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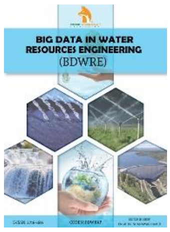

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RESEARCH ARTICLE

GROUNDWATER FLOW DIRECTION EVALUATION FOR FLOOD AND CONTAMINATION CONTROL IN OSUBI, SOUTHERN NIGERIA

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ABSTRACT

The determination of groundwater flow direction is essential in flood and groundwater contamination control. This study aimed at determining the groundwater flow direction in the study area to infer possible areas of further spread of contaminants and identify areas that might be prone to flooding shortly. Fifty (50) hand-dug wells were sampled with the aid of a long tape (200/60m) and a global positioning system (GPS) to determine their hydraulic heads, while topography and groundwater flow direction maps of the study area were generated using surfer 13 and groundwater modeling software, respectively. The result revealed that the hydraulic heads and static water level (SWL) values range from 0.63-27.15 m and 1.15–4.88 m, respectively, while the elevation values range from 5–30 m. The study area is characterized by undulating and relatively flat terrain in different parts of the area, while the groundwater flow direction depicts a non-uniform directional flow of groundwater in the study area. This suggests that the groundwater contamination discovered in the area might soon spread to contaminate their nearby environs if not promptly and urgently controlled. It is hereby recommended that every anthropogenic activity, such as abattoirs, mechanic workshops, dumpsites, etc., that can increase the rate of groundwater contamination in the study area be restricted to the north-eastern, eastern, and southeastern parts due to their low hydraulic heads.

KEYWORDS

Contamination, Groundwater Flow Direction, Wells, Hydraulic Heads, Flood

1. INTRODUCTION

There have been several observations of groundwater contamination in different parts of the Osubi municipal area resulting from either anthropogenic or geogenic activities. Some parts of the area seem to be enjoying good portable water, while the majority of the inhabitants are complaining about the lack of availability of portable groundwater due to contamination of the groundwater within the study area. More so, the increase in reported cases of flooding in Nigeria, especially in riverine areas, demands urgent concerns about possible ways of mitigating any future occurrence. A number of studies have been done on the flooding system, looking at its causes, effects, solutions, and suggestions for making things better looked into one area of the Niger Delta to find out the direction of groundwater flow in order to figure out where to put septic tanks and dump sites in relation to where an existing or planned borehole is (Ebuzoeme 2015; Nura and Alison 2022; Ogbozige and Toko, 2020). It was deduced that the groundwater flows in the southern and south-western directions; hence, the residents were advised to take cognizance when sitting at dumpsites, landfills, and septic tanks with respect to proposed or existing boreholes. In the same vein, utilized sixteen (16) hand-dug wells within the Yenegoa metropolis to determine the groundwater flow direction in the study area (Oborie and Nwankwoala, 2017). The result shows that groundwater flow direction is predominantly towards the south-western parts of the city, with the main forces affecting groundwater movement being gravity and external pressure due to pumping. Hence, it was recommended that sanitary landfills be confined to the south-western regions of the study area, while municipal water wells and boreholes for domestic supply should be sited in the northern part. Researched to determine the groundwater flow direction of an area in Akwa Ibom State (Jason et al., 2012). It was discovered that it tends towards the NE-SW of the study area. Hydrology is the scientific study of the movement, distribution, and management of water on Earth and other planets, including the water cycle, water resources, and drainage basin sustainability (USGS 2015). It uses the principle of hydraulic head determination to generate the groundwater flow direction. The hydraulic head is the height above a datum plane, such as sea level, of the water column that the hydraulic pressure at a specific point in a groundwater system can support. Hydraulic heads indicate the direction of groundwater flow and are used to determine hydraulic gradients (groundwater dictionary, second edition). The study's goal is to create a groundwater modeling flow of the study area using GPS data and groundwater modeling software (GMS). This will help figure out the direction of the groundwater flow, where the contamination might spread next, and which areas might be more likely to flood soon.

