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GEO-ENVIRONMENTAL INFLUENCE ON GROUNDWATER QUALITY IN NDELE, SOUTHERN NIGERIA

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ABSTRACT

Groundwater contamination has been a growing issue in recent times as a result of population growth, urbanization and industrialization. Groundwater is highly susceptible to impacts associated with anthropogenic activities such as the release of waste materials to the environment. The groundwater vulnerability of an area is a function of the geologic and environmental factors of the area. The purpose of the study was to determine the impact of geological and environmental factors on groundwater quality in the Ndele Area of Southern Nigeria. Estimations of groundwater flow direction and overland flow direction in the study area were used to establish the likely groundwater vulnerable areas. The water quality index of groundwater sourced from hand-dug wells and boreholes in the study area was used to appraise the groundwater quality of different locations in the area. Water Quality Index is a means of summarizing and reporting water quality in a consistent manner. The mean values of water quality index parameters evaluated revealed that the WQI of water samples sourced from hand dug wells in the lower altitudes and hydraulc head areas (mini-watershed area) were found to be 101.5, which is categorised to be "unsafe for drinking," while those of the two control locations with higher altitudes and hydraulic heads were 69.0 and 67.2, respectively, and are categorised to be "poor water quality." Water samples sourced from boreholes with average depths of 40m in the lower altitudes and hydraulic head areas (mini-watershed areas) and two control areas were found to be 39.0, 44.3, and 41.2 m respectively and categorized to be "good water quality". Thus, based on some environmental ill practices such as the use of open pit toilets, discharge of suckaway to flow with surface runoffs, and improper disposal of domestic wastes in the area, this study has revealed that groundwater at the locations with lower hydraulic heads and altitudes (mini-watershed area) is highly vulnerable. This may be attributed to the fact that lower lands and hydraulic head areas are susceptible to overland and groundwater flow; hence, infiltration and water table recharge by water from higher altitudes that contaminate groundwater in such areas.

Keyword: Geo-Environmental, Lower altitudes, Lower hydraulic heads, Overland flow, Water Quality

INTRODUCTION

Groundwater is the water that lies beneath the ground surface in cracks, crevices, and pore spaces of rocks in an area called an aquifer. The confined and unconfined aquifers are the two sources of groundwater, and the most important difference between water stored in both sources is their susceptibility to contamination from either the surface of the earth or nearby contaminated groundwater

(Fetters, 2001). The unconfined aquifer is highly vulnerable to contamination, while the confined aquifer has a lower susceptibility to contamination and is therefore the major source of water for human consumption (Etu-Efeotor and Akpokodje, 1990).

However, groundwater is a tremendously important earth resource necessary for the sustainability of human life and the earth's overall geologic processes. Over 75 percent of the earth is occupied by water, and groundwater accounts for just about 0.6 percent of the world's distribution of water (Plummer et al., 2003).

Groundwater vulnerability is the potential of a groundwater system to get contaminated from the surface of the earth. The recharge system of groundwater has been identified as the major source of its contamination (Nwankwoala and Udom, 2011). Drainage system failure in settlements without good waste management plan can pose threats to the watershed areas. During the raining season, due to regular rain fall and flow of surface runoffs downslope, leachates formed from the waste materials can be transported and deposited at the downslope area. Pathogens, fecal coliforms and leachates from waste materials deposited can infiltrate soil strata and contaminate the groundwater in the area.

Study Area

The study area is parts of Ndele community, in Emuoha L.G.A of Rivers State. Located within latitude 04^{0}58'05" – 04^{0}58'08" N and longitude 006^{0}44'44" – 006^{0}45'05" E (Fig. 1). Ndele is bounded to the north by Elele alimini and Rumuekpe and then to the south by Rumuji. The study area is accessible from the Ndele axis of the East-West road, approximately five hundred (500) meters from the Ndele bus stop on the East-West Expressway.

