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Effects of Pesticides and Fertilizers on Groundwater Quality Using Geophysics and Physicochemical Analysis in Oko-Efo, Lagos State University, Ojo (LASU)

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ABSTRACT

Modern agriculture uses pesticides and fertilizers to improve agricultural production, and increase yield, thereby ensuring food access and reducing the ongoing danger of plant-pathogen infections. However, indiscriminate use of pesticides and fertilizers harms the environment and human health, resulting in soil loss and nutritional imbalances. This study investigated the potential effects of pesticides and fertilizer on groundwater in Oko-Efo, LASU. An electrical resistivity survey using Three (3) Horizontal profiling and Twelve (12) Vertical Electrical Sounding (VES) points was done and physiochemical analysis to study groundwater pollution due to pesticides and fertilizers used by farmers. The results suggest possible geoelectric layers in the study location: Topsoil, Clayey sand, Sand and Saturated sand. The topsoil composed of conglomerate with resistivity ranging from 323 – 666 Ωm up to the depth of 5 m which is suspected to be polluted. Water samples were collected at an average depth of 3 m, and the physiochemical analysis further justified the presence of contamination as dissolved oxygen (DO), pH and electrical conductivity (EC) were above WHO standards. It is therefore recommended that the use of pesticides and fertilizers are regulated to prevent groundwater contamination.

Keywords: Agriculture, Groundwater, Contamination, Physicochemical, Geoelectric

INTRODUCTION

Agriculture is recognized as a major source of water pollution, which is also the most difficult to eliminate due to its spatial character (Lawniczak et al., 2016). In California, multiple groundwater basins are, or may be, affected by discharges of waste from irrigated lands, and over 100 small water systems that are documented and monitored have had at least one incident of nitrate contamination over the maximum contaminant level (MCL) for nitrate (Harter et al., 2012). Groundwater is the major supply of drinking water, domestic, industrial and agricultural purposes in Nigeria. The most serious water quality degradation in agricultural regions, caused by fertilizer and pesticide use, results in runoff of chemicals and excess nutrients such as nitrates, phosphates, and potassium from agricultural fields, and their percolation into groundwater (Opoku-Kwanowaa et al., 2020).

Pesticides and Fertilizers belong to a category of chemicals used worldwide as herbicides, insecticides, fungicides, rodenticides, nematicides, and plant growth regulators, in order to control weeds, pests and diseases in crops as well as for health care of humans and animals (Verma & Kumar, 2023). The positive aspect of pesticide use renders enhanced crop/food productivity and drastic reduction of vector-borne diseases. On the other hand, excess use of fertilizers threatens the groundwater (Wang et al., 2019). Agricultural runoff is described as surface water leaving cultivated fields as a result of an excess of received water as compared to the infiltration rate of the soil. Pesticides can enter water through surface runoff or through leaching. These two fundamental processes are linked to the earth's hydrologic cycle (Kaur & Sinha, 2019). Pollutants that result from farming and ranching include sediment, nutrients, pathogens, pesticides, metals, and salts (Ayenew, 2016). In arid areas, for example, where rainwater does not carry minerals deep into the soil, evaporation of irrigation water can concentrate salts. Excessive irrigation can affect water quality by causing erosion, transporting nutrients, pesticides, and heavy metals. Insecticides, herbicides, and fungicides can also enter and contaminate water through direct application, runoff, and atmospheric deposition (Artiola et al., 2019). They can contaminate food sources, and destroy the habitat that animals use for protective cover (Singh et al., 2022).

It is estimated that one-third of the world's population use groundwater for drinking purposes. Therefore, water quality issues and its management options need to be given greater attention in the developing countries. Rigorous agricultural activities have increased the demand on groundwater resources in India. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices (Pant et al., 2021). The rapid growth of industrialization and urbanization has created negative impact on the environment. Due to industrial, municipal and agricultural waste, groundwater has been polluted by leaching processes, transporting pesticides, insecticides, fertilizer residues and heavy metals to the groundwater. These pollutants are infiltrated into the groundwater and soil system through various human activities and rapid growth of industrialization which affect human health directly or indirectly (Deshmukh & Aher, 2016).

