NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Evaluating Groundwater Contamination in the Vicinity of a Cemetery for Environmental Concerns

***Esther E. Ambrose-Agabi*[*1], *Chritopher O. Izinyon*[*2], *Augustine I. Agbonaye*[*3]**

[*1,2,3] Department of Civil Engineering, Faculty of Engineering, University of Benin, Benin City, Nigeria.

Article Info

Keywords: *Cemetery, Contaminants, Groundwater analysis, Groundwater Quality water quality, Groundwater pollution, analytical techniques*

Received 4 March 2024
Revised 17 May 2024
Accepted 22 May 2024
Available online 26 June 2024

https://doi.org/10.5281/zenodo.12562271

Abstract

Groundwater pollution near cemeteries poses risks to the environment and public health. This study investigated groundwater quality around the Third Cemetery in Benin City, Nigeria, using analytical techniques like a PQWT water detector. Groundwater samples from boreholes near the cemetery were analyzed for physico-chemical and bacteriological parameters. Water Quality Index (WQI) modeling assessed drinking water suitability. Geophysical surveys with a PQWT-TC 300 detector identified subsurface anomalies indicative of potential contaminants. Results revealed elevated levels of contaminants like bicarbonate, magnesium, manganese, ammonium, iron, lead, and chromium exceeding recommended limits. Spatial correlations showed higher contamination levels in boreholes closer to the cemetery, suggesting cemetery-related activities as contributing factors. Lead, chromium, and ammonium were consistently present across distances. The WQI categorized the water as "Very Poor" and "Unsuitable for Drinking," indicating health risks. The study highlights the need for action to preserve the environment, promote public health, and improve access to clean water in areas near cemeteries.

1. Introduction

Water is one of the most important natural resources in the world. Its importance can be evaluated with reference to plants, animals, and humans since none of these can exist without the supply of water for their day-to-day activities. Therefore, there should be a safe, adequate, and accessible water supply for all as water is the key to prosperity and wealth [1-2]. Water occurring beneath the surface of the ground in saturated geologic materials e.g., soil, sediment, and rock is called groundwater. When saturated, geologic materials which can produce or transmit usable quantities of water are called aquifers. Water in the aquifer is not stationary but moves or flows underground according to forces acting on the groundwater [3]. Groundwater is part of the hydrologic cycle therefore, contaminants in the other parts of the cycle such as atmosphere or surface water bodies can be transferred to groundwater thereby affecting the groundwater [4-5]. When analyzing groundwater systems, considerations must be given to the effects of groundwater withdrawals on water levels in nearby wells, and the flow of contaminants towards wells as groundwater can travel distances underground and with it any contaminant. The Environmental Protection Agency (EPA) states that water quality is affected by the thickness of various layers and physical make-up of those layers regarding permeability and percolation rates, the depth of the water table, location and type of sand and gravel that may exist in the profile, how thick the saturated material is and the presence of restrictive or limiting layers or rock or clay that may change the vertical penetration and flow of contaminants [6]. Water contamination does not only affect water quality but also threatens human health, economic development, and social prosperity [7]. Human death and burial practices are inherent aspects of society, yet they pose a significant risk to groundwater quality and particularly where cemeteries are in centers of human habitation and around them, water supply wells are located. The fluids from cemeteries may contain hazardous substances, such as pathogens, microbes and nitrogen compounds. However, the World Health Organization (WHO) and US Environmental Protection Agency (EPA) classifies these compounds as hazardous waste as well as other chemicals. World Health Organization, (1998) has thus concluded that cemeteries may cause serious impacts on the environment and public health [8-9]. Hence, poses challenges to groundwater quality due to burial activities. Studies in Mbaiorbo, and Maiduguri, Nigeria, reveal significant groundwater contamination near cemeteries. The high concentrations of heavy metals and organic pollutants highlight the environmental risks associated with burial practices, urging attention to mitigate potential hazards. [10-11-12-]. Using the DRASTIC index and GIS tools for assessment in Portugal revealed aquifer vulnerability near cemeteries, emphasizing the need for protective measures [13]. Also, elevated physicochemical and microbial contaminants in groundwater near cemeteries were revealed in Tabriz Vadi-e Rahmat, Iran, necessitating proactive management [14]. The assessment on groundwater quality carried out along cemeteries and associated potential health concerns in Dar es Salaam, Tanzania where 23 boreholes in five wards were sampled for the study revealed elevated nutrient levels and mineral concentrations in the water [15-16]. Casket manufacturers are classified by the Environmental Protection Agency (EPA) as generators of hazardous waste arising from the chemicals such as varnishes, sealers, preservatives, and metal components employed in casket production. These substances contain minerals capable of contributing to groundwater contamination. The soil profile in Benin City where the third cemetery is located predominantly consists of reddish-brown sandy laterite, interspersed with layers of porous sands and sandy clays reaching significant depths [17], there is a concern regarding the potential for contaminant transport from the cemetery to the surrounding area creating danger for public water supply.

