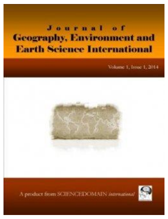

Journal of Geography, Environment and Earth Science International
2(3): 117-125, 2015; Article no.JGEESI.2015.011

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Implication of Open Dumpsite on Groundwater Quality in Calabar Metropolis, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author JE conceived and designed the study. Author EAO did the field work and developed the first draft. Literature searches were done by both authors. Both authors read and approved the final draft.

Article Information

DOI: 10.9734/JGEESI/2015/16144
Editor(s):
(1) Eman Ghoneim, Department of Geography and Geology, University of North Carolina, Wilmington, USA.
Reviewers:
(1) Sisir Kanti Nag, Department of Geological Sciences, Jadavpur University, West Bengal, India.
(2) Abdel Razik Ahmed El-Sayed Zidan, Irrigation and Hydraulics Department, El-Mansoura University, Egypt.
(3) Anonymous, China.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=1104&id=42&aid=9023

Original Research Article

Received 10th January 2015
Accepted 26th March 2015
Published 28th April 2015

ABSTRACT

Aim: This study investigates the implication of the waste dumpsite on the groundwater quality.
Place of Study: The study was conducted in Calabar Metropolis, the Capital of Cross River state of Nigeria.
Methodology: 22 boreholes were selected for the study. Data on these boreholes location, depths and static water levels were obtained from Water Agencies in Cross River State and confirmed during field work. These data were used to develop the groundwater flow map of the study area in a Geographical Information Systems environment. The interpretation of the groundwater flow was done in relation to the major dump site in the City.
Results: Static water level in Calabar metropolis ranged from 0.28 m to 49.6 m with a mean value of 15.83 m and a modal class 0 to 3.99 m. The groundwater flow direction is such that water flows from the northern side down south because of high pressure gradient and high elevations in the north.
Conclusion: It is therefore possible for dissolved waste to be transported through the direction of flow and infiltrate the aquifer, thereby contaminating the groundwater. A new site has suggested in the southern part of the city with coordinates 426679.186E and 554807.648N for the relocation of

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the dumpsite. Further studies should be conducted to examine the level of contamination of the groundwater by this dump site.

Keywords: Groundwater quality; waste dumpsite; Calabar; geographical Information systems; Nigeria.

1. INTRODUCTION

Open dumpsites usually lead to the contamination of groundwater resources. Leachates from dumpsites migrate in the direction of rainwater percolation to contaminate the groundwater. In the developing countries like Nigeria, many users of groundwater hardly treat the water before usage and this poses a serious threat to their health as they employ it for domestic purposes, agriculture, and so on. Securing water of suitable quality is one of the leading environmental concerns of the 21st century. It is estimated that around 80 per cent of diseases and 33 per cent of deaths in the world are related to the consumption of contaminated water. With the daily increase in population growth, demands for freshwater supplies are expected to increase and groundwater is the largest readily available freshwater reservoir in many areas of the world [1].

Obviously, the quest to satisfy human needs and wants and the development have led to the consumption of various commodities and generation of wastes. This waste generation is as old as man himself because man has been involved in one form of activity or the other, and solely depends on such activities for his survival right from inception [2]. Moreover, as settlements grow, they become sophisticated due to high rate of urbanisation giving rise to increase in waste generation [2-4]. The disposal of such wastes, if not properly done can result in the contamination of both surface and groundwater. For instance, open dumpsite has been recognised as the major source of groundwater contamination under a wide range of conditions all over the world [5].

The environmental degradation caused by inadequate disposal of waste can be expressed in the contamination of groundwater through infiltration of leachate [6]. In addition, it is argued that [7] landfills are a threat to water quality when rainfall percolates through wastes, leaching out a variety of substances which infiltrate into the groundwater thereby contaminating it.

The location of dumpsite within an urban environment should be a primary concern particularly where a greater percentage of the population depends on groundwater for their domestic activities. It is well known that groundwater moves from a higher energy level to lower energy level where the energy is primarily determined by elevation and pressure [8]. The theory of groundwater movement is based on Darcy's law [9]. Where dumpsites are located at levels of higher energy, there is the tendency for leachates to infiltrate the groundwater and flow towards levels of lower energy. This would contaminate the groundwater along its flow path. Making use of such water for domestic purposes without treatment can have deleterious effect on human health.