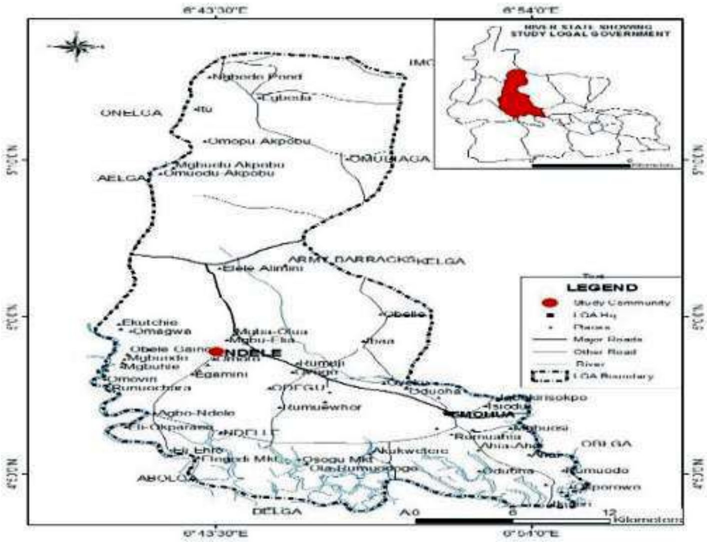

Figure 1: Map of the study area

Geology of the Study Area

Ndele is located within the Niger Delta region of Nigeria, situated in the Gulf of Guinea and therefore has same geology of the Niger Delta.

The Niger Delta is composed of marine shale at the base of its stratification, an overlying formation of intercalation of sandstone and clays of marginally marine origin, but eventually grading upward into a huge

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sandstone deposit. The groundwater formation is a multi-aquifer system because of the presence of certain clayey strata in formations of various thicknesses that acts as confining layer between two rock strata.

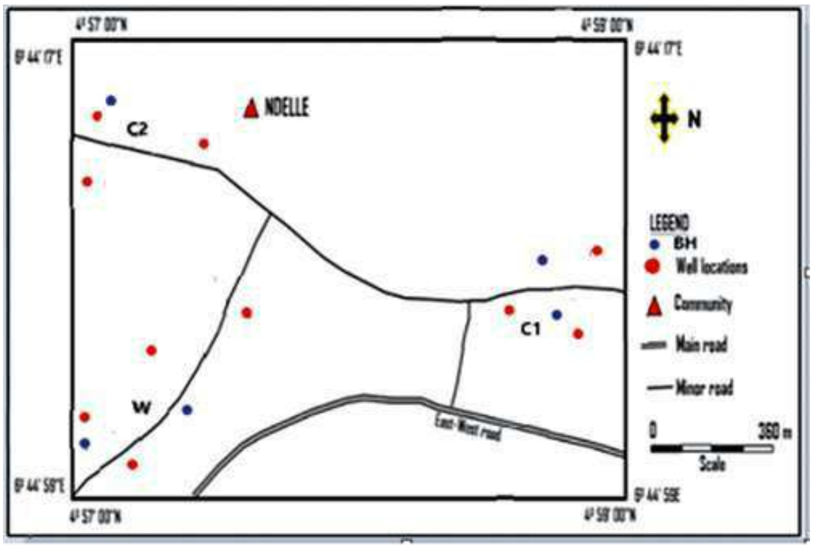

Figure 2: Base map showing wells and borehole locations

The present-day Niger Delta was formed during the tertiary period as a result of the interplay between subsidence and deposition arising from a succession of transgression and regression of the three main tertiary subsurface litho-stratigraphic units of Akata, Agbada, and Benin Formations (Short, and Stauble, 1967). Further studies and evidence from deep wells in the Niger Delta have also proven that the Niger Delta has a three litho-stratigraphic depositional succession (Akata, Agbada and Benin Formations) with an approximate thickness of over 5000m of sediment body (fig 3).

Relief and Drainage

The study area lies within the coastal flat plains of the Niger Delta, which is a depositional environment basically of almost featureless land sloping gently above mean sea level at the coastal fringe, though relatively low elevation occurs around the shore lines, waterfronts, and streams (Etu-Efeotor, 1997). The area is affected by tides, with a maximum range of tide fluctuating between 1.8m below mean sea level and 2.2m above mean sea level (Iloeje, 197). The study area, which is in Rivers State, is drained by numerous rivers and creeks sourced from the River Niger. The study area, Ndele is drained by the new Calabar River (Iloeje, 197).