The sources of groundwater contaminants are commonly believed to be from agriculture, industries, domestic waste, and landfills with little or no attention given to cemeteries as possible sources of pollution. Cemeteries as sources of groundwater contaminants has been investigated in several regions of the world mainly Brazil, Australia, the Republic of South Africa, Portugal, the United Kingdom and Poland [18-19], but little or no attention is focused on it in this part of the world.

2.0. Methodology

2.1. Description of the Study Area

The cemetery under investigation is the third cemetery in Benin City, Edo State, Nigeria. It is the largest of the three cemeteries in Benin City which covers a land area of about 5.167 ha [20]. The burial load with respect to the number of people buried weekly is 18 to 42 bodies of varying sizes [21]. It is geographically defined by latitude 6° 11' and 6° 29' North and longitude 5° 33' and 5° 47' East. The area is categorized by dry and wet seasons.

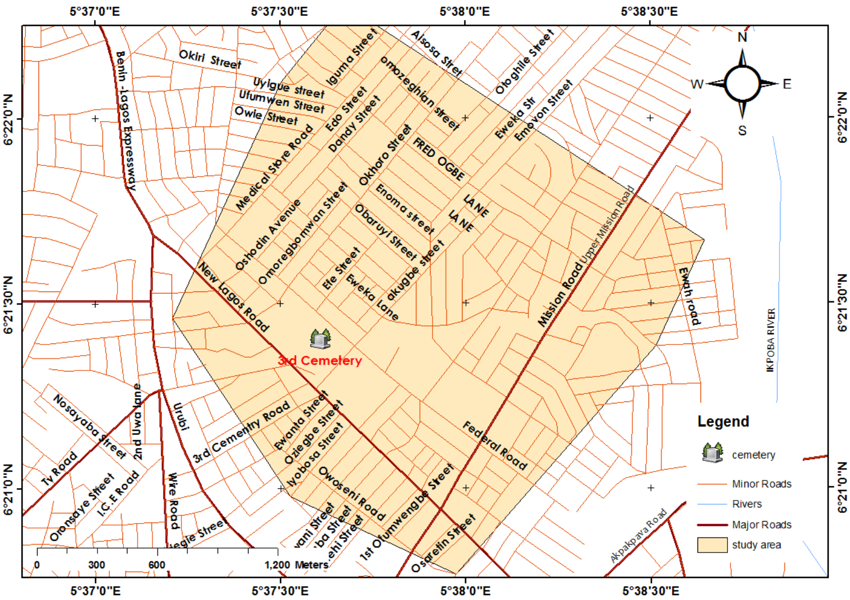

Figure 1. Location Map of third Cemetery in Benin City

2.2. Samples collection and analysis

Water samples were collected from twenty-one (21) existing boreholes located around the cemetery. Boreholes were selected based on their proximity to the cemetery, indicating a focus on understanding the groundwater quality near the cemetery and accessibility, ensuring that boreholes were reachable for sampling. A systematic method was employed to select boreholes at different distances from the cemetery to have an overview of the groundwater quality across varying proximities. The selection of boreholes was determined by the need to assess the risk associated with groundwater quality, concerning potential contamination from cemetery activities. The water samples were collected after the discharge pipes were flushed, and the sample bottles were rinsed about 2 to 3 times with the borehole water to be sampled. The collected samples were labeled properly and then placed inside a cooled ice box. The ice box was transported to the laboratory following the recommended guidelines by WHO for water quality analysis. The physico-chemical and bacteriological parameters of the water sample were determined for risk assessment of the boreholes.

