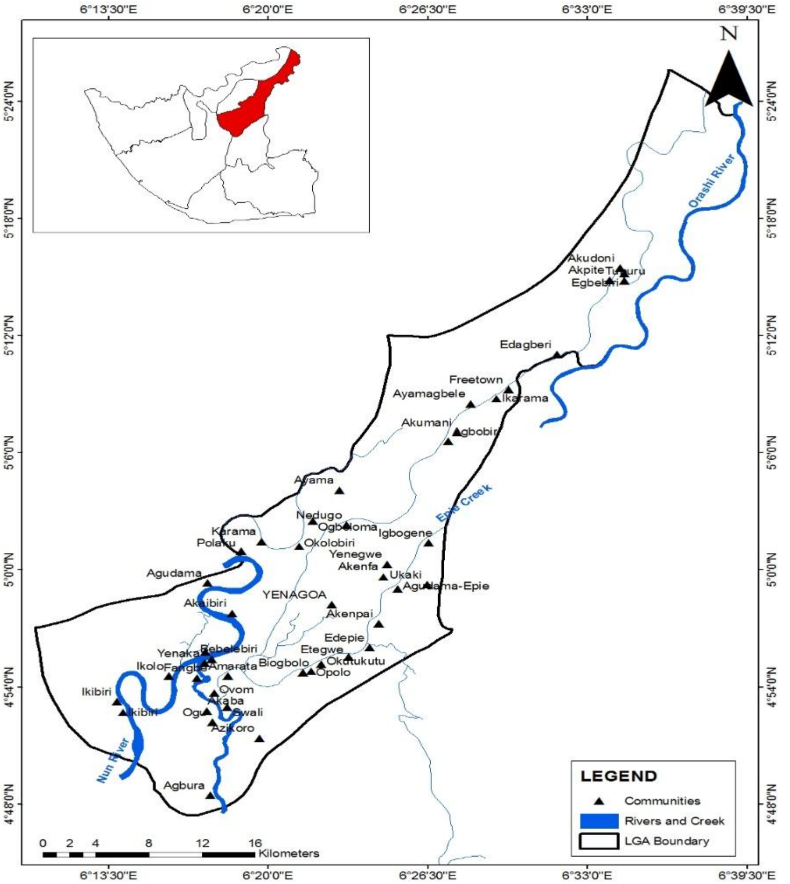

FIGURE NO 1 MAP OF STUDY AREA.

II1DRASTIC METHOD

DRASTIC model is a groundwater vulnerability assessment model developed by a group of experts(aller et at..1987) for the United States Environmental Protection Agency in partnership with theNational Well Association.This model is a forward looking approach or tool established to explain the groundwater preservation and protection in respect to contamination in view of evaluating areas that are more vulnerable to contamination in difference to low vulnerable areas.The DRASTIC method is an index and overlay method which is based on assembling information about the most common factors (soil type, geologic formation type, recharge etc) that affect aquifer vulnerability.(Evans and Myers, 1990)

The method was derived from weight, ratings, with respect to the seven parameter as shown in table 1. DRASTIC is an acronym for the most important factors that control the groundwater pollution potential where

D – Depth to Water
R – (Net) Recharge
A – Aquifer Media
S – Soil Media
T – Topography (Slope)
I – Impact of Vadose Zone
C – Conductivity (Hydraulic) of the Aquifer

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

$$DI = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W = \text{Pollution potential}$$

Where r – rating
w - weight

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)

Different Colours were assigned to each class range of aquifer vulnerability and the DRASTIC index vulnerability scores sorted out in class range and scale was put into ARC-GIS software to develop the Aquifer Vulnerability Map for all the study areas.

Table 1: DRASTIC Model parameters and their weight

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

III. Results And Discussion

Depth to Water Table: This is the distance from the surface to the water table. Hence, the shallower the depth,the higher

the vulnerability of the groundwater is to contamination. Hence, the shallower the depth, the higher the vulnerability of the groundwater is to contaminationThe source data for depth to water table was obtained from newly Drilled borehole and borehole log information. Depths to water table range and rating are shown in table 2.

Table 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

Net Recharge:

This involves the total amount of infiltration or rainfall each year that enters the ground and reaches the water table. The higher the net recharge the greater chance for contamination the net recharge.The data for net recharge was obtained from Nigeria Metrological Agency, Omagua, Port Harcourt. This net recharge data range and rating was Obtained using table 3

Table 3: Ratings of Net 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

Soil Media:

This is the uppermost portion of the earth characterized by significant biological activity. It represent the upper weathered zone of the earth which averages 3ft (1m) or less. The type of clay present and the grain size of the soil nature o affects the contaminant ease and quantity that can enter into the ground .The soil media data for the study area was obtained by particle size distribution test(sieve analyses and hydrometer test) and geologic reports. and the actual range and the soil mediarating is given in Table 4.

