

Subsurface Mapping of Groundwater Contamination Pathway at Using Very Low Frequency Electromagnetic Method at Waste Site of Kubanni Basin, Zaria, Kaduna State

M. Umar^{*1}, Z. Ahmed², B. Balarabe¹, M. Sa'adu¹ and M. W. Abdullahi¹

¹Department of Physics Ahmadu University, Zaria

²Department of Physics Federal College of Education Zaria

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ABSTRACT

Groundwater contamination result from solid waste and leachate produced on daily basic by human activities. The increase in population led to indiscriminate disposal and mismanagement of this waste in most of the society. Geophysical survey is carried out in order to reveal the presence of subsurface structure that enhance hydraulic contact between the leachate and the groundwater. Very low frequency electromagnetic method (VLF-EM) was used to map the pathway for groundwater contamination at waste site of kubanni. Three profiles of VLF-EM reading were taken at 5m intervals along the profile. The aim is to investigate the structural zones or permeable zones that may serve as groundwater contamination pathway. The Microsoft excel and Fraser and Karous-Hjelt filtering software were used to interpret the result. The crossover point were observe at 85m, 95m, 110m and 135m which indicate good conductive ground which is an indication of contaminant plume zones. The point of maximal negative in both the in-phase and out-phase are 170m and 165m, revealing substantial fracture in the form of a dyke. This fracture can serve as the pathway for the contaminant to seep into the groundwater. The contaminated plume zones will move through the fractures in the subsurface to contaminate the underground water.

Keywords: Contamination, Leachate, Groundwater, Vulnerability and Fraser

Introduction

Groundwater in most areas is becoming increasingly scarce due to increased demand and declining quality caused by pollution (Nwosu and Nwosu, 2016). Groundwater is contaminated as a result of solid waste produced on daily basis by inevitable human activities. The intensity of human activity has led to increasing volume of waste disposal worldwide (Ganiyu *et al.*, 2015). The increase in population also has led to indiscriminate disposal and mismanagement of

solid waste in most of the society (Samuel *et al.*, 2022).

Solid waste landfills constitute integral part of the soil hydrological system (Rosqvist *et al.*, 2003), therefore this pose a serious threat of polluting both groundwater and downstream surface water. Solid waste decomposed over a period of time and generate leachate with decomposing products which are hazardous pollutants that seep into the underground aquifers and thus polluting the groundwater.

Corresponding Author: M. Umar

Department of Physics Ahmadu University, Zaria
umardk06@yahoo.com; +2348036865363



As such, a lot of geophysical studies were done to investigate the migration and vulnerability of the groundwater contamination by numerous authors using geophysical and geochemical method (Pantelis *et al.*, 2007; Wilkinson *et al.*, 2009; Abdullahi *et al.*, 2011; Utom *et al.*, 2012; Muhammed *et al.*, 2013; Iyola *et al.*, 2013; Elijah *et al.*, 2013; Ganiyu *et al.*, 2015; Tsapav *et al.*, 2015; Nwosu and Nwosu, 2016; Nwosu and Nwosu, 2019; Umar *et al.*, 2017; Ugbor *et al.*, 2021; Marques *et al.*, 2021; Samuel *et al.*, 2022).

However, more geophysical method need to be explore in investigation of groundwater contamination because some land are more vulnerable to pollution than others. The quality of groundwater also need to be monitored on a regular basis since large human population depend on it for both domestic and industrialization need. Hence, the need of this research arise to compliment the works done in the study area.

Environmental and toxicological effects of the dust particles on waters from the rivers and groundwater that received effluents from the cement factory have not been investigated. Bakare *et al.* (2019) revealed the genotoxic effect of water from Awba Dam on *Allium cepa* and mice. These earlier reports inform the choice of this sampling site in the present study. From the aforementioned, this study investigated the biochemical effects of waters from Awba Dam and rivers (Itori, Alaguntan, Elebute), and groundwater around Ewekoro cement factory, Ogun state, Nigeria on selected tissues of African catfish.

Materials and Methods

Location of the study area

The area under study is located within the Samaru main campus of Ahmadu Bello University Zaria. It is approximately bounded by latitude $11^{\circ}10'12''N$ and $11^{\circ}10'46''N$ and longitude $07^{\circ}36'55''E$ and $07^{\circ}44'12''E$. and consists of a septic tank and six ponds that are about 2 m deep, unlined, separated and protected on all sides by earthen dikes.



Fig. 1: A Google Earth satellite image of the Research Area (Umar *et al.*, 2017)

Geology of the Study Area

The research region is part of the Nigeria Basement Complex, which according to McCurry (1973) is made up of two separate rock types:

Basement gneiss, which occurs mostly in stream channels/valleys in extensively worn forms. Examples may be seen around the Kubanni Valley.