A hand-held Garmin Global Positioning System (GPS) 72 receiver was used to determine the geographical locations. This involved physically visiting each borehole location and using the GPS device to capture and record the geographical locations of boreholes. The coordinates obtained were then recorded alongside other relevant information such as the codes and, distance from the cemetery for each borehole as presented in Table 1.

Table 1. particulars of the boreholes used for water sample collection

Sample Code	Distance from Cemetery (m)	Geographical Location	
		Latitude	Longitude
B_1	735	6.35695	5.62751
B_2	632	6.35624	5.62692
B_3	335	6.35833	5.6262
B_{4a}	480	6.35395	5.62459
B_{4b}	489	6.35273	5.6236
B_5	230	6.35463	5.6484
B_6	359	6.35494	5.6308
B_7	944	6.35408	5.63121
B_8	1250	6.35707	5.63137
B_9	1210	6.35765	5.63097
B_{10}	1033	6.35818	5.62887
B_{11}	840	6.35572	5.63888
B_{12}	559	6.35323	5.62883
B_{13}	1241	6.35248	5.62943
B_{14}	383	6.35196	5.62989
B_{16}	202	6.35458	5.62999
B_{17}	510	6.35737	5.62708
B_{18}	455	6.35825	5.62638
B_{19}	844	6.36116	5.62283
B_{20}	665	6.36237	5.62226
B_{21}	625	6.37194	5.6288

2.3 Determination of Water Quality Parameters

Following the standard method for water analysis, we investigated a total of 31 physico-chemical and 4 microbiological water quality parameters for each sample we collected. The selection of the water quality parameters was selected based on its significance in evaluating water quality and potential health risks. We immediately analyzed parameters such as NH4, Alkalinity, COD, and NO3 upon arrival at the laboratory as these have a permissible storage time of 24 hours as recommended by the WHO in 2003. The remaining samples were stored in the laboratory refrigerator at about 4°C until analyzed for other parameters within two weeks. The determination of water quality parameters for the collected samples was conducted using the established standard methods by the American Public Health Association (APHA), [22]. We conducted field determination of certain water quality parameters through in-situ measurements of pH, electrical conductivity (EC), total dissolved solids (TDS), and temperature

2.4 Geophysical Survey of the Study Area

A geophysical survey was carried out in the study area to investigate the subsurface structure. The survey employed a geophysical prospecting instrument known as the PQWT-TC 300 groundwater detector, which was used to determine the electrical resistivity of the subsurface, minerals of the groundwater, and contaminant zone in the study area. Before the survey, a measuring reference station was selected, and its geographic East-West and north-south direction was determined with the aid of a compass. The survey profiles were then tagged and orientated in that direction. To ensure the proper working condition of the entire circuit of the instrument, a line test was conducted, which involved looping the M and N electrodes before the measurements. For each profile, electrodes were placed at predetermined measuring stations, starting from zero, for reconnaissance to check for activity occurring in the subsurface at 1-meter intervals. After one hundred frequencies, a complete reconnaissance was achieved at each point, and measurements were carried out immediately for each of the profiles. The data obtained were stored in the machine and later extracted into a computer for further analysis. To explore the subsurface up to a depth of 300m, the profile survey was selected in the instrument, and the measurement interface was set at a depth of 300m for the exploration, with a measurement line number of 001. A 10m electrode bar equidistance for the M and N was used for the measurement. The M electrode was inserted near the host into the tape position of zero meters, while the N electrode was placed into the tape position of 10m. Each measurement point was positioned in the middle of the two electrodes; hence the first measurement point was in the position of 5m, and the distance between point to point (1 meter/5 meters) was maintained. A Schematic Profile Map of the Study Area was created, as presented in Figure 2, to provide a graphical representation of the subsurface structure in the study area.