Hydrology of the Study Area

Although the Agbada Formation has a sandy unit with aquifer qualities and confirmed water saturation, its depth has made it an unsuitable source for groundwater in the region. Aquifers of the Benin Formation bear the groundwater needs of the region. The poorly sorted Benin coastal sands become increasingly sandy and unconsolidated towards the surface. These parameters increase the porosity and permeability and, thus, the increase in storage coefficient of the aquifer. The region is composed of multiple aquifer systems due to the presence of thin clayey or silty layers acting as confining layers and boundaries between distinct aquifer formations. The groundwater in the area is recharged either by a nearby body of water such as surface water or a more prolific aquifer and extensive percolation from rainfall. This has resulted in a productive hydrologic unit with depths to the water table ranging from 0.3 to 15 metres (Offodile, 2002).

METHODOLOGY

Estimation of direction of flow for surface runoffs

Direction of flow of surface runoffs was determined by estimating the slope and its direction in the study area. This was done by the use of Global Positioning System (GPS) etrex-30 to determine the surface elevations of different points in the study area with respect to mean sea level. A contour map showing the variation of surface elevations in the study area was then produced indicating the direction at which the surface runoffs flow; from a region of higher elevation to a region of lower elevation.

Determination of Groundwater Flow Direction in the Area

A total of ten (10) hand dug wells (fig.2) were used to estimate the hydraulic heads at different locations in the study area (Table 1). With the aid of water level meter, the depth to water table was measured and recorded. The Global Positioning System (GPS) was used in determining the latitudes and longitudes of the wells and the surface elevation with respect to mean sea level on the surface of the earth. The surface elevation at different locations varied. This uniform water level coincided with static water level in the case of the unconfined aquifer while it was the piezometric surface of the aquifer that was confined (Buddermier and Schloss 2000). The values of the static water levels were contoured on the map with lines that represent the water table contours. According to Buddermeier and Schloss (2000), groundwater flows from the highest values of hydraulic head to the lowest values in a direction perpendicular to the hydraulic head contour lines.

RESULTS AND DISCUSSIONS

Table 1: Field records obtained from hand-dug well

Wells	Latitude(N)	Longitude(E)	Surface Elevation (m)	W table Depth(m)	Hydraulic head (m)
1	$04^{0}\ 58^{I}\ 219^{II}$	$006^{0}\ 44^{I}\ 699^{II}$	21	1.26	19.7
2	$04^{0}\ 58^{I}\ 058^{II}$	$006^{0}\ 44^{I}\ 494^{II}$	21	2.54	18.5
3	$04^{0}\ 58^{I}\ 065^{II}$	$006^{0}\ 44^{I}\ 437^{II}$	23	2.28	20.7
4	$04^{0}\ 58^{I}\ 024^{II}$	$006^{0}\ 44^{I}\ 495^{II}$	21	2.34	18.7
5	$04^{0}\ 58^{I}\ 038^{II}$	$006^{0}\ 44^{I}\ 434^{II}$	31	3.09	27.9
6	$04^{0}\ 58^{I}\ 093^{II}$	$006^{0}\ 44^{I}\ 446^{II}$	33	3.26	29.7
7	$04^{0}\ 58^{I}\ 114^{II}$	$006^{0}\ 44^{I}\ 390^{II}$	31	3.82	27.2
8	$04^{0}\ 58^{I}\ 719^{II}$	$006^{0}\ 44^{I}\ 751^{II}$	30	2.73	27.3
9	$04^{0}\ 58^{I}\ 791^{II}$	$006^{0}\ 44^{I}\ 657^{II}$	32	2.88	29.1
10	$04^{0}\ 58^{I}\ 853^{II}$	$006^{0}\ 44^{I}\ 727^{II}$	32	2.70	29.3

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Estimation of Direction of Flow of Surface Runoffs

2D elevation contour map of the study area (Fig. 3) and 3D elevation contour map of the study area (Fig. 4), explains that the direction of flow of surface runoffs in the study area are towards one direction, the South. This is simply attributed to the uneven elevation encountered at different points in the study area which results to a downward sloping towards the mini-watershed area. The mini-watershed location is situated down South of the study area and this implies that the surface runoffs flow to the mini-watershed area. This makes the mini-watershed area highly susceptible to flow due to surface runoffs. Furthermore, it is also observed that all surface runoffs in the study area are directed towards the mini-watershed area which has the drainage system that channels water to a fresh water swampy forest in the area. Due to failure of the drainage system in this area, all surface runoffs that flow down slope stagnates on the street and in the compounds of residents of the mini-watershed area, this poses great threat to the environment and health of the residents of this area