Table 4: soil type rating

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

Aquifer Media:
aquifer media **media** refers to the consolidated or unconsolidated medium that stores and transmits water and. the way and flow pattern pollutant is dependent on the aquifer flow system and it wheels the contaminant processes of attenuation if the grain size is large, permeability will be high and the vulnerability will be high. the aquifer media source data was obtained from borehole data on the newly drilled well/boreholes in the study area and hydrologic reports. The range and rating are given in table 5 .

Table 5: Ratings of the aquifer media

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

Topography:
It is defined as the slope variability of the surface of the land. The topography also known as slope controls the possibility that a pollutant will run off or remain on the surface in one area long enough to infiltrate.The topography data was derived from digital elevation modeland The ASTER Global Digital Elevation Model V002 (ASTER GDEM2) data of Nigeria were collected from the Land Processes Distributed Active Archive Center (LP DAAC) .The topography range and rating are given in table 6.

Table 6: Ratings of topography (slope percent)

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

Impact to Vadoze Zone:
This involves the zone that is unsaturated above the water table. it is characterised by attenuation processes and activities that controls the time the contaminnat will reach the water table and aquifer. this attenuation characteristic is a function of the depth to water table and soil media. the source data was obtained from the geological map and new drilled bore hole data of the study area. The different subzone of the vadoze zone media are given below in table 7

Table 7:vadoze zone media rating

Unsaturated Zone Material	DRASTIC Rating
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

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. It relates to bedding planes, fractures, intergranular porosity etc. The higher the hydraulic conductivity, The higher the vulnerability of the aquifer.the data for hydraulic conductivity was obtained from pumping test and the values for rating are shown below

Table 8: 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

Aquifer Vulnerability Map:

The aquifer vulnerability map in the study area identifies three different range zone of high, moderate and low aquifer vulnerability represented by three different shaded colours. The shaded red colour zone are the areas that have highly vulnerable aquifers and a DRASTIC index of 119-124. The shaded purple colour range zone are the areas that have moderate vulnerable aquifer and a DRASTIC index of 116. The shaded green colour range zone are areas of low vulnerable aquifers and a DRASTIC index of 114. The map of aquifer vulnerability is shown below in figure 2.

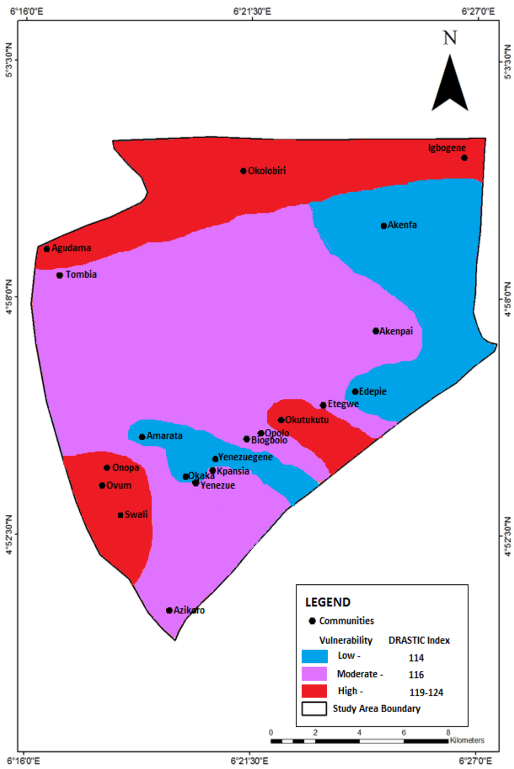

Figure no 2 Map of Aquifer Vulnerability of Study Area

IV. Conclusion

The result of this study has led to the delineation of aquifers in parts of Yenagoa into high, medium and low vulnerability using DRASTIC Method. The aquifer vulnerability map shows the areas of high, moderate and low vulnerability shaded by different colours. The shaded red colour zone is the most vulnerable zone. This is because zone has the high net recharge and hydraulic conductivity rating, permeable aquifer media and shallow depth to water table. This communities in this high vulnerable zone include Swali, Ovum, Igbogene, Okutukutu, Onopa and Okolobiri. The shaded purple colour is the moderately vulnerable zone attributed to the restrictives permeabillities of silty loam in soil media and silty clay in vadoze zone, high net recharge and low topography slope percent. The communities in this moderately vulnerable zone include Kpansia,Etegwe,Yenezue, Azikoro, Opolo, Tombia,Biogbolo and Akenfa. The blue shaded zone is the low vulnerable zone attributed to having lowest rating of topography slope percent and hydraulic conductivity, impermeable clay loam in the soil media and high depth to water table. The communities in this low vulnerable zone include Amarata, Yenezuegene, Edepie, Azikoro, Akenfa and Okaka.

V. Recommendation

Boreholes/wells in high vulnerable areas should be evaluated for water quality periodically to ensure drinking water is safe and free from contamination. Government should enforce immediately enact laws and policies to regulate oil companies , industries toward protecting the future use of groundwater resources and finally,public enlightnent programmers should be carried out to educate people living in the communities on the dangers of drinking contaminated water

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