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RESEARCH ARTICLE

VULNERABILITY ASSESSMENT OF GROUNDWATER TO POLLUTION IN PORT HARCOURT METROPOLIS

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ABSTRACT

Groundwater vulnerability refers to the sensitivity of groundwater to contamination. The seriousness of the impact on water use depends on the extent and magnitude of the pollution and the value of the groundwater resource. Groundwater vulnerability mapping is used as a guide in determining which areas are more susceptible to groundwater contamination within the mapped area. The vulnerability map produced in this work was derived from field data using the DRASTIC index method. The computed values of DRASTIC Index (DI) indicate that the groundwater of 34 communities in the study area are of 5No categories or classifications in vulnerability to contamination: 2.94% rated as low (DI of 131-140); 20.59% as moderately low (DI of 141-145); 20.59% as moderate (DI of 146-150); 50.00% as moderately high (DI of 151-155) and 5.88% as high (DI of 156-160).

INTRODUCTION

Port Harcourt has abundance of Water Supply Sources but lacks potable water. Due to population explosion between 1953 (213,440) and 2008 (1.3miliion), there seems to be a great threat to available sources of drinking water in the area. The unprecedented population growth is tied to the growth in the oil & gas industry. There is increase in water related diseases due to poor sanitation across the city (poor disposal of wastewater from households/ industries; unplanned growth of the metropolis (Etu-Efeotor & Odigi, 1983; Nwaogazie,1990; Nwaogazie,2006); mixed land use patterns, and lack of proper sanitary system.

Given the level of industrialization in the Port Harcourt metropolis, groundwater contamination is of great concern. Groundwater vulnerability mapping is used as a guide in determining areas susceptible to groundwater contamination. The DRASTIC index method is adopted to actualize groundwater vulnerability mapping (Wegwu, 2012). DRASTIC index on itself involves seven number hydrogeologic parameters that are assigned constant weighting values and each parameter attracts a range of values with a corresponding ratings (Wegwu, 2012).

The summation of the products of the weighting and ratings values of the 7No. hydrogeologic parameters gives the DRASTIC index (Harter, 2001: Walker, 2001).

METHODOLOGY

Study Area

Port Harcourt (4.46°N; 7.01°E) is the capital of Rivers State, Nigeria. It lies along the Bonny River, an eastern tributary of the Niger River, 66km upstream from the Gulf of Guinea. Port Harcourt features a tropical monsoon climate with lengthy and heavy rainy season and very short dry season in the year. Only the months of December and January truly qualify as dry season months in the city.Port Harcourt and its environs (34No. Communities) constitute the study area (See Figure 1). The Land area covers 924,000km^2; ground level ranges from 7.2 to 16.9m above Mean Sea Level, MSL (Akpokodje, 1979).

Data Collection

Seven hydrogeologic parameters (see Table 1 and Appendix-A) are needed to compute DRASTIC index. Depth to water (or static water level) for 34No communities were obtained from

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Niger Delta River Basin Development Authority (see Table 2). Land use data were extracted from land use map (see Figure 2). Aquifer media; Soil media; Impact of Vadose zone; and Hydraulic conductivity were extracted from previous work done in the region. Topographic data were derived from topographic map of Port Harcourt (see Figure 3).

Data Analysis

The model for determining the DRASTIC index is:

$$P=\sum_{i=1}^{n=7} r_i w_i = r_D w_D + r_R w_R + r_A w_A + r_S w_S + r_T w_T + r_I w_I + r_C w_C \quad \ldots (1)$$

Where; P = Product of r and w, which gives the DRASTIC index for each of the seven hydrogeologic parameters; r designates the rating; and w the weighting.

The smallest possible DRASTIC index rating is 23, and the largest is 226.The various values of r and w corresponding to the DRASTIC parameters in Table 1 are obtained from literature (NSCEP, 2011) and the details are presented next.

Rating of Seven DRASTIC Index parameters

Depth to water (same as static water level) constitutes the thickness of soil beneath the ground level travelled by a contaminant before reaching the groundwater table. Shallow water tables are more susceptible to contamination. Table 1 gives the rating of depth to water for different ranges. Ratings for other DRASTIC index parameters are similar to Table 1 (see also Appendix A) and will find use in actual DRASTIC index computation.