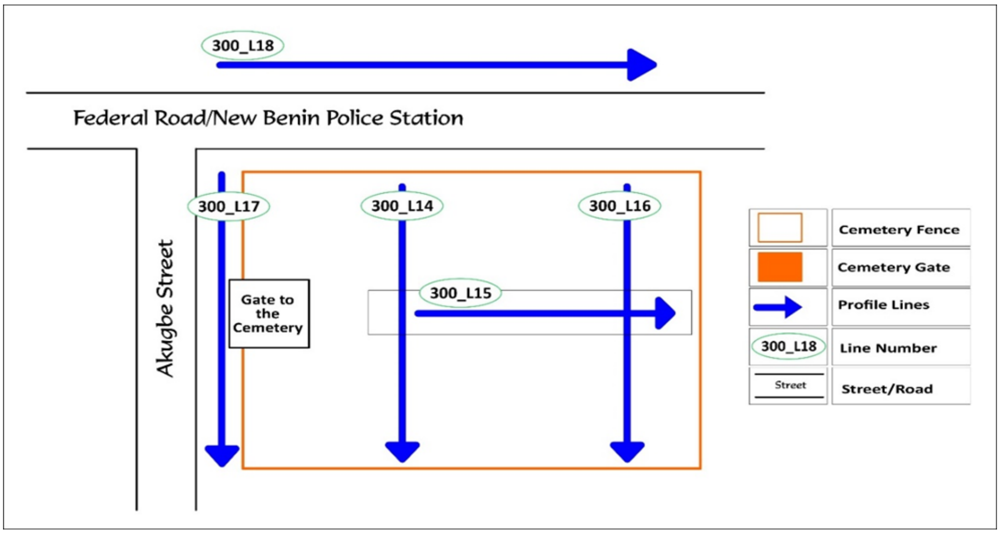

Figure 2. A Schematic Profile Map of the Study Area

3.0. Results and Discussion

The study employed a water quality analysis to determine the physico-chemical parameters of borehole water samples collected around the study area. The water quality index was used to assess the overall quality of water sources based on various parameters obtained from water quality analysis. Additionally, a geophysical survey was carried out to detect and locate subsurface contaminants such as heavy metals, hydrocarbons, and other pollutants, to identify areas of high contamination.

3.1 Ground Water Quality Analysis

The water quality analysis examined 29 physico-chemical parameters, including odor, color, and various elements. The obtained water quality parameters were then subjected to statistical analysis, and the results are presented in Table 2. The analysis of water samples is necessary for ensuring the safety of drinking water and preventing the occurrence of waterborne diseases. Therefore, this study provides valuable insights into the quality of groundwater in the study area and can inform strategies for maintaining and improving water quality standards.

Table 2. Descriptive Statistics of the Water quality Physico-Chemical Parameter

Parameter(mg/l)	Minimum	Maximum	Mean	Std. Deviation
Ph	4	5.2	4.6571	0.35153
EC	23	465	183.1429	125.87068
Sal	0.01	0.21	0.0818	0.05388
TDS	11	233	105.0952	66.82956
COD	12	33.6	18.7857	5.28008
HCO3	18.3	170.8	75.5286	31.2835
Na	0.07	0.65	0.2957	0.19067
K	0.03	7	0.4305	1.50627
Ca	0.58	3.81	1.7704	0.94578
Mg	0.33	2.1	1.0548	0.57015
CL	35.2	142.2	61.9429	29.71332
P	0.01	0.09	0.0385	0.02189
NH4	0.14	0.84	0.5057	0.18261
NO2	0	0.11	0.031	0.02614
NO3	0.4	2.75	1.619	0.78698
SO4	0.02	0.21	0.0718	0.05811
Fe	0.05	0.87	0.404	0.23355
Mn	0.03	0.3	0.1531	0.07592
Zn	0.04	0.77	0.244	0.16279
Cu	0.01	0.11	0.0453	0.02544
Cr	0.01	0.09	0.0394	0.02273
Cd	0	0.04	0.0129	0.0101
Ni	0	0.08	0.0165	0.0223
Pb	0.01	0.05	0.0224	0.0143
V	0	0.01	0.0046	0.00364

The study evaluated the quality of water in the sampled boreholes by comparing the recommended standard guidelines established by various organizations such as the Nigeria Standard for Drinking Water Quality (NSDWQ, 2007), the World Health Organization (WHO, 2011), and the European Union (EU, 2014). The aim was to determine the parameters that exceeded the recommended values of the water quality so that any potential source of pollution or contamination could be identified and the quality and safety of water could be ensured. The findings of the study revealed that while some physico-chemical parameters in the sampled boreholes were within the recommended standards for drinking water, others such as pH, Bicarbonate, Magnesium, Ammonium, Iron, Manganese, Chromium, Cadmium, Nickel, Lead Pb, and Vanadium did not meet the recommended standards for human consumption. This suggests potential health risks associated with the consumption of such water.