Groundwater is exposed to active pollution in the major cities of Nigeria due to the increase of urbanization and indiscriminate waste disposal. There are cities without organized waste disposal systems; and where poorly managed municipal landfills exist (Ogundele et al., 2018). The negligence and improper management of domestic wastes, as well as human activities, could encourage nitrate accumulation. The direct source of nitrate in groundwater originates as NO_3 from wastes or commercial fertilizers applied to the land surface. In some other cases, nitrates are introduced by conversion of organic nitrogen or NH_4, which occurs naturally or is introduced into the soil zone by man's activities (Ghaly & Ramakrishnan, 2015). In certain areas, these intensive agricultural practices and industrial activities have been going on for several decades (Srivastava et al., 2015).

Environmental management in the agricultural sector involving pesticides and fertilizers usage, is very important to ensure products, consumers, nearby communities, and the natural environment are protected from the resulting negative effects of their applications. However, if agrochemicals are not used sustainably, it could lead to serious socioeconomic problems, thereby endangering the existence of life. Nowadays, the environmental issues arising from agrochemicals use are numerous, and are the direct consequences of improper regulations and enforcement policies, particularly in developing countries (Suleiman et al., 2019).

Farming activities have been on-going in the study area for over twenty years. Therefore, this study seeks to investigate the effects of fertilizers and pesticides on groundwater quality in the study location. This is based on the background study that the residues of agrochemicals which do not undergo agricultural processes, percolate into the ground through precipitation and run-off, thereby leading to contamination of groundwater (Syafrudin et al., 2021). Several research works have been conducted and many are on-going on the effects of pesticides and fertilizers on groundwater quality. These studies have shown significant results so far, as the impacts need to be further consolidated so that our

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environment can be safe from destruction. Therefore, this paper is geared towards using geophysical methods and physicochemical analysis to establish the existence of or otherwise, effects of pesticides and fertilizers as these may pose potential harm on the quality of groundwater in the research area.

Geology of the Study Area

The study area, Lagos State University, is located in the Ojo Local Government Area of Lagos State, Nigeria. The geological setting of the study area reveals that it lies solely within the extensive Dahomey basin, the basin extends from Accra to Lagos. The area consists of sediment, of clay, unconsolidated sands and mud with a varying proportion of vegetable matter along the coastal areas, while the alluvial deposit consists of coarse claying unsorted sand with clay lenses and occasional pebble beds. (Ogungbe et al., 2020)

Location of the Study Area

The location of the study area is at Oko-Efo, within Lagos State University, Ojo Local Government, Lagos State. It lies between 355776.0 to 356176.0E and 723200.0 to 722880.0N as shown in Figure 1. The elevation varies between 3.0 to 16.0 m above the sea level. Lagos State University is a developing tertiary institution which is surrounded by farm lands.