Figure 1 Map of study area, Port Harcourt Metropolis (with 34 No. Communities)

Source: www.googlemap.com/location/13-06-2015

Table 1 Assigned Weight, Range and Rating to DRASTIC Parameter

Parameter	Weight	Parameter	Range (ft)	Rating
Depth to water	5	Depth	*0 – 5	*10
Net Recharge	4	To	*5 - 15	*9
Aquifer Media	3	Water	*15 - 30	*7
Soil Media	2		30 - 50	5
Topography	1		50 - 75	3
Impact of Vadose Zone	5		75 - 100	2
Hydraulic Conductivity of the Aquifer	3		100^+	1

Source: NSCEP (2011); * *Ratings and ranges that were used for DRASTIC index calculation.*

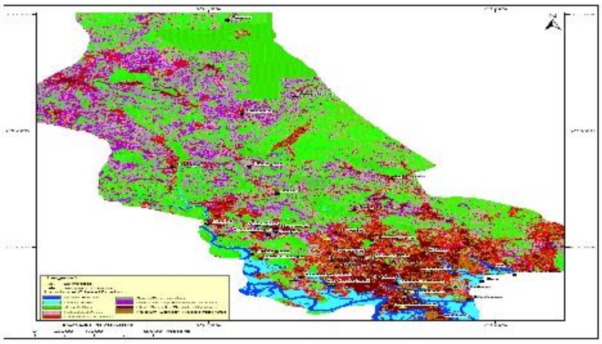

Figure 2 Land use map of Port Harcourt metropolis

Source: Wegwu (2010)

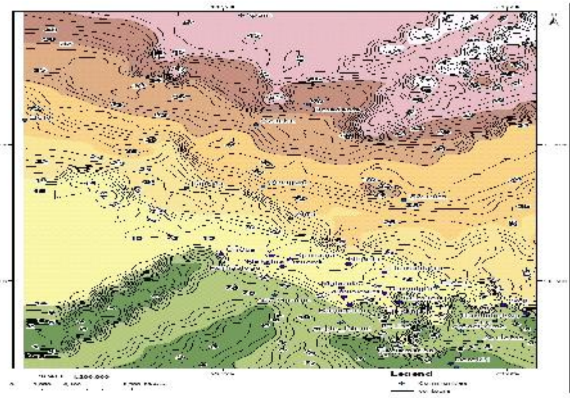

Figure 3 Topographic map of the study area (Port Harcourt Metropolis)

Source: Brown (2010)

RESULTS AND DISCUSSION

Computation of DRASTIC index for thirty four (34No.) communities in Port Harcourt metropolis was carried out using estimates of the 7No. hydrogeologic parameters (see Table 2). From Table 2, four out of 7No. parameters are constants (land use, aquifer media, impact of vadose zone and hydraulic conductivities).Only 2 out of 7No. parameters show significant variations (depth to water and topography (%)) and 1 out of 7 indicates minor variation (soil media) of which 32 out of 34 is sandy while 2 out of 34 are either sandy loam or clay. Thus, any variations in the computed DRASTIC indices between communities are accounted for by three parameters only (depth to water, hydraulic conductivity and soil media).

Typical examples of DRASTIC index computation are those of Aluu and Rumuosi communities with the largest and least indices, respectively (see Table 3). Selected values of applicable DRASTIC index parameters for Aluu and Rumuosi in Table 3 and Tables 1 and 2 for weighting and rating values are all that are needed to compute DRASTIC index. Computed vulnerability indices are plotted on location map for quick referencing (see Figure 4). Levels of vulnerability of groundwater at 34No sampling locations are of 5No. categories or classifications, namely: 131-140 as low; 141-145 as moderately low; 146-150 as moderate; 151-155 as moderately high; and 156-160 as high.

Out of 34 No. sampling locations the following distributions of 1, 7, 7, 17 and 2 Nos. (or percentage-wise 2.94, 20.59, 20.59, 50.00 & 5.88%) conform to each of the 5No. categories of groundwater vulnerability (see Figure 5 and Table 4). In effect, the DRASTIC index distribution indicates that the groundwater of major towns of Port Harcourt metropolis is **moderately high** in vulnerability to contamination. Depth to water parameter (static water level) was generally within the range of 1- 9m (3-32feet). This signifies that Port Harcourt has shallow water table which makes it vulnerable to groundwater contamination.

The net recharge or land use analysis indicates that Port Harcourt is majorly an urban centre with industries and much development (Figure 2). These industries are major producers of consumer goods that after use eventually translate to contaminants (e.g. leachate) if improperly disposed in a dumpsite insteady of sanitary landfill. The aquifer media type in Port Harcourt is mainly sand and gravel. This type of material will encourage mobility of contaminants. Soil media is sand, sandy clayey, loamy but mainly sand. Sand has low holding capacity and encourages high travel time of the contaminants. Topography, slope percentage ranges between 0-2 and 12-18 (Figure 4). The steeper the slope the lower the retention capacity. Major communities have generally undulating terrain which has high capacity for retention, that is, slow flow of surface substances. Impact of vadose zone (ground portion between soil cover and aquifer) is majorly sand with intercalations of silt and clay. Sand will easily allow the flow of contaminants from the surface, while clay will slow travel time of contaminants. The hydraulic conductivity ranges from 1- 100gallons per day per feet square and it helps to determine the amount of water percolating to the aquifer.