The Older granite is medium to coarse grained and moderately to weakly foliated. It comes in two textural varieties: porphyritic and uniformly grained medium to coarse. It has poor foliation and is most commonly seen as inselbergs and low whalebacks. Pegmatites and aplites cut across much of its exposure.

The rocks typically found within the basement complex of the NW Nigeria include gneisses, migmatites, metasediments and some intercalation of amphibolite (Ike, 1998). The metasediments are accommodated in the basement complexes, which are formed of gneisse. Exposures are limited and very weathered. The rock types include biotite, gneisses, granite gneisses, and, in certain cases, subordinate migmatites. The contact between the gneisses and metasediments is gradated. Granitic intrusions produce a complex of batholiths known as the Zaria Batholiths, one of which is visible as Kufena Hill. The gneisses are found as small belts within the granite intrusions, and are also found

east and west of the batholiths (Ike, 1998). The biotite gneiss extends westwards to form a gradational boundary with the schist belt. The gneiss continues eastwards to some extent and is occasionally broken up by the Older Granite. The Older Granite intrusion is supposed to have been formed at the bottom of a fold mountain belt.

Result and Discussion

The in-phase and out-phase data was plot against distance in each of the profile with their corresponding Karous Hjelt Sections. The region of high positive peaks in the real component (in-phase) with a minimum negative anomaly in the imaginary constitute an anomalous zone. A maximum negative anomaly in both real and imaginary components indicate a zone of shallow overburden and likely to reveal major fracture inform of dyke. Even distribution of both real and imaginary data point over the plots (figs. 2, 4 and 6) shows a fairly thick overburden. The inflexion points between real and imaginary curves, also indicates anomalous zones as reported in the work of Pirttijav, (2004).

The Karous and Hjelt pseudo-section provide a pictorial indication of the depth of various current concentration and hence the spatial distribution of subsurface geologic features. The pseudo-section shown as color codes with conductivity increasing from negative to positive; such apparent current density cross-section plots is possible to qualitatively discriminate between conductive and resistive structures. A high positive value correspond to conductive subsurface structure and low negative value are related to resistive one as reported in the work of Pirttijav, (2004).

In Fig 2, the plot of the in-phase and out-phase component of the acquired data show high positive peaks in the real component which correspond to the low negative at the out-phase at distance of 65m-80m, 110m-120m, and 140m-160m and maximum negative anomaly in both the component at 170m in the plot. Also, the plot show crossover point at 85m, 98m, 110m and 135m.

However, in the fig. 3, the Karous and Hjelt pseudo-section show high current density at 37m-42m distance with depth of 15m, 65m-80m distance with depth of 20m, 87m-90m distance with depth of 28m, 110m-120m distance with depth 15m and 140m-160m distance with depth of 20m. The areas of high current density correspond to the point of high positive peak in the in-phase and low negative anomaly in the out-phase.

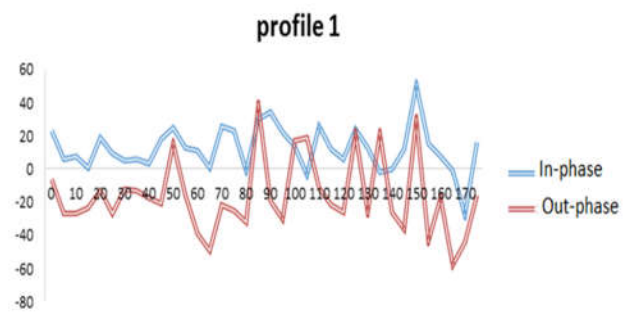


Fig 2: Plot of in-phase and out-phase of profile 1

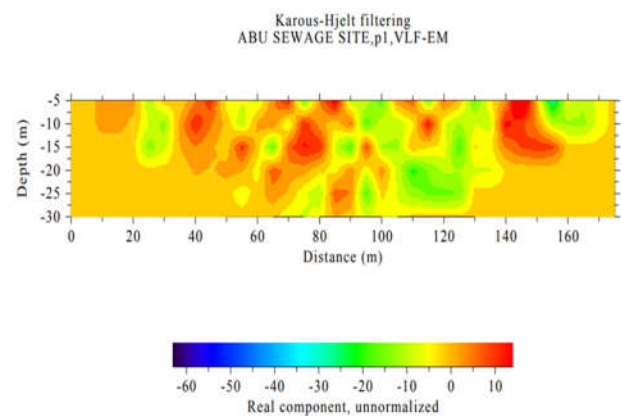


Fig 3: Fraser Filter with K-H pseudo-section for profile 2

Thus, these areas correspond to the points of high conducting area which are suspected to be contaminant plume zones. The crossover point also indicate relative good conductor in conductive ground. The point of maximum negative in both the in-phase and out-phase also reveal major fracture in form of dyke.