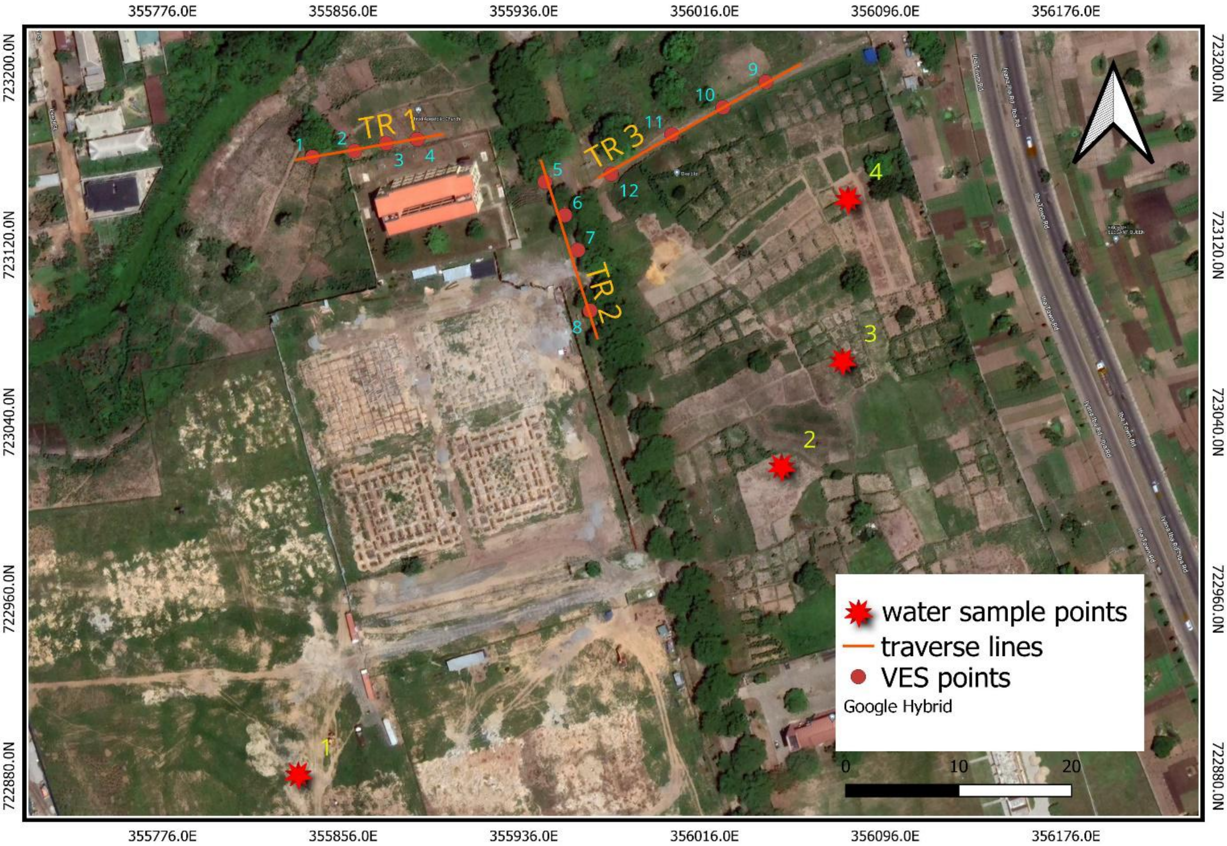

Figure 1: Base map of the study area.

METHODS

Geophysical Method

The geophysical method employed involves the use of 2-D Constant Separation Traversing (CST) and the Vertical Electrical Sounding (VES) method, using PASI Resistivity Meter and its accessories for the ERT.

The Wenner array electrode configuration was used for the 2D resistivity imaging. Three (3) profiles were run with the spacing between the profile depending on the accessible points on the field. Measurements

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were made at sequences of electrodes at 10, 20, 30, 40, 50 and 60 m interval using four (4) electrodes for all the three traverses covering a maximum distance of 220 m.

The Schlumberger current configuration was used to acquire twelve (12) Vertical Electrical Sounding Stations at different points along the three traverses. The Schlumberger current electrode spacing (AB) was varied from a minimum of 2.0 m to a maximum of 500.0 m at the VES locations. On each 2D electrical imaging (EI) profile, four VES points were carried out in order to integrate the VES and the 2D.

Physicochemical Analysis

Water samples were collected from four different hand-dug wells around 3 m depth in Oko Efo, as shown in Fig. 1, which indicates the water table is averagely 3 m. The four samples were collected using 1.5 litres of pre-cleaned plastic bottles for each sampling location, and then sealed. pH of the samples was carried out in-situ with a pH meter, while total dissolved solids was done using a TDS meter. The collected water samples were analysed for other physicochemical parameters and compared with WHO standards (World Health Organization, 2009). Statistical Package for Social Sciences (SPSS 20) was used for data analysis, and performed descriptive statistics and correlation analysis (CA).

RESULTS

The summary of the interpreted VES results is presented in Table 1. The 2D Electrical Resistivity images are shown in Figure 2, 3 and 4. Table 2 presents the summary of Physiochemical Analysis.