Hence, it is important to carry out groundwater flow analysis before locating a waste disposal site. Groundwater is the major source of freshwater in many urban centres in developing countries like Nigeria. In Cross River State, hundreds of boreholes have been drilled in the capital city of Calabar, in order to provide the teaming population of with potable water [10]. Yet, there are no records to show that this kind of analysis was conducted for Calabar metropolis before the open dumpsite was located at Ikot Effanga Mkpa (Plate 1). The sanitary condition around the dumpsite is very poor. Most times, the wastes overflow and obstruct the road as shown on Plate 1.

Also, the stench that comes from it is a serious health hazard. Thus, it's a major source of air pollution in the area and an eyesore, as it degrades the aesthetic value of the developing area. The human population in this area is growing day by day as houses are springing up here and there taking advantage of the infrastructural facilities available in the area now. The increasing population goes with an attendant waste generation.

2. METHODOLOGY

2.1 Study Area

Calabar lies between longitudes 24°.15' and 5°.15'N and latitudes 8°.15' and 80.25'E. It is the capital city in Cross River State and covers about 233 sqm (604 km^2) (Fig. 1). It is situated at the extreme South East of Nigeria. The Calabar area belongs to the low and swampland of South-

Eastern Nigeria [11]. Calabar Elevations are generally less than 100 m above the main sea level. Two main rivers dominate the landscape of Calabar: the Calabar River and the Great Qua River [12,13].

Calabar has a sub-equatorial climate and is characterized by a double maxima rainfall which starts from April and ends in October, reaching its peak in June and September. The average annual rainfall is about 1830 mm. However, there is rainfall throughout the year but over 80% of the annual rainfall falls over the period stated above. The temperature of the area rarely falls below 19°C and averages 27°C all year round [14].

Geologically, Calabar is composed of Tertiary to Recent, continental fluvial sands and clays known as the coastal plain sands. This formation is characterized by alternating sequence of loose gravel, sand, silt, clay, lignite and alluvium [15]. It is underlain mostly by rocks of the cretaceous Calabar flank and Precambrian Oban massif. The coastal plain sand (Benin formation) is by far the most prolific aquifer in the area.

The major geomorphic features in the area as include the bold Marina Escarpment or Cuesta, running from Calcemco beach through Nsidung beach; the parallel ridges a geosynclines between the ridges, the Calabar and Great Kwa River and the Marchland and estuarine swamps [16,17]. The controls of these geomorphic features are likely to extend beyond surface flow to groundwater flow.

2.2 Data Collection

Data on boreholes location and depth, and static water level (Table 1) were obtained from Rural Water Supply and Sanitation Agency (RUWATSSA), Cross River Basin Development Authority (CRBDA), and Cross River State Water Board Limited (CRSWBL). A Geographical Positioning System (GPS) reading was taken for boreholes whose coordinates were not available at the water institutions where secondary data had earlier been collected. A GPS reading and photographs of the city dumpsite were taken. A total of 22 boreholes data were selected for the study.

2.3 Data Pre-Processing and Analysis

The obtained data were pre-processed and then analysed using the Geographical Information Systems (Surfer and ArcGIS software). To allow for uniformity of dataset, all borehole locations obtained in the geographic coordinate systems (decimal degrees), were transformed to their projected UTM (Universal Transverse Mercator) equivalents x and y (x - easting and y - northing) in metres.

Plate 1. Open dumpsite at ikot effanga mkpa in Calabar

This study therefore examines the implications of the waste dumpsite on the groundwater hydrology using the Geographical Information Systems (GIS)