1.1 Description of the study area

Osubi is a developing neighborhood near Warri that exists between latitudes $5^0$35'0"N and $5^0$36'0"N and longitudes $5^0$48'0" and $5^0$50'0" East (Figure 1). The Warri Airport (also known as Osubi Airstrip) is nearby. Due to the proximity and prominence of Nigeria's Niger Delta oil-producing region, there is rapid infrastructure development around the airport region. With the rapid expansion of building projects for modern living, Osubi is quickly becoming a bustling modern community. Nearby is the world-famous Nigeria Petroleum Training Institute (PTI), as well as other infrastructure developments in the area. This has resulted in an

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uncontrolled migration of people to the area and the indiscriminate dumping of industrial and domestic wastes, both of which pose direct threats to the quality of the environment, particularly surface and groundwater resources. During the rain, leachate from industrial and domestic landfills may percolate and contaminate groundwater. As a result, landfill pollution causes potentially infectious diseases. Groundwater transports dissolved chemicals, including contaminants, at the subsurface level. Groundwater from the burial or disposal site may transport materials dissolved in waste, resulting in contaminated groundwater that affects the quality of water from wells. Furthermore, natural aquifer discharges, such as springs and seeps, can return contaminants to the surface. Furthermore, contaminants from dumpsites typically enter the aquifer system through the land surface, percolating down through aerated soil and an unsaturated (vadose) zone. This may extend 6 or 9 m into the soil, where many reductive and oxidative biological processes occur, potentially lowering soil quality (NRC, 1984; Okumoko and Izeze 2020).

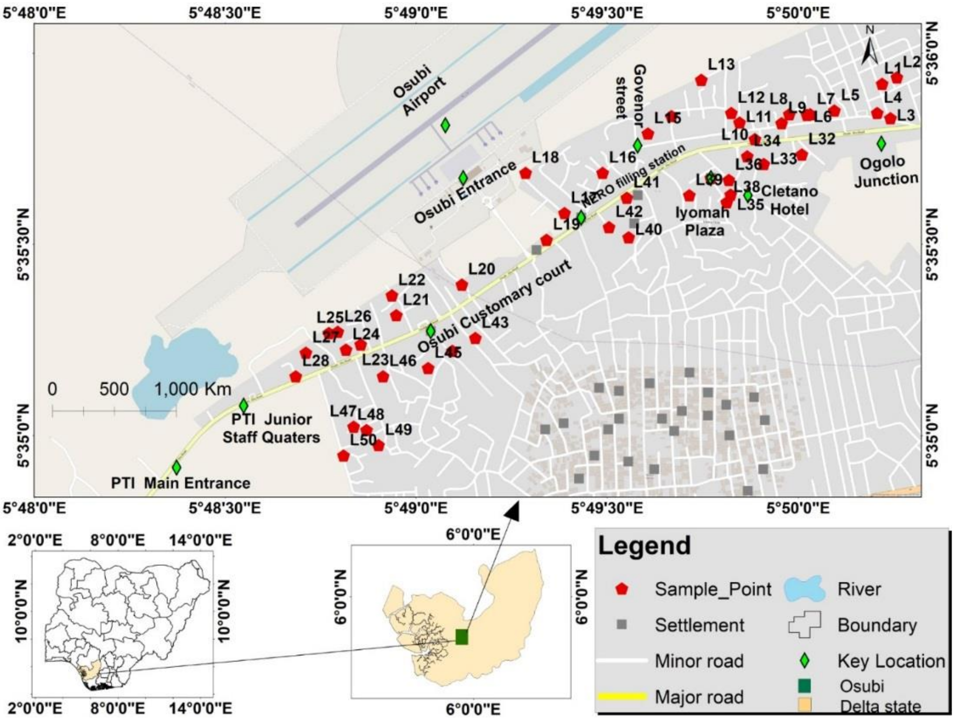

Figure 1: Base map of the study area showing the sampled wells

2. Research Methodology

To define groundwater flow directions and rates through aquifers, individual measurements of hydraulic head are combined to generate contour maps of water level, or potential energy. In this study, the direction of groundwater flow was determined by using hand-dug well data generated within the study location from a total of 50 wells, while the elevation of the hand-dug well points above mean sea level was measured using an Etrex Global Positioning System (GPS). The static water level (SWL) of each well was measured using a Stanley long 200/60 m tape. The static water levels obtained at each well were then subtracted from the GPS-acquired elevation to obtain the hydraulic heads. The hydraulic heads and their coordinates were scale-gridded using Surfer 13 software, and groundwater modeling software (GMS) was used to generate the groundwater flow direction of the study area. Equation 1 shows how to calculate the hydraulic heads (H.H.) of the various hand-dug wells by deducting their corresponding earth surface elevations (E) from the static water levels (SWL).