2D Structure on Traverse one

Traverse 1 was acquired in a NE–SW trend across the farmland as presented in Figure 2. It covers a lateral distance of 110 m with an electrode spacing of 5 m and the resistivity values ranging from 146 ohm-m to 587 ohm-m along the traverse which is indicative of a sandy formation. Four major subsurface geologic layers are observed in the 2D resistivity structure along this traverse. The First layer (purple colour) with the highest resistivity value ranging from 414 Ωm to 587 Ωm between o - 3 m depth and lateral distance 10 to 85 m is interpreted to be a topsoil layer and it is suspected to be contaminated due to the farming activities. The second layer (red colour) with resistivity value ranging from 292 Ωm to 414 Ωm is interpreted to be a clayey sand layer. It has a uniform distribution from lateral distance 0 to 110 m and it is suspected to be less contaminated. The third layer (green colour) with resistivity values ranging from 206 Ωm to 292 Ωm is interpreted to be a sandy layer and it is non-uniformly distributed along the traverse.

The fourth layer (blue colour) with the depth ranging from 15 to 25 m with resistivity values ranging from 146 Ωm to 206 Ωm is suggested to be the saturated sandy layer. The resistivity of the layers in this traverse are reducing from the Topsoil and this correlate with the VES result in traverse one with majorly QH curve as shown in Table 1.

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Table 1: Table of VES results showing resistivity, thickness, depth and curve type

	VES No	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	CURVE TYPE
TRAVERSE ONE	1	1	3492.6	1.1	1.1	QH
		2	359.1	6.0	7.1	$\rho_1 > \rho_2 > \rho_3$
		3	77.9	31.7	38.8	$< \rho_4$
		4	118.8	-	-	
	2	1	1218.1	0.6	0.6	KHK
		2	1765.8	3.4	4.0	$\rho_1 < \rho_2 > \rho_3$
		3	1249.8	4.8	8.8	$< \rho_4 > \rho_5$
		4	2483.8	18.4	27.2	
		5	550.1	-	-	
	3	1	3927.5	0.7	0.7	QHK
		2	767.2	1.5	2.3	$\rho_1 > \rho_2 > \rho_3$
		3	243.4	5.2	7.5	$< \rho_4 > \rho_5$
		4	617.9	17.7	25.2	
		5	79.6	---	---	
	4	1	4482.1	0.8	0.8	QHK
		2	957.1	1.4	2.2	$\rho_1 > \rho_2 > \rho_3$
		3	238.4	5.0	7.2	$< \rho_4 > \rho_5$
		4	745.3	17.5	24.7	
		5	126.5	---	---	
TRAVERSE TWO	5	1	196.7	0.8	0.8	KQH
		2	595.4	4.7	5.4	$\rho_1 < \rho_2 >$
		3	208.4	8.3	13.7	$\rho_3 > \rho_4 < \rho_5$
		4	62.8	33.6	47.3	
		5	400.4	---	---	
	6	1	150.2	0.8	0.8	KH
		2	452.3	6.9	7.7	$\rho_1 < \rho_2 > \rho_3$
		3	110.1	27.3	35.0	$< \rho_4$
		4	865.3	---	---	
	7	1	405.5	0.7	0.7	
		2	717.1	3.1	3.8	QQH
		3	246.6	16.1	19.9	$\rho_1 > \rho_2 >$
		4	52.2	56.0	75.8	$\rho_3 > \rho_4 < \rho_5$
		5	225.3	---	---	
	8	1	2550.6	0.6	0.6	
		2	422.6	2.7	3.4	QQH
		3	103.8	13.8	17.2	$\rho_1 > \rho_2 >$
		4	21.3	58.5	75.7	$\rho_3 > \rho_4 < \rho_5$
		5	174.9	---	---	
TRAVERSE THREE	9	1	2322.9	0.9	0.9	QQ
		2	437.4	5.0	5.9	$\rho_1 > \rho_2 >$
		3	158.2	25.3	31.2	$\rho_3 > \rho_4$
		4	57.3	---	---	
	10	1	2100.6	0.8	0.8	QQ
		2	769.2	4.9	5.7	$\rho_1 > \rho_2 >$
		3	235.1	19.9	25.6	$\rho_3 > \rho_4$
		4	63.6	---	---	
	11	1	1559.2	0.8	0.8	QQ
		2	439.4	5.9	6.7	$\rho_1 > \rho_2 >$
		3	183.5	26.2	32.9	$\rho_3 > \rho_4$
		4	73.9	---	---	
	12	1	1498.9	0.9	0.9	HK
		2	389.0	5.4	6.3	$\rho_1 > \rho_2 <$
		3	683.6	18.2	24.5	$\rho_3 > \rho_4$
		4	141.3	---	---	