3.2 Water Quality Index Analysis(WQI)

Table 3 presents the water quality index for each water sample, determined using the average weighted index method. This statistical approach combines multiple water quality parameters into a single index value to evaluate water quality variation at specific locations around the cemetery. Each water quality parameter was assigned a weight based on its importance in determining overall water quality. The value of each parameter was multiplied by its assigned weight. These weighted values were then summed up and the sum of the weighted values was divided by the sum of the weights to obtain the overall WQI for each water sample.

Table 3: Computed overall water quality index Analysis for each sampled borehole

S/No	Water Samples	Computed W Q I	Overall Status
1	Sample 1	134.82	Unsuitable for drinking
2	Sample 2	533.59	Unsuitable for drinking
3	Sample 3	337.99	Unsuitable for drinking
4	Sample 4	83.33	Very Poor
5	Sample 5	108.32	Unsuitable for drinking
6	Sample 6	746.46	Unsuitable for drinking
7	Sample 7	1042.46	Unsuitable for drinking
8	Sample 8	190.52	Unsuitable for drinking
9	Sample 9	79.43	Very Poor
10	Sample 10	693.74	Unsuitable for drinking
11	Sample 11	181.91	Unsuitable for drinking
12	Sample 12	387.65	Unsuitable for drinking
13	Sample 13	287.82	Unsuitable for drinking
14	Sample 14	236.11	Unsuitable for drinking
15	Sample 15	158.15	Unsuitable for drinking
16	Sample 16	340.32	Unsuitable for drinking
17	Sample 17	768.74	Unsuitable for drinking
18	Sample 18	2144.33	Unsuitable for drinking
19	Sample 19	155.23	Unsuitable for drinking
20	Sample 20	369.99	Unsuitable for drinking

The computed overall water quality index for each sampled borehole was assessed, and the results showed that water samples 4 and 9 had WQI values of 83.33 and 79.43, respectively. These values fall within the range of 76 – 100, categorized as "very poor". This indicates that these water sources exhibit various issues related to water quality parameters, which may make the water unsuitable for direct human consumption. Furthermore, all other samples in the dataset yielded WQI values exceeding 100, classifying them as "unsuitable for drinking". These findings raise significant concerns regarding the safety of these water sources for human utilization. Hence, it is recommended that appropriate measures be taken to ensure the quality of these water sources is improved to meet the necessary standards for safe human consumption.

3.3 Geospatial Analysis of Water Samples

The physico-chemical analysis of water samples collected from various boreholes reveals that certain parameters exceed the recommended standard values. It appears that boreholes located closer to the cemetery exhibit higher concentrations of contaminants compared to those situated farther away. Correspondingly, there is a spatial correlation between the distance of the boreholes from the cemetery and the presence of contaminants, suggesting a trend in the patterns of contamination. Borehole B4, situated 480 meters away from the cemetery, contained HCO3. The widespread presence of manganese (Mn) and magnesium (Mg) in all the sampled boreholes suggests that they may originate from natural sources or broad-scale environmental factors. Nitrogen in the form of ammonium (NH4) was detected in boreholes B1 and B4, located at distances of 735 meters and 480 meters, respectively, from the cemetery, indicating a potential influence of cemetery-related activities on water quality in these areas. Iron (Fe) was found in several boreholes at varying distances from the cemetery, ranging from 335 meters to 1250 meters, indicating a widespread contamination pattern, possibly influenced by factors beyond cemetery activities, such as geological characteristics or land use practices. Lead (Pb) was detected in boreholes B1, B2, B6, and B7 at distances of 735 meters, 632 meters, 359 meters, and 944 meters, respectively, from the cemetery, suggesting a potential association with cemetery-related contamination. Chromium (Cr) was detected in boreholes B1, B6, and B7 at distances of 735 meters, 359 meters, and 944 meters, respectively, from the cemetery, indicating a potential spread of contamination over a considerable distance from the cemetery. Based on our assessment, we suggest a correlation between the proximity of the boreholes to the cemetery and the presence of certain contaminants. Furthermore, the consistent presence of Mn and Mg in all boreholes sampled suggests a widespread distribution of these contaminants. The results of this study indicate the need for further investigation to identify the specific sources of contamination and to develop appropriate mitigation strategies