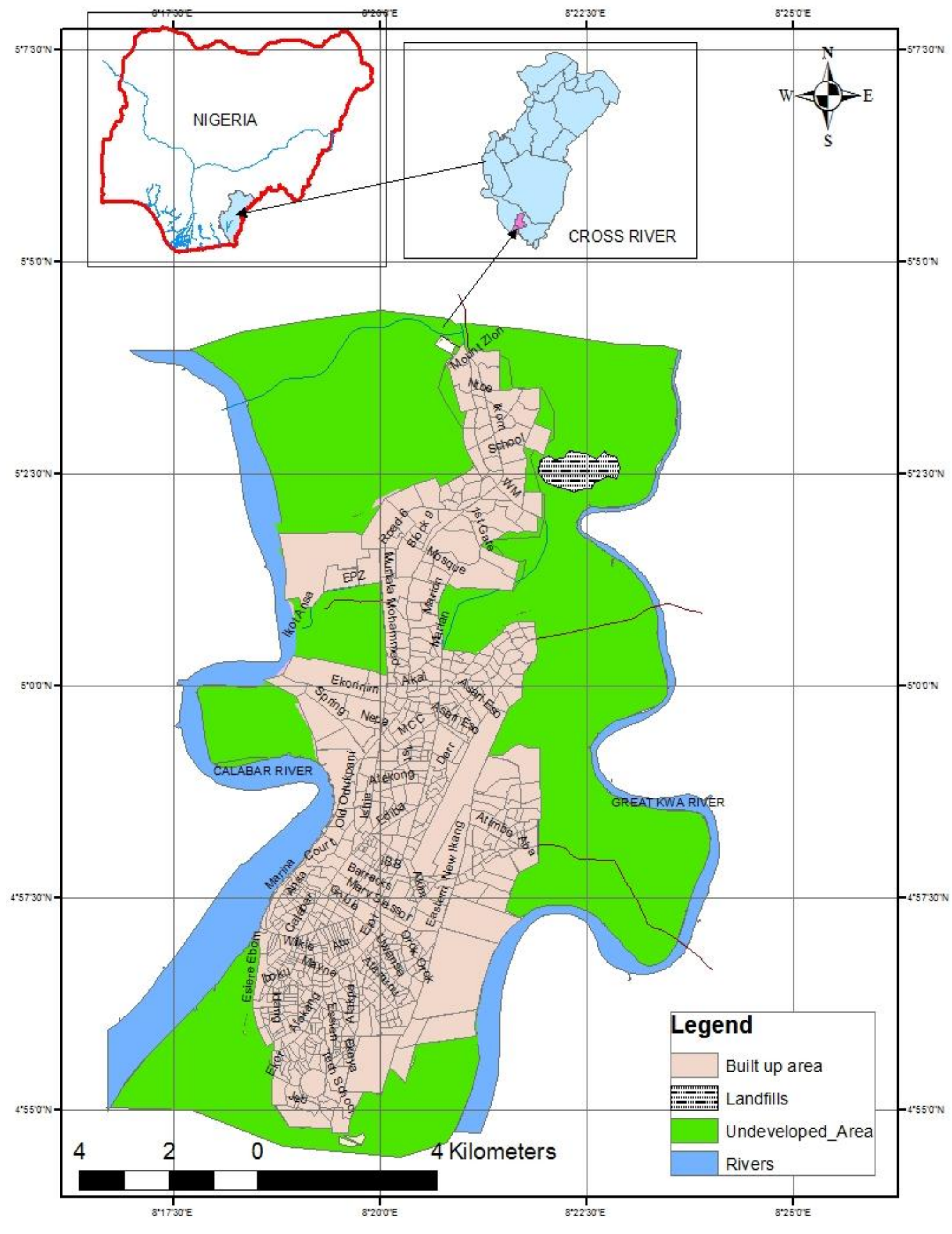

Fig. 1. Map of Calabar Metropolis

Predicting groundwater flow for a given area requires knowledge of the variation in static water levels (SWLs) across that area. Given SWLs collected from boreholes located at strategic locations, an easy way to predict values between boreholes would be to interpolate or contour these SWL values. Data of SWLs were imported into the GIS anchoring on their coordinates. The data was gridded with the x and y representing the coordinates and z representing SWLs. An interpolation technique (kriging) was applied on the data and contours were automatically generated at 2 metres (SWL) intervals. A vector map and 3D model showing groundwater flow direction was subsequently generated from the grid file.

3. RESULTS AND DISCUSSION

Table 1 shows the data obtained for this study. It displays the location of boreholes, the coordinates (latitudes and longitudes) of the locations, borehole depth in meters, static water level (SWL) in meters, projected UTM (Universal Transverse Mercator) equivalents x and y (x - easting and y - northing) in meters and the source of data. The static water level ranged from 0.28 m to 49.6 m with a mean value of 15.83 m and modal class of the static water level is 0 to 3.99 m.

Figs. 2 and 3 show the flow direction of groundwater modeled from contours of static water level (SWL) taken from boreholes and wells across the study area. The contour lines are 2 m apart from each other. The black arrows show the flow directions where groundwater moves from areas of high elevation to low elevation. Also it can be seen that the present dumpsite is in a depressed area, i.e. in between two cliffs or elevated areas.