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Tranverse 1 (2-D Resistivity Structure)

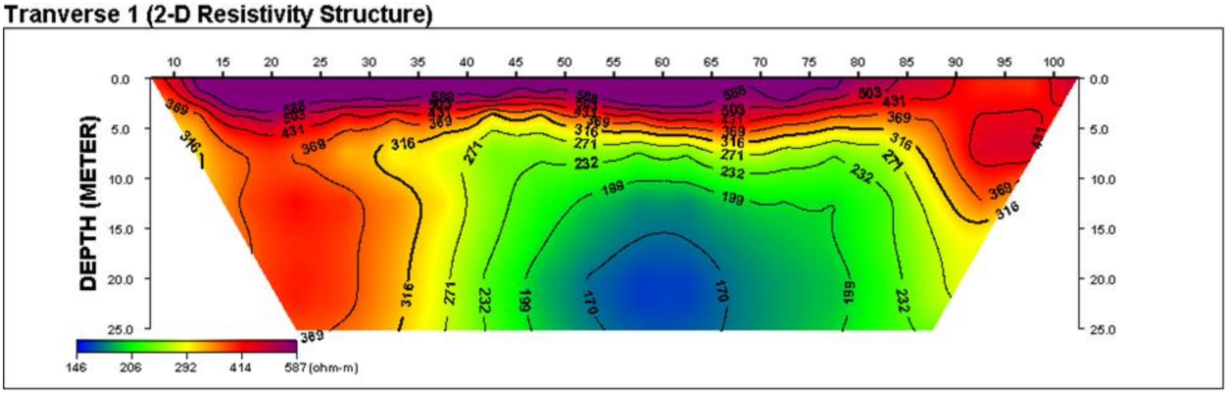

Figure 2: Werner (2D) resistivity structure for traverse 1.

2D structure on Traverse two

Traverse 2 covers a lateral distance of 190 m with an electrode spacing of 10 m and runs in the East-West direction as presented in (Figure 3). The resistivity value ranges from 55 Ωm to 402 Ωm along the traverse and four major geologic layers are observed in this 2D resistivity structure. The first layer represented by purple color with highest resistivity value ranging from 323 Ωm to 402 Ωm across a lateral distance of 200 m is interpreted to be topsoil layer and this is suspected to be contaminated. The second layer represented by red color with a resistivity value ranging from 208 Ωm to 259 Ωm is interpreted to be a clayey sand layer and it is suspected to be less contaminated. The third layer (green) along this traverse with resistivity values ranging from 86 Ωm to 134 Ωm is interpreted to be a Sandy clay layer and it is suspected to be uncontaminated. The fourth layer (blue) is suspected to be clay with resistivity value ranging from 55 Ωm to 69 Ωm and depth of the traverse between lateral distance 20 to 45 m and 90 to 160 m. The resistivity of the layers in this traverse are also reducing from the Topsoil, and this correlates with the VES result in traverse one with majorly QH curve as shown in Table 1.

Traverse 2 (2-D Resistivity Structure)