3.4 Geophysical Investigation

Using the PQWT instrument to evaluate groundwater contaminant zones and subsurface features in the cemetery, the findings indicated that low-frequency electromagnetic measurements were more sensitive to grain shape, which makes it easier for contaminants to penetrate the subsurface. Additionally, low frequencies showed less conductive subsurface materials, whereas higher frequencies indicated conductive materials at greater depths. The subsurface area of the study consisted of lateritic soil, sandy silt, and clayey sand, with an unconsolidated sandy aquifer being the predominant material. The sandy formation was highly permeable and porous. Figure 3 below presents the level of contaminants

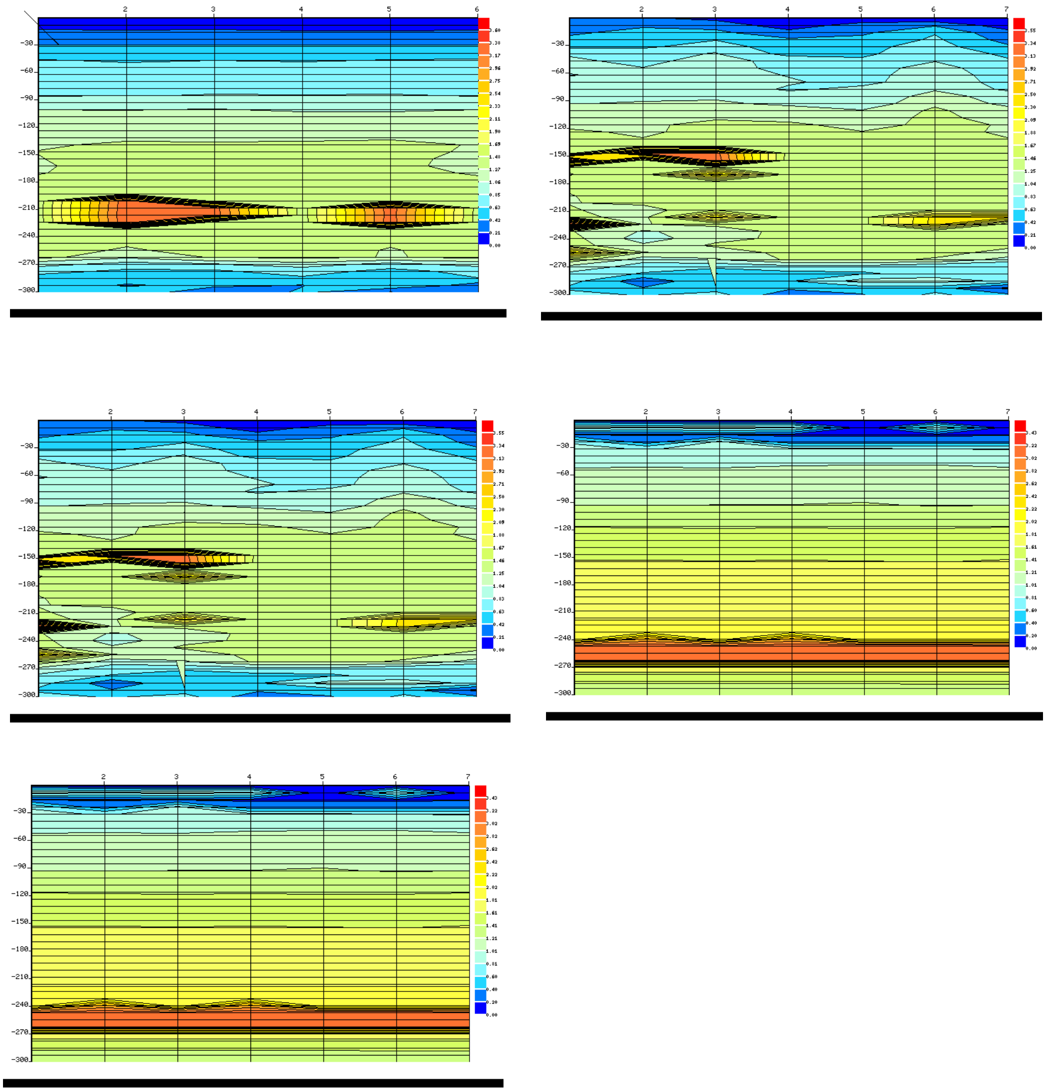

Figure 3 profile map of the subsurface of the study area

Figure 3 shows the profile map of the subsurface section of the study area and reveals a significant concentration of contamination that is filtering horizontally to a depth of 100 meters. The maximum concentration is found within a depth range of 0 to 20 meters. The section comprises a layer of lateritic soil, which is underlain by thin horizons of sandy silt and clayey sand. The sandy formation exhibits high porosity and permeability, facilitating the rapid flow of leachate. The diagram shows leachate plumes emanating from the laterite layer downwards to the sandy formation, indicating that the leachate plume exists in the subsurface soil at a range of 0 to 30 meters deep. The laterite/clay layer at a depth of 30 meters is insufficiently thick to impede the further downward migration of the leachate plume, resulting in its filtration to a depth of 50 meters. The contaminant is highly concentrated at depths of 0 to 20 meters, denoted by a deep blue coloration. In the event of the shallow aquifer being polluted, there is a high likelihood that the nearby deep-confined, coarse sand aquifer at a depth of 90 meters is at risk, especially if the protection capacity of the underlying clay is unsatisfactory. The boreholes drilled around the study area are less than 70 meters deep, indicating that the cemetery could be a possible source of groundwater contamination in the study area.

4.0 Conclusion

Cemeteries have been found to have a significant impact on the environment, and their potential to increase certain physico-chemical parameters in groundwater is a matter of growing concern. To assess the level of pollution and evaluate how cemeteries affect groundwater quality, a comprehensive study was conducted. The study aimed to determine the impact of cemeteries on groundwater quality by analyzing physico-chemical parameters, including pH, Bicarbonate, Magnesium, Ammonium, Iron, Manganese, Chromium, Cadmium, Nickel, and Lead Pb, across