$$H.H = E - SWL \qquad (1)$$

The GMS software considers the geographic coordinates and elevation (topographic nature) of the study area and other relevant data, such as the hydraulic conductivity of the geology formation present, well, river, recharge, lake, stream information, and so on, if available. This tool helps address water resource management, environmental protection, and other groundwater-related challenges.

3. Discussion of Results

Table 1: Data for determination of groundwater flow direction in Osubi

S/N	Street name	Wells coordinates		Elevation	Static water level	Hydraulic heads
		Latitude (N)	Longitude (E)	(m)	(SWL)	(m)
1	Ugolo layout	5°35’55.2	5°50’13.2	23	1.91	21.09
2	Ugolo layout lane	5°35’56.2	5°50’15.5	9	1.84	7.16
3	Victory school junction	5°35’49.8	5°50’14.5	11	4.63	6.37
4	Back of Luxe mirage	5°35’50.6	5°50’12.4	8	4.33	3.67
5	Back of Luxe mirage	5°35’51	5°50’5.7	19	4.244	14.756
6	Entrance of Osubi community	5°35’50.3	5°50’1.4	13	4.88	8.12
7	Block industry	5°35’50.4	5°50’1.9	8	4.38	3.62
8	Victory close	5°35’50.4	5°49’58.6	11	4.22	6.78
9	Hostel after JD Hotel	5°35’49	5°49’57.4	12	4.34	7.66
10	Along Osubi road	5°35’46.5	5°49’53.2	14	4.13	9.87
11	back of AK shop complex	5°35’49.1	5°49’50.8	13	2.61	10.39
12	Colonel Newton street	5°35’50.6	5°49’49.5	10	2.18	7.82

Table 1: Data for determination of groundwater flow direction in Osubi

13	Colonel Newton street	5°35’55.8	5°49’44.8	19	2.02	16.98
14	Our redeemer school	5°35’50.1	5°49’40.1	17	1.15	15.85
15	Mr Francis Odogun lane	5°35’47.4	5°49’36.4	18	2.08	15.92
16	Along Osubi road	5°35’41.2	5°49’29.3	18	2.88	15.12
17	Osubi Airport hotel street	5°35’34.9	5°49’23.3	16	3.24	12.76
18	Pst Davis lane	5°35’41.2	5°49’17.2	12	2.90	9.1
19	Before airport	5°35’30.7	5°49’20.5	19	3.43	15.57
20	K.B bar	5°35’23.7	5°49’7.19	14	2.47	11.53
21	Vulcanizer close	5°35’18.9	5°48’56.9	17	2.86	14.14
22	Vulcanizer close	5°35’22	5°48’56.2	18	2.00	16
23	Bast house local	5°35’14.3	5°48’51.3	14	2.22	11.78
24	Opp victory Joe street	5°35’13.5	5°48’49	14	3.12	10.88
25	Along Osubi road	5°35’16.1	5°48’46.3	15	2.34	12.66
26	Before Kay cakes	5°35’16.3	5°48’47.7	13	2.69	10.31
27	Kay cakes	5°35’13	5°48’42.7	16	2.81	13.19
28	Mechanic joint	5°35’9.3	5°48’41.1	15	3.14	11.86
29	Tuwere close	5°34’3.4	5°48’25.9	14	2.32	11.68
30	Behind classic hair saloon	5°34’46.5	5°48’12.5	13	1.37	11.63
31	Bike mechanic joint	5°34’48	5 °48’7.9	14	1.25	12.75
32	After Cletano hotel	5°35’44.1	5 °50’0.6	13	4.80	8.2
33	Lucky London	5°35’42.6	5°49’54.6	5	4.37	0.63
34	Onos cut off	5°35’43.8	5 °49’52	14	4.80	9.2
35	Onos str	5°35’37.8	5°49’49.4	16	3.97	12.03
36	Iyomah p,laza end	5°35’40.1	5°49’49.1	9	4.23	4.77
37	Iyomah plaza beginning str	5°35’40.4	5°49’46.3	27	3.65	23.35
38	In btw iyomah/Ajayi str	5°35’36.6	5°49’48.8	12	4.55	7.45
39	Ajayi close	5°35’37.7	5°49’42.9	15	3.17	11.83
40	Felicia str	5°35’31.1	5°49’33.4	14	4.01	9.99
41	Ei shaddai str	5°35’37.3	5°49’33.1	16	3.42	12.58
42	Oppo market/check point	5°35’32.7	5°49’30.3	17	3.76	13.24
43	Poultry lane	5°35’15.3	5 °49’9.3	10	2.47	7.53
44	Health Centre/magistratye court	5°35’13.3	5°49’5.7	12	2.61	9.39
45	Before Winggate hospital lane	5°35’10.6	5°49’1.9	28	3.06	24.94
46	Along wing gate lane	5°35’9.3	5°48’54.8	16	3.46	12.54
47	Frank Edward layout road 2	5°35’1.4	5°48’50.2	15	2.89	12.11
48	Chief Mokwenye close	5°35’0.9	5°48’52.2	17	2.92	14.08
49	Chief Mokwenye close	5°34’58.5	5°48’54.1	30	2.85	27.15
50	Chief Mokwenye close	5°34’56.9	5°48’48.6	21	3.11	17.89