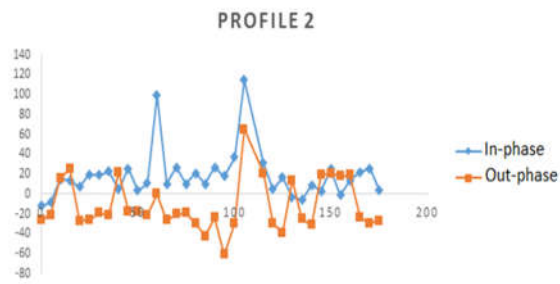


Fig. 4: Plot of in-phase and out-phase of profile 2

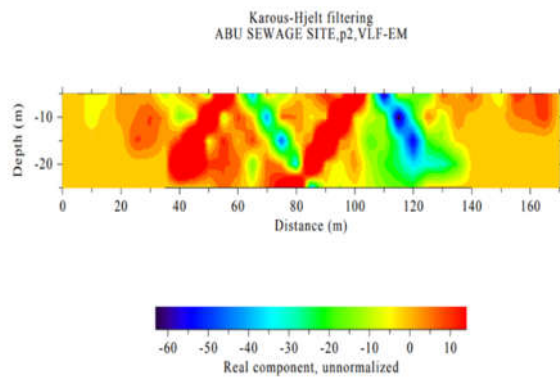


Fig. 5: Fraser Filter with K-H pseudo-section for profile 2

In Fig.4, the plot of the in-phase and out-phase component of the acquired data show high positive peaks in the real component which correspond to low negative at the out-phase at distance of 20m-34m, 38m-48m, 70m-80m, 80-100m and 155m-17m in the plot. Also the plot show crossover 8m-18m ,38m-43m, 127m-134m and 142m-162m.

However, in Fig.5, the karous and Hjelt show high current density at 20m-34m distance with depth of 20m, 38m-48m distance with depth of 30m, 70m-80m distance with depth of 30m, 80m-100m distance with depth of 28m and 150m-170m with depth of 15m. The areas of current density correspond to the point of high positive peak in the in-phase and low negative anomaly in the out-phase.

Thus, these areas correspond to the point of high conducting area which are suspected to be contaminant plume zones. The crossover point

also indicate good conductor in the conductive ground and presence of fracture in the subsurface.



Fig. 6: Plot of in-phase and out-phase of profile 3

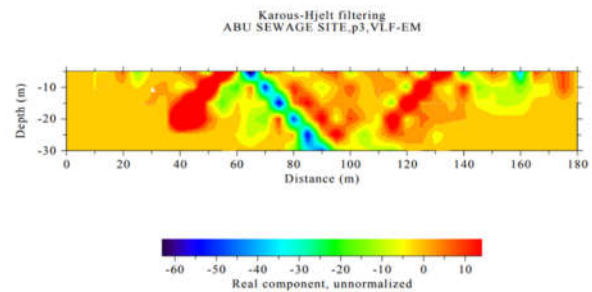


Fig. 7: Fraser Filter with K-H pseudo-section for profile 3

In Fig 6, the plot of the in-phase and out-phase component of the acquired data show high positive peaks in the real component which correspond to the low negative at the out-phase at distance of 55m-64m, 70m-80m, 80m-90m, 90m-105m, 105m-130m, 130m-140m, 140m-150m, 150m-165m and 165m-175m and maximum negative anomaly in both the component at 165m in the plot. Also, the plot show crossover point at 50m, 78m, 81m,88m,92m,102m,110m,140m and 142m.

However, in the fig.7, the Karous and Hjelt pseudo-section show high current density at 18m-22m distance with depth of 8m, 35m-53m distance with depth of 25m,90m-104m distance with depth of 28m, 111m-132m distance with depth 25m and 173m-178m distance with depth of 18m. The areas of high current density correspond to the point of high positive peak in the in-phase and low negative anomaly in the out-phase.

Thus, these areas correspond to the points of high conducting area which are suspected to be contaminant plume zones. The crossover point also indicate relative good conductor in conductive ground. The point of maximum negative in both the in-phase and out-phase also reveal major fracture in form of dyke. The result of the research agreed with Abdullahi *et al.*, (2011) and Umar *et al.*, 2017.

Conclusion

The result of geophysical investigation of groundwater at waste site of kubanni using very low frequency VLF method reveal the nature of the subsurface. Interpreted data shows the areas of high conducting subsurface and presence of fractures in the subsurface. The high conducting zones are suspected to be contaminant plume zones. The fractures in the subsurface can serve as the pathway for the contaminant to contaminate the underground water.

Base on the information of the subsurface, the contaminated plume zones move through the fractures in the subsurface to contaminate the underground water in the area of this research.

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Conflict of interest

There is no conflict of interest in this research.

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