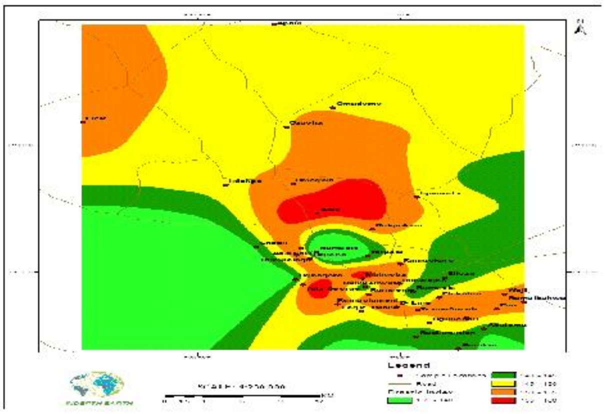

Figure 4 DRASTIC index map of the study area

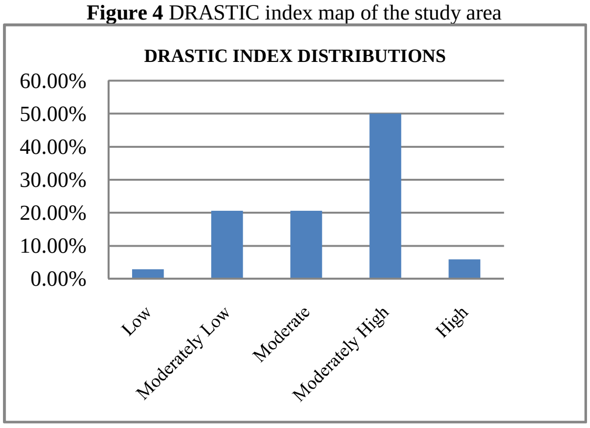

Figure 5DRASTIC index distribution of 34No. Communities in Port Harcourt metropolis

Table 2 Estimates of the Seven. Hydrogeologic Parameters for the Study Area

S/No.	Town	Depth to Water	Land Use	Aquifer Media	Soil Media	Topography	Ivz*	Conductivity
1	Abuloma	16	Urban	4-9	sand	2-6	sand	1-1000
2	Ada George	13.01	V	v	v	v	V	V
3	Alakahia	12.8	V	v	v	v	V	V
4	Amadi-ama	11.49	V	v	v	6 - 12	V	V
5	Apani	2.2	V	v	v	18^+	V	V
6	Aluu	1.6	V	v	v	0 - 2	V	V
7	Borokiri	10.53	V	v	v	v	V	V
8	Choba	28.1	V	v	v	v	V	V
9	D-line	14.2	V	v	v	0-2	V	V
10	Eliozu	12.4	V	v	v	v	V	V
11	Elekahia	8.92	V	v	v	v	V	V
12	Isiokpo	1.6	V	v	Clay	6-12	V	V
13	Mgbouba	5.46	V	v	v	2 - 6	V	V
14	Nkpolu	19.3	V	v	v	v	V	V
15	Ogbogoro	12.4	V	v	v	2-9	V	V
16	Ogbunabali	9.6	V	v	v	6-12	V	V
17	Ozuoba	15	V	v	v	v	V	V
18	Omagwa	0.4	V	v	v	18^+	V	V
19	Omerelu	2.2	V	v	v	12-18	V	V
20	Omademe	2.5	V	v	v	v	V	V
21	Reclamation	16.72	V	v	v	0-2	V	V
22	Rumuolumene	10.99	V	v	v	v	V	V
23	Rumukwuta	5.5	V	v	v	v	V	V
24	Rumubekwe	5.5	V	v	v	v	V	V
25	Rumuigbo	8.92	V	v	v	v	V	V
26	Rumuola	16.79	V	v	v	2-6	V	V
27	Rumuokoro	8.3	V	v	v	v	V	V
28	Rumuosi	32	V	v	v	6-9	V	V
29	Rumalogu	8	V	v	v	v	V	V
30	Rumueme	9.95	V	v	v	2-6	V	V
31	Rukpuku	11.62	V	v	v	0-2	V	V
32	Trans-Amadi	14.9	V	v	v	v	V	V
33	Woji	12.4	V	v	v	v	V	V
34	Zoo	8.1	V	v	v	0-2	V	V