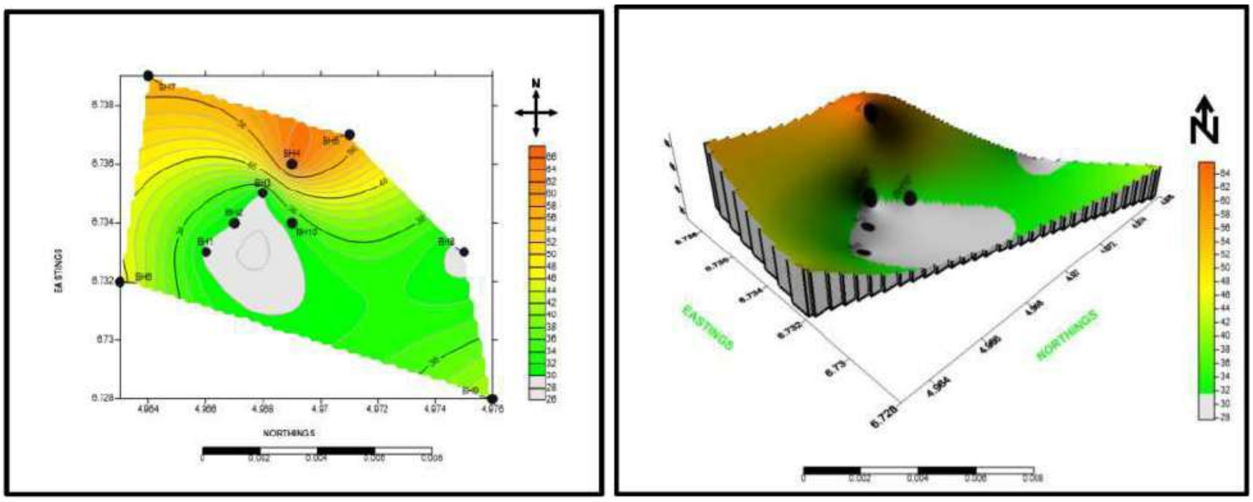

Fig. 3 & 4: 2D & 3D Elevation Contour map showing the direction of flow of surface runoffs

Determination of Groundwater Flow Direction

The values of the hydraulic head and static water level obtained from each well location were contoured carefully on a map by joining equal values of the hydraulic heads (Fig. 5). The water table elevation values which are also representing the hydraulic head values of the various wells are in meters and are also placed beside the contour map decreasing downwards from higher heads to lower heads.

According to Buddermier and Schloss (2000), groundwater flows from regions of higher hydraulic heads to regions of lower hydraulic heads. Thus, from the hydraulic head map plotted with the aid of surfer 8 computer software (Fig 5), groundwater in the study area is observed to flow to the South, South-East directions. Consequently, the mini-watershed location is observed to be the vulnerable area because it is susceptible to flows due to surface runoffs and groundwater flow.

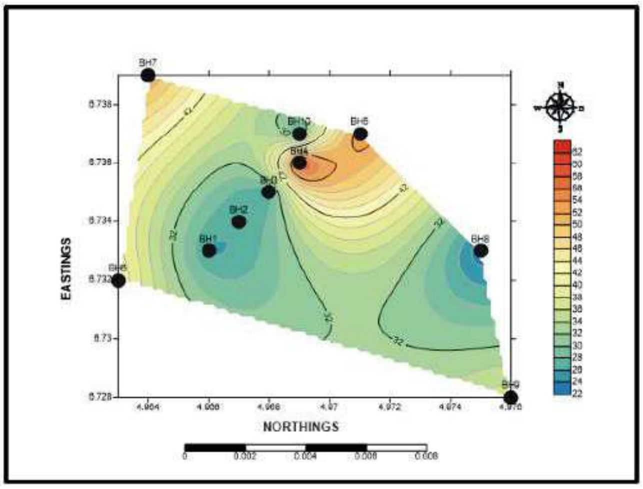

Fig 5: 2D Hydraulic Head Contour map showing groundwater flow direction in the study area

Table 2: Summary of mean values of water quality parameters of water sample from the area