Figure 2 revealed that the study area is characterized by an undulating terrain. It has relatively flat terrain on the south-eastern and south-western flanks of the study area, while the northeastern and north-central parts of the study area are highly undulating.

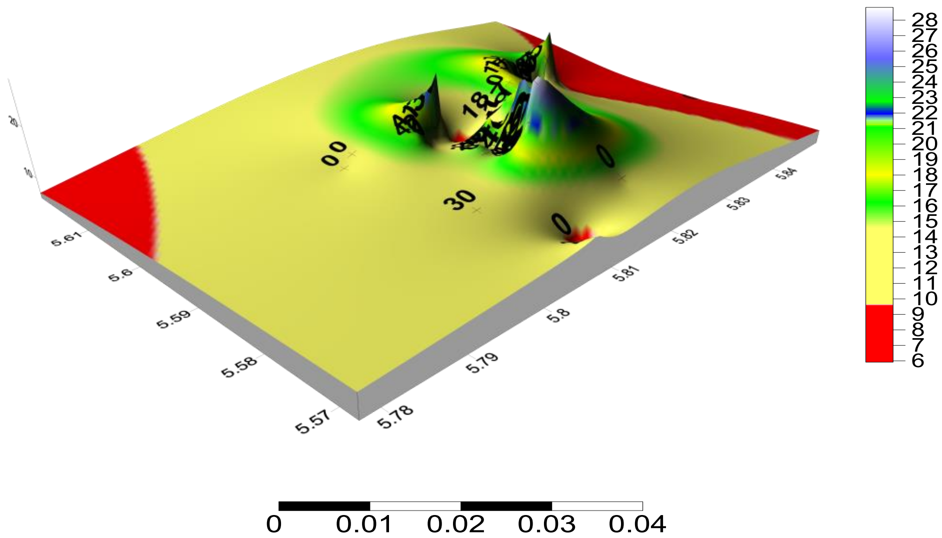

Figure 2: Topography map of the study area.

Figure 3 shows the groundwater flow direction of the study area. It reveals a non-uniform directional flow of groundwater all over the area. The groundwater flow direction tends to flow from the middle flank of the study area towards the northern part and also from the middle part of the study area towards the southern part. The center part of the study area depicts a very high hydraulic head, which makes the groundwater move in another direction in the area. This implies that the suspected groundwater contamination found in the study area is likely to spread all over its environs from time to time. Because of their low hydraulic heads and inadequate drainage systems, the northeastern, eastern, and southeastern regions are particularly vulnerable to flooding during the rainy season. All of the results show that dumping trash anywhere, mechanics working at mechanic shops in the area, abattoirs in the study area, and any other human-made or natural source of groundwater contamination in the study area could soon spread to nearby areas if they are not fixed quickly and effectively. However, if these anthropogenic activities must continue in the study area, they are to be sited in the northeastern, eastern, and southeastern parts of the study area to minimize the spread of their contaminants.