Ivz * = Impact to Vadose Zone

Table 3 DRASTIC Index Computation for Aluu and Rumuosi Communities

Parameter	Aluu Community				Rumuosi Community			
	Range Media	Weight-ing, w	Rating, r	Product = r*w	Range media	Weigh- ting, w	Rating, r	Product = r*w
Depth to water	1.6	5	10	50	32	5	5	25
Net recharge/land use	Urban	4	3	12	Urban	4	3	12
Aquifer media	4 - 9	3	8	24	4-9	3	8	24
Soil media	Sand	2	9	18	Sand	2	9	18
Topography	0 - 2	1	10	10	6-9	7	5	5
Impact of vadose zone	Sand	5	8	40	Sand	5	8	40
Conductivity	1 - 100	3	1	3	1-100	3	1	3
DRASTIC index =				∑157				∑127

Table 4 Computed DRASTIC indices for 34 No. Communities in the study area

Low	Moderately low	Moderate	Moderately high	High
131-140	140-145	145-150	150-155	155-160
Rumuosi	Omerelu	Isiokpo	Igwuruta	Aluu
	Rumuokuta	Apani	Elele	Mgbuoba
	Rumuola	Omademe	Omagwa	
	Reclamation	Ozuoba	Amadi-Ama	
	Nkpolu	Borokiri	Rumuolumini	
	Ogbogoro	Ogbunabali	Elekahia	
	Choba	Eagle Island	Rumuigbo	
			Ada goerge	
			Zoo	
			D-line	
			Rumuibekwe	
			Rukpoku	
			Rumuokoro	
			Alakahia	
			Ozuoba	
			Rumualogu	
			Eliozu	

Appendix – A

Tables A1-A6 are taken from one source: http://nepis.epa.gov/Exe/zyNET.exe/2007kl. (2011)

Table A-1 Net recharge range and rating

Factors	Range(inches/year)	Rating
Net Recharge	0 - 2	1
	2 - 4	3
	4 - 7	6
	7 - 10	8
	10+	9

Table A-2 Land use rating points

Land use	Ratings
*Urban	*3
Irrigated agriculture	2
Range land	2
Dryland agriculture	1
Forest	1

* Ratings and ranges that were used for DRASTIC index calculation.

Table A-3 Aquifer media range and rating

Factors	Range	Rating	Typical rating
Aquifer media	Massive shale	1 - 3	2
	Metamorphic/igneous	2 - 5	3
	Weathered metamorphic/igneous	3 - 5	4
	Glacial Till	4 - 6	5
	Bedded sandstone, limestone, shale	5 - 9	6
	Massive sandstone ,massive limestone	4 - 9	6
	*Sand and gravel	4 - 9	*8
	Basalt	2 - 10	9
	Karst limestone	9 - 10	10

* Ratings and ranges that were used for DRASTIC index calculation.

Table A-4 Soil media range and rating

Factors	Range	Rating
Soil media	Thin or Absent ,Gravel	10
	Sand	9
	Peat	8
	Shrinking and/or aggregated clay	7
	*Sandy loam	*6
	Loam	5
	Silty loam	4
	Clay loam	3
	Muck	2
	Non shrinking and non aggregated clay	1

* Ratings and ranges that were used for DRASTIC index calculation.

Table A-5 Percent slope versus rating

Parameter	Range(% slope)	Rating
Topography (%).	*0 - 2	*10
	*2 - 6	*9
	*6 - 12	*5
	*12 - 18	*3
	18 +	1

* Ratings and ranges that were used for DRASTIC index calculation.

Table A-6 Impact of vadose zone range/rating

Factors	Range	Rating	Typical rating
Impact of the vadose zone media	Confining layer	1	1
	Silt/clay	2 – 6	3
	Shale	2 – 5	3
	Limestone	2 – 7	6
	Sandstone, Bedded	4 – 8	6
	limestone, sandstone, shale, Sand and gravel	2 - 8	4
	Metamorphic/igneous	6 – 9	*8
	*Sand and gravel	2 - 10	9
	Basalt	8 - 10	10
	Karsts limestone		

CONCLUSION

Based on the results of this study, the following conclusions can be drawn:

1. Groundwater in major communities in Port Harcourt metropolis range from moderate to high vulnerability;
2. Results of DRASTIC index should act as a guide to Town planners and Governmental bodies in determining the type of industries that should be allowed to operate in any of these communities;
3. The degree of vulnerability made known to the public will help people's choice of land purchase and general land use; and
4. DRASTIC index can be used as a preventive tool for industries that produce harmful contaminants, burying of pipeline and other operational activities of industries

and also governmental decisions on location of landfills. There should be constant monitoring of groundwater in these vulnerable communities.

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