multiple boreholes located near the cemetery. The results of the study indicate that boreholes closer to the cemetery have higher concentrations of contaminants, which suggests that cemetery-related activities are contributing to the decline in water quality. The higher concentrations of Ammonium, Chromium, Cadmium, Nickel, and Lead Pb in boreholes located closer to the cemetery underlined the need for enhanced protective measures to mitigate the potential threat that cemeteries pose as a source of groundwater contamination. The study also identified subsurface anomalies, which indicate that contaminants may be seeping into the groundwater and causing long-term harm to the environment. The identification of these anomalies emphasizes the need for better management practices to reduce the impact of cemeteries on the environment. In conclusion, the study highlights the need to take proactive steps to address the environmental risks associated with cemeteries. It is essential to develop and implement better management practices to reduce the impact of cemetery-related activities on groundwater quality. The findings of the study can be used to inform policies and practices aimed at safeguarding the environment for future generations.

References

[1] Chakraborty, S.K., 2021. Water: Its properties, distribution, and significance. Riverine Ecology Volume 1: Eco-functionality of the Physical Environment of Rivers, pp.23-55.

[2] Methods for Mapping Groundwater Contamination Saround Aule Area, Akure, Southwestern Nigeria". International Journal of Water Resources and Environmental Engineering Vol. 5(7), pp. 442-451

[3] Emmanuel, O.O., 2022. Assessment of Groundwater Pollution from Leakages of Underground Storage Tanks of Filling Stations in Ilorin Metropolis, Nigeria (Doctoral dissertation, Kwara State University (Nigeria)).

[4] Methods for Mapping Groundwater Contamination Saround Aule Area, Akure, Southwestern Nigeria". International Journal of Water Resources and Environmental Engineering Vol. 5(7), pp. 442-451.

[5] Aderemi A.O, Oriaku A. V, Adewumi G.A, and Otitoloju A.A. (2011): "Assessment of groundwater contamination by leachate near a municipal solid waste landfill" African Journal of Environmental Science and Technology Vol. 5(11), pp. 933-940.

[6] Oyelami, C.A., Kolawole, T.O. and Ojo, G.S. (2021), Assessment of Vadose Zone Characteristics for Environmental Impact Audit of Selected Cemeteries Around Osun State, South-Western Nigeria. Journal of Mining and Geology Vol. 57(1) 2021. pp. 113 – 126.

[7] Mahammad, S., Islam, A. and Shit, P.K., 2023. Geospatial assessment of groundwater quality using entropy-based irrigation water quality index and heavy metal pollution indices. Environmental Science and Pollution Research, 30(55), pp.116498-116521.