	Watershed Mean value		Control 1 Mean value		Control 2 Mean value		
Parameters	$Well_W$	BH_W	$Well_1$	BH_1	$Well_2$	BH_2	WHO
Ph	6.06	7.12	6.01	6.9	5.6	6.6	6.5-8.5
EC	190.2	63.45	170.1	63.8	171	72	300
TDS	172	80.25	112	93.9	215.5	47.9	500
Hardness	137	63	89.4	42.3	75.5	61.1	100
Ca	33	17.05	43.3	6.5	13.5	24.1	70
Nitrate	2.34	2.17	3.0	1.1	4.5	1.4	10
S	158	17.0	123	21.0	83	14.2	200
DO	6.3	2.3	5.2	3.7	5.8	3.0	5
BOD	7.8	1.5	1.7	1.25	1.9	1.2	5
Mg	19.2	8.45	22.3	8.7	2.25	12.2	30
Cl	10.35	4.1	15.0	24.6	16.7	8.9	250

Table.3: Summary of Water Quality Index of groundwater in the study area in accordance with Mishra and Patel, (200) and Naik and Purohit (2001).

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S/N	Location	SAMPLE ID	WQI	Water Class
1	WATERSHED	$Well_W$	101.5	Unsafe for drinking
2		BH_W	39.0	Good water quality
3	CONTROL 1	$Well_1$	69.0	Poor water quality
4		BH_1	44.3	Good water quality
5	CONTROL 2	$Well_2$	67.2	Poor water quality
6		BH_2	41.2	Good water quality

CONCLUSION

The results obtained from the 2D and 3D elevation contour map of Ndele indicates that groundwater flows from the North, North-eastern part of the community (the two control areas with higher altitudes and hydraulic heads) to the South and South-western part of the community (the mini-watershed area with lower altitudes and hydraulic heads). This implies that groundwater at the mini-watershed area is highly susceptible to contamination and thereby possesses a higher level of vulnerability, especially the hand dug wells (the unconfined aquifer). Water Quality Index was estimated using mean value concentrations of eleven (11) physiochemical parameters (Table 2). The results revealed that water the samples sourced from hand dug wells in the mini-watershed area are highly contaminated and showed water class of "unsafe for drinking" (Table 3) than those from the two control areas with water classes of "poor water quality" each. The WQI of water sourced from boreholes at the mini-watershed area and two controls showed no contaminations with water class of "good water quality" respectively.

Recommendations

Based on the aquifer vulnerability in the study area, it is recommended that the drainage system at the mini-watershed area be reconstructed to allow free flow of surface runoffs into the fresh water swampy forest. Also, there should be an appropriate waste disposal and management in the study area, this will reduce the leachates formed from human and domestic wastes produced by the residents of the study area. The use of water sourced from hand dug wells in the study area should be totally prohibited especially in the mini-watershed area. Rather, boreholes of with average depth of 45m is recommended for all boreholes in the study area.

REFERENCES

Buddemeier, R. W. and Schloss, J. A; (2000). Groundwater Storage and Flow. www.kgs.ku.edu.

Etu-Efeotor, J. O. (1997). Fundamentals of Petroleum Geology. Paragraphics Ltd., 114-116.

Etu-Efeotor, J. O. and Akpokodje, E. G. (1990). Aquifer systems of the Niger Delta. Journal of Mining Geology, 26(2):279 – 284.

Fetter, C. W; (2001). Applied Hydrogeology- 4th Ed, Prentice Hall, New Jersey. 598.

Iloeje, P. (1972). A preliminary sub-soil investigation, International Journal of Environmental Science Management and Engineering Research. 1(2), 459-522.

Mishra, P.C., Patel, R. K (2001). Indian Journal for Environmental and Ecoplanning, 2001, 5(2): 293-298

Naik, S. Purohit, K. M (2001). Indian Journal for Environmental and Ecoplanning, 2001, 5(2): 397-412

Nwankwoala, H.O. and Udom G. J. (2011); Hydrogeochemical evaluation of Groundwater in parts of eastern Niger Delta. Journal of Academic and Applied Studies 1(2). 33-58.

Plummer, C. C., McGeary, D. and Carlson, D. H., (2003). Physical Geology, ninth edition, 259- 278