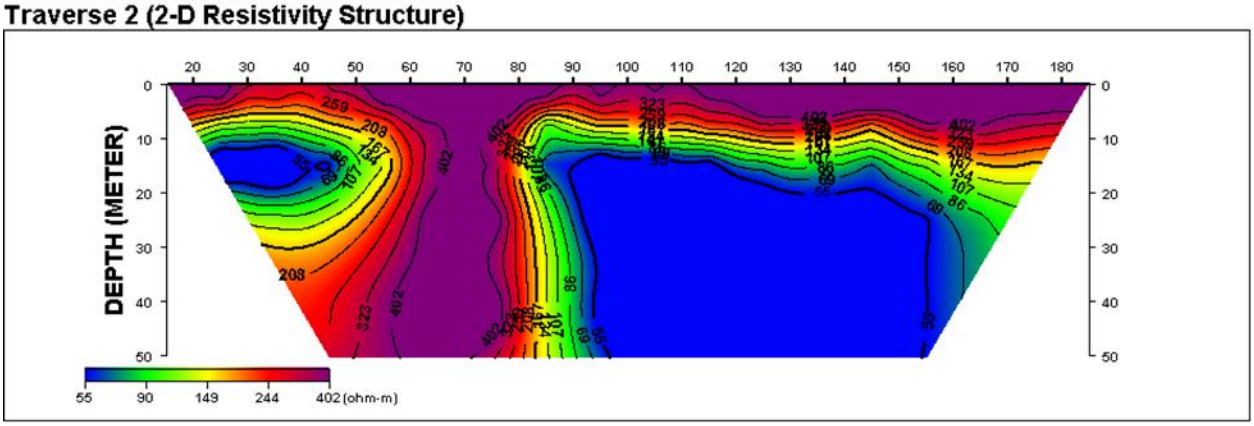

Figure 3: Werner (2D) resistivity structure for traverse 2.

2D Structure on Traverse three

Traverse 3 covers a total spread of 110m with an electrode spacing of 10m with an electrode spacing of 5 m and runs in the South-North direction as presented in Figure 4. The resistivity values range from 119 Ωm to 666 Ωm was observed along the traverse. Four major layers are observed in this 2D resistivity structure. The first layer (purple colour) is observed uniformly across the traverse with highest resistivity values ranging 550 Ωm to 666 Ωm with depth up to 4 m is interpreted to be topsoil layer and it is suspected to be contaminated. The second layer (red colour) is observed uniformly across the traverse with depth of about 10 m with resistivity values ranging 375 Ωm to 550 Ωm is interpreted to be a clayey sand layer, and it is suspected to be slightly contaminated. The third layer (green colour) with a resistivity value ranging from 212 Ωm to 256 Ωm is interpreted to be a Sandy clay layer occurring at a depth of about 10m downward and it is suspected to be uncontaminated. The resistivity of the layers in this traverse are also reducing from the Topsoil and this correlates with the VES result in traverse one with majorly QH curve as shown in Table 1.

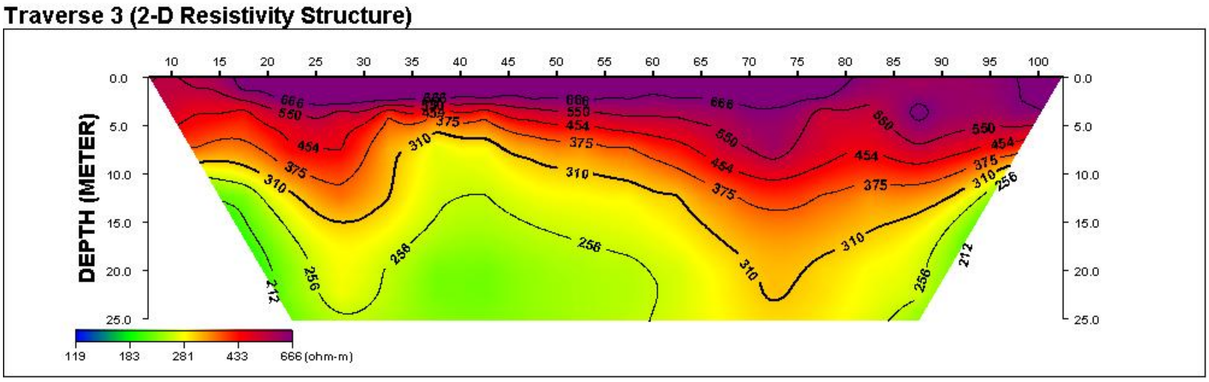

Figure 4: Werner (2D) resistivity structure for traverse 3.