[8] Neckel, A., Toscan, P.C., Kujawa, H.A., Bodah, B.W., Korcelski, C., Maculan, L.S., de Almeida Silva, C.C.O., Junior, A.C.G., Snak, A., Moro, L.D. and Silva, L.F., 2023. Hazardous elements in urban cemeteries and possible architectural design solutions for a more sustainable environment. Environmental Science and Pollution Research, 30(17), pp.50675-50689.

[9] A.G. Fineza, E.A.G. Marques, R.K.X. Bastos, L.S. Betim. (2015), Impacts on the Groundwater Quality Within a Cemetery Area in Southeast Brazil. https://www.researchgate.net/publication/271072503 A.G. Fineza, E.A.G. Marques, R.K.X. Bastos, L.S. Betim. (2015), Impacts on the Groundwater Quality Within a Cemetery Area in Southeast Brazil. https://www.researchgate.net/publication/271072503

[10] Itodo, A.U., Eneji, I.S., Agbendeh, Z.M. and Kormi, A.A., 2021. Estimation of Embalming Contaminants in Soil and Groundwater Samples from Cemetery Leachates in Mbaiorbo, Mbadim-Mbatiav Leachfield In Gboko, Nigeria. Journal of Chemical Society of Nigeria, 46(3).

[11] Turajo, K.A., Abubakar, B.S.U.I., Dammo, M.N. and Sangodoyin, A.Y., 2019. Burial practice and its effect on groundwater pollution in Maiduguri, Nigeria. Environmental Science and Pollution Research, 26, pp.23372-23385.
[12] Afangideh, C.B. and Udokpoh, U.U., 2022. Environmental impact assessment of groundwater pollution within cemetery surroundings. Indian Journal of Engineering, 19(51), pp.100-115.
[13] Gonçalves, V., Albuquerque, A., Carvalho, P., Almeida, P. and Cavaleiro, V., 2023. Groundwater vulnerability assessment to cemeteries pollution through GIS-Based DRASTIC index. Water, 15(4), p.812.
[14] Vaezihir, A. and Mohammadi, S., 2016. Groundwater contamination sourced from the main cemetery of Tabriz, Iran. Environmental forensics, 17(2), pp.172-182.
[15] Leopord Sibomana Leonard. (2022), Assessment of groundwater quality along cemeteries and associated potential health concerns in Dar es Salaam, Tanzania. Water Practice & Technology Vol 17 No 5, 1218 doi: 10.2166/wpt.2022.041.
[16] Cornelia Jonker and Jana Olivier. (2012), Mineral Contamination from Cemetery Soils: Case Study of Zandfontein Cemetery, South Africa. International Journal of Environmental Research and Public Health ISSN 1660-4601.
[17] Ikhide, J.I., Sulaiman, A.N. and Atta, H.I., 2023. A Microcosm-Based Study on the Biodegradation of Nigerian Crude Oil by Bacillus subtilis Isolated from a Hydrocarbon-Impacted Soil. J Petro Chem Eng, 1(1), pp.6-9.
[18] Józef Z˙ ychowski and Tomasz Bryndal. (2015), Impact of cemeteries on groundwater contamination by bacteria and viruses – a review. Journal of Water and Health.
[19] Joseph T. Zume. (2011), Assessing the potential risks of burial practices on groundwater quality in rural north-central Nigeria. Journal of Water and Health.
[20] Ibhadode, O., Bello, T., Asuquo, A.E., Idris, F.W., Okougha, F.A., Umanah, I.I., Ugonna, M.C. and Nwaigwe, D.N., 2017. Comparative-study of Compressive-strengths and densities of concrete produced with different brands of ordinary portland cement in Nigeria. International Journal of Scientific & Engineering Research, 8(9), pp.1260-1275.
[21] Idehen and Ezenwa. (2019): "Influence of Third Cemetery Location on the Quality of Domestic and Groundwater Resources in Benin City, Nigeria". Journal of Applied Sciences and Environmental Management. Vol. 23 (1) 05–11
[22] El-Khayat, H.M., Gaber, H.S. and Flefel, H.E., 2022. Experimental studies on the toxicity of certain heavy metals and persistent organic pollutants on the Nile tilapia health. Egyptian Journal of Aquatic Biology & Fisheries, 26(3).