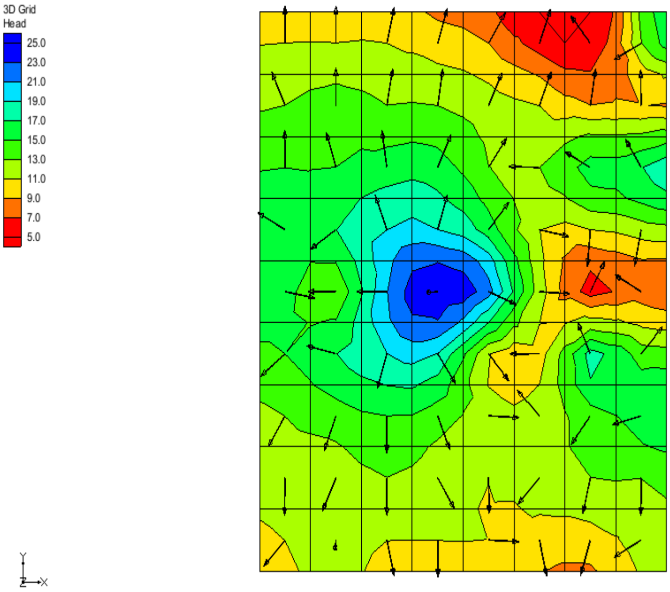

Figure 3: The ground water flow direction of the study area.

4. Conclusion and Recommendation

4.1 Conclusion

In conclusion, this study undertook a critical examination of groundwater flow direction in the study area, employing a comprehensive approach that combined field measurements and advanced mapping techniques. The assessment, conducted through the sampling of fifty hand-dug wells, revealed a diverse range of hydraulic heads and static water levels, indicative of the complex hydrogeological nature of the region. Utilizing Surfer 13 and groundwater modeling software, topography and groundwater flow direction maps were generated, unveiling a non-uniform directional flow of groundwater across the study area. The observed undulating and relatively flat terrains, coupled with the identified groundwater flow patterns, highlight the vulnerability of certain areas to potential flooding and the spread of contaminants. Notably, the study discerned those anthropogenic activities, such as abattoirs, mechanic workshops, and dumpsites, could significantly contribute to groundwater contamination. Consequently, a key recommendation emerges from this investigation: the restriction of such activities to the north-eastern, eastern, and south-eastern parts of the study area, characterized by their lower hydraulic heads. This strategic measure aims to curb the imminent threats posed by the non-uniform directional flow of groundwater, safeguarding both the environment and the local population from the expanding reach of contaminants. Urgent and decisive action is imperative to prevent the escalation of groundwater contamination, and this study provides valuable insights for effective groundwater management and environmental protection in the region.

4.2 Recommendations

It is hereby recommended that;

1. Implement zoning regulations that restrict anthropogenic activities, including abattoirs, mechanic workshops, and dumpsites, to the north-eastern, eastern, and south-eastern parts of the study area to minimize the further spread of contaminants.
2. Soil and water samples from the study areas should be subjected to a thorough geochemical investigation to find out where the other contaminants that are present in areas that are not near any of the above human activities come from and how bad they are.
3. Drainage systems should be established in the study area, especially in the north-eastern, eastern, and south-eastern parts of the study area, to prevent flooding.
4. Do a combined geophysical investigation using 1D, 2D, and 3D electrical resistivity tomography (ERT) to find out how far the contamination goes across the study area, both horizontally and vertically.
5. Launch awareness campaigns to educate residents, businesses, and stakeholders about the risks associated with groundwater contamination and the importance of responsible waste disposal.
6. Promote community involvement in maintaining a clean environment and understanding the implications of groundwater flow patterns.

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