Descriptive Analysis of Physicochemical Parameters

Table 2 below shows the descriptive data for physicochemical parameters in the Oko Efo groundwater samples. The physicochemical analyses included dissolved oxygen, total hardness, CO_2, acidity, alkalinity, pH and electrical conductivity. The dissolved oxygen values ranged between 5.80 and 8.00 mg/L, with a mean concentration of 6.85 mg/L, which were all within the WHO allowable range of 6.5 – 8.0, and this suggests possible contamination as it is close to the limit. Total hardness is usually caused by the presence of cations such as magnesium and calcium, or anions such as bicarbonate, chloride, and sulphate in water. The mean concentration of total hardness was 39.78 mg/L, and had a range of 23.00 – 83.10 mg/L. Carbon dioxide (CO_2) had values within the range of 3.00 and 5.00 mg/L, with a mean value of 4.25 mg/L. The mean value of acidity in the Oko Efo groundwater samples was 24.50 mg/L, with a range of 15.00 – 42.00 mg/L. Alkalinity had values within the range of 16.00 and 42.00 mg/L, with a mean concentration of 23.75 mg/L. Water samples with pH values less than 6.5 are identified with acidity, which is dangerous to human health, and could cause acidosis, while water samples with pH values higher than 8.5 are said to be alkaline, and unfit for consumption. pH values for the groundwater samples were between 5.00 and 6.00, with a mean concentration of 5.5, indicating acidity as all the values were below the WHO allowable limits. This also suggests possible contamination due to the effect of pesticides and fertilizers. The electrical conductivity (EC) for the water samples ranged between 691.00 and 1665.00 µs/cm. 50% of the groundwater samples had EC values above the WHO allowable limit of 1400 µs/cm. The high concentrations of EC could be caused by the involvement of ions in the groundwater quality.

Correlation Analysis

The Pearson correlation coefficient shows correlations between variables, as ‘strong’, ‘medium’, or ‘weak’, as well as positive or negative correlations. The Correlation Coefficient analysis for physicochemical data in the Oko Efo groundwater samples

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(Table 3) showed strong inter-elemental associations between some of the parameters. pH had strong inter-elemental association with dissolved oxygen (r = 0.71). Total hardness also showed a strong correlation with acidity (r = 0. 95) and alkalinity (r = 0.98). There was a strong correlation, as well, between acidity and alkalinity (r = 0.98).

Table 2: Descriptive Analysis for Physicochemical Parameters

Parameters	Min	Max	Mean	SD	CV%	SEM	Exceedance	WHO
Dissolved Oxygen (mg/L)	5.80	8.00	6.85	0.90	13.00	0.45	0.94	6.5 – 8.0
Total Hardness (mg/L)	23.00	83.10	39.78	29.00	72.90	14.50	0.08	500
CO_2	3.00	5.00	4.25	0.96	22.58	0.48		
Acidity (mg/L)	15.00	42.00	24.50	11.96	48.82	5.98		
Alkalinity (mg/L)	16.00	42.00	23.75	12.29	51.75	6.14		
pH	5.00	6.00	5.50	0.58	10.55	0.29	0.73	6.5 – 8.5
EC (µs/cm)	691.00	1665.00	1263.75	469.44	37.15	234.72	0.90	1400

Table 3: Correlation Analysis for Physicochemical Parameters in Oko Efo Groundwater Samples.

Parameters	Dissolved Oxygen (mg/L)	Total Hardness (mg/L)	CO_2 (mg/L)	Acid (mg/L)	Alkaline (mg/L)	pH	EC (µs/cm)
Dissolved Oxygen (mg/L)	1						
Total hardness (mg/L)	-0.795	1					
CO_2 (mg/L)	-0.406	0.592	1				
Acidity (mg/L)	-0.672	**0.953***	0.364	1			
Alkalinity (mg/L)	-0.794	**0.976***	0.404	**0.984***	1		
pH	**0.706**	-0.529	0.302	-0.628	-0.681	1	
EC (µs/cm)	0.030	0.571	0.578	0.604	0.492	0.211	1

CONCLUSION

An integrated electrical resistivity survey involving 2D Horizontal Profiling (HP) and Vertical Electrical Sounding (VES) was carried out at Oko-Efo, LASU, Ojo. The results are based on the interpretation of geo-electrical data, which indicates the resistivity of each geo-section layers which are; topsoil, clay, clayey sand and sand. Based on the interpretation, the Topsoil is suspected to be contaminated due to its high resistivity value. The high resistivity value is suspected to be as a result of the percolation of pesticide and fertiliser residues. This was further justified by physicochemical analysis, of the presence of contamination in the water samples, as some of them had mean values of dissolved oxygen (DO) and electrical conductivity (EC) above the WHO allowable limits, and pH values in all the water samples below the WHO standards.

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