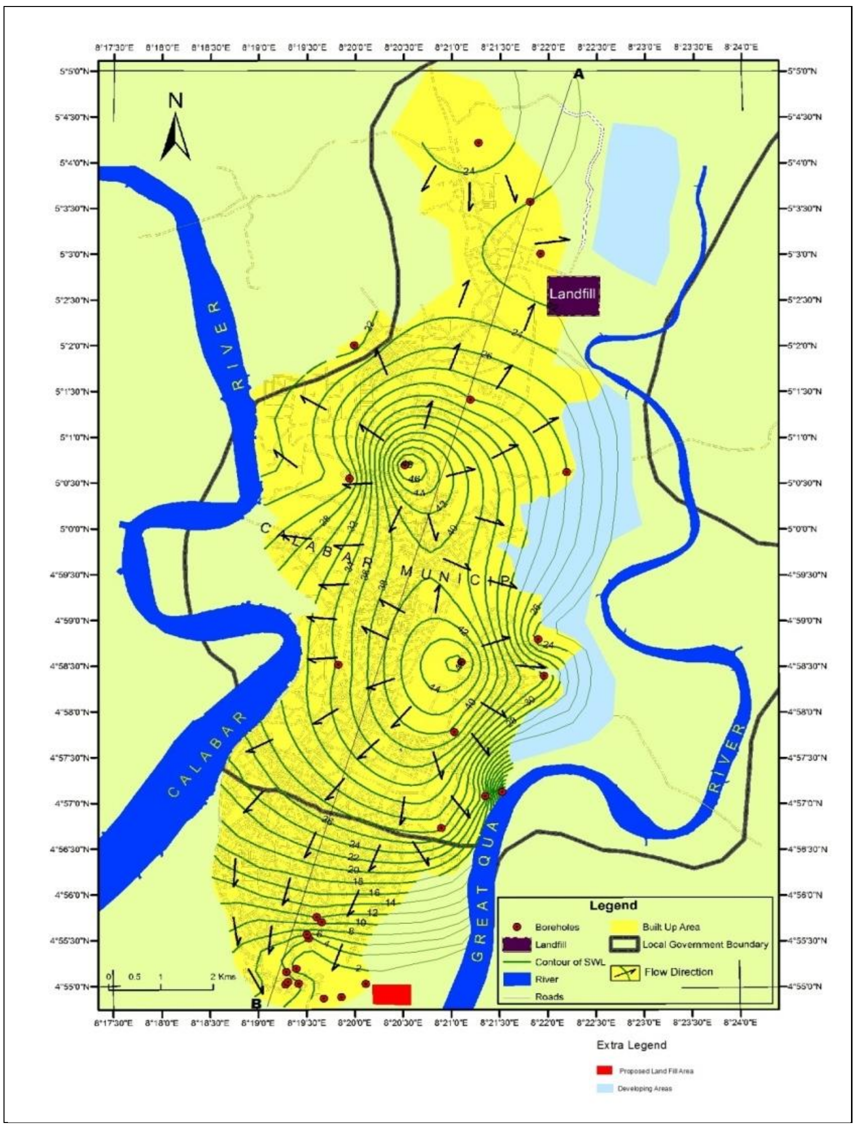

Fig. 2. Groundwater flow directions in Calabar metropolis

Table 1. Static water level, borehole depth and geographic locations

S/N	Location	WGS 1984 UTM Zone 32 N		BH depth	SWL
		Easting	Northing	(m)	(m)
1	Idim Ita	426294.3083	543537.3209	28.73	0.29
2	Uyi Effiong	425830.5783	543268.0518	18.56	0.4
3	Ebuka- Ebuka	425490.1642	543244.073	25.45	0.28
4	Ikoneto Community	424964.1099	543844.8681	26.47	0.48
5	Esuk Atu (Chief Okon Etim House	428589.7597	547317.9332	50.2	23.58
6	Esuk Atu (Satellite town)	428913.5816	547403.845	50.19	1.15
7	Esuk Atu (Behind ACB Junction)	426075.5804	556393.5171	36.3	21.33
8	Govt. Primary sch. Nkonib Layout	425988.5671	553708.9545	51.3	24.58
9	Anantigha	425009.2667	543546.3488	22.9	5
10	Ikot Ansa	427048.5325	553980.147	62.41	49.6
11	Diamond Hill (Wapi)	425771.649	549967.9938	55.91	34.13
12	Edim Otop (Margaret Ekpo Sec Sch)	427993.6141	548610.4692	57.87	39.7
13	Nasarawa (Govt. Day Sec. Sch.)	428458.8442	560471.2582	35	25.2
14	9 Utibe (Off New Airport Rd)	425203.2316	544454.717	70	3
15	Female hostel Unical	427746.2736	546675.3817	73.15	28.7
16	Federal Govt. College	428129.4763	550016.8067	115	47.05
17	10 Efio-Anwan Street	425357.6577	544884.4618	25.2	12.5
18	18 Spatt Avenue	425449.9472	544779.9642	27	10.7
19	14 Usoro Street	425166.3511	544531.5223	12.9	6.7
20	18 Anantigha Street	424758.7883	543524.7386	14	4.9
21	15 Anantigha Lane	424771.3666	543779.5958	13.5	4.3
22	2 Okon Edet Street	424805.0396	543576.894	14.6	4.6

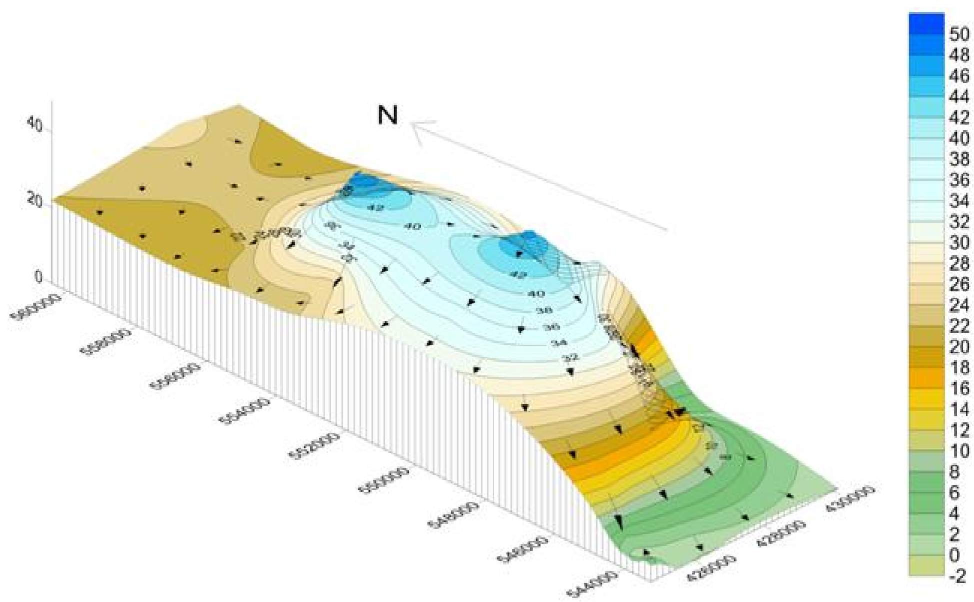

Fig. 3. 3-D Groundwater flow model of Calabar Metropolis (in metres)

Calabar is hemmed in by two rivers that run parallel to each other – Calabar River and Great Qua River (see Fig. 2). There are also two cliffs or points of high elevation from which groundwater flows downwards in all directions. In other words, the direction of flow is such that water at higher elevation (high pressure gradient) flows to lower elevation (low pressure gradient). This is in agreement with Henry Darcy's law on groundwater flow, where he postulated that groundwater moves from higher elevation to lower elevation and from locations of higher pressure to lower pressure. He further said that groundwater movement is always in downward direction of the hydraulic gradient. Because the flow is in all directions, some of the water flows into the Calabar River and Qua River, while some run through the city southwards [18].

Water being a universal solvent dissolves materials or substances (toxic and non-toxic) which infiltrate into the ground and are transported in the direction of the flow. Calabar is a coastal region with mainly sedimentary bedrock with permeability that allows for easy percolation and flow of water and other dissolved materials (toxic and non-toxic). Thus, the possibility of water table contamination with dissolved toxic substances is high. This finding is supported by literature which reveals that groundwater contamination arising from landfill sites are usually in the direction of groundwater flow [19].

From Fig. 2, it could be seen that the present dumpsite at Lemna Road could be considered a good location for Calabar metropolis as at the time it was established. This is because it is located between two cliffs or higher elevations. At the time it was established years ago, that area was not inhabited by people and there were no infrastructures like tarred roads and electricity. But today, the construction of a dual carriage way beside the dumpsite and provision of electricity in the area has attracted a lot of development to the area. Presently, there are a lot of residential houses, a petrol station and other structures around the dumpsite which makes the site no longer suitable.

The dumpsite through the process of percolation and infiltration contaminates the groundwater in that area. It has been argued that water dissolves biodegradable materials in the wastes, which then contaminates groundwater through infiltration and recharge process [20]. They also affirmed that dumping of wastes close to recharge zones or on recharge zones leaks through and contaminates the aquifer.

The dumpsite poses a great threat as it is a major cause of environmental degradation, groundwater contamination and public health concerns in many developing countries including Nigeria. Study has shown that who landfills contain mixture of general, toxic, infectious or radioactive waste which degrade the environment and contaminate groundwater and can cause serious harm to scavengers [21].

The implication of the dumpsite on groundwater hydrology is that leachates from dumpsite infiltrate into the ground and also move in the direction of groundwater flow thereby contaminating the groundwater along its path. This movement is from the north (higher pressure gradient) down south (lower pressure gradient). This is affirmed by Henry Darcy who postulated that groundwater moves from higher elevations or higher pressure gradient to lower elevations or lower pressure gradient. Thus, movement of sediments and water also follow this pattern. In addition, it has been affirmed that landfill/dumpsite is a major source of groundwater pollution as the migration of these leachates follow the flow of groundwater hydrology [22]. For this reason, waste must be kept off from the direction of flow of groundwater.

The profile in Fig. 4 displays static water level across the study area. The point labeled ‘A’ is the northern part of the city while ‘B’ is the southern part of the city. The present dumpsite is located at the depression at point ‘A’ and is between two cliffs. The new suggested dumpsite is located at point ‘B’.

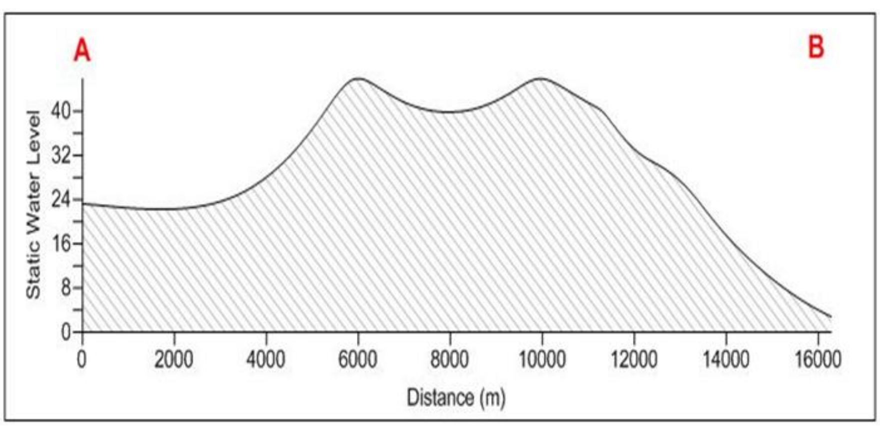

Fig. 4. Profile of static water level (in metres) across Calabar Metropolis

4. CONCLUSION

This study has examined the present location of the dumpsite in Calabar metropolis and its implication on the groundwater hydrology of the city. The result of the study shows that the present dumpsite in Calabar could be considered suitable as at the time it was established, but owing to the present development taking place there resulting in growing population around the area, it is no longer suitable. Residents in the area also sink boreholes. The percolation of dissolved substances from the dumpsite affects the groundwater quality of the area. Where toxic substances are dissolved, it contaminates the groundwater and renders it unsuitable for human consumption.

Arising from the above, an alternative site for a new dumpsite is suggested. The suggested new site is at the southern part of the City with coordinates 426679.186E and 554807.648N (Calabar South), a location that will not impact much on human life as there is no human habitation in the immediate vicinity and the chances of residential houses springing up there are very slim because of the swampy nature of the area. Moreover, the groundwater at this suggested location flows away from the city.

ETHICAL APPROVAL

It is not applicable

COMPETING INTERESTS

We declare that there are no competing interests.

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Peer-review history:
The peer review history for this paper can be accessed here:
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