Vol. 1 No.1, July 2021

FUAM Journal of Pure and Applied Science

Available online at
www.fuamjpas.org.ng

An official Publication of
College of Science
Joseph Sarwuan Tarka University,
Makurdi.

FUAM Journal of Pure and Applied Science
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https://fuamjpas.org.ng/
Vol.1. No. 1. July, 2021

Geophysical Assessment of Toxicological Effects of Agrochemical Runoff in Groundwater: A Case of Dikumari, Yobe State.

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Received: 19/04/2021 **Accepted**: 14/07/2021 **Published online**: 24/07/2021

Abstract
This study employs the technique of Vertical Electrical Sounding (VES) combined with physicochemical analysis to evaluate the toxicological effects of agrochemicals runoff in groundwater aquifer in Dikumari, an irrigated environment. Ten (10) VES measurements (D1 – D10) were recorded across the study area using Schlumberger electrode configuration. Each VES measurement covers 200 m of current electrode spacing, which implies an AB/2 of about 100 m. Five (5) groundwater samples collected from different tube wells across the study area were also analyzed using Atomic Absorption spectroscopy (AAS) to evaluate groundwater contamination and to draw correlation with aquifer contamination. The shallow aquifer layer revealed resistivity variation ranging from 7.5 Ωm in D6 to about 173 Ωm in D2 with thickness variation ranging from 6.9 m in D3 to about 11.0 m in D6. Low resistivity variation occurred mostly away from residential area, and on irrigated sitewhich accounted for contamination (high conductivity) due to application of agrochemicals on the irrigated sites. Arsenic, Lead, and Nitrate concentrations were <0.01 mg/L, <0.01 mg/L and <50 mg/L respectively. Contamination due to agrochemical runoff in Dikumari, at present does not constitute public health concern, but may expose people to health risk, if pesticides, made up of highly toxic chemical compounds, capable of contaminating aquifer system in and around the study area.

Keywords: Vertical electrical sounding, Physicochemical analysis, Agrochemical

Introduction

Groundwater plays a critical socioeconomic role in Dikumari Yobe State, as it remains the lone source of water for drinking and irrigation. Man-made activities such as irrigation (application of agrochemical to farmland to control pests and increase yields) are known factors causing groundwater resource to become unfit and unsafe for human consumption and other domestic usages. Agrochemical is a composite term which incorporates all chemicals used in agriculture, including pesticides, fertilizers and herbicides. These chemicals, though play critical role in food production by increasing yields and frequency of crop plantation on same farmland, they largely portent toxic health problems in humans. Chemicals used for irrigation remain in the soil through runoff, and subsequently percolate into groundwater aquifers. Thus, such water when consumed by humans expose them to both acute and chronic health effects, depending on the quantity of intake, i.e. prolong intake of contaminated water and crops grown from contaminated water. In developed countries, there are a number of effective pesticides (pesticides with less concentration of toxic chemicals)used by farmers. However, most of the pesticides used in developing countries contain highly toxic compounds especially the arsenic (calcium arsenate and lead arsenic).

The aim of the present study was to employ geophysical technique, in particular, the Vertical Electrical Sounding (VES) method toevaluate the toxicological effects of agrochemicals runoff in groundwater aquifer in Dikumari Yobe State. Physicochemical analysis was also conducted on groundwater samples to check arsenic level and to draw correlation between geophysical and the physicochemical analyses. A total of ten (10) vertical electrical sounding measurements (D1 – D10) were conducted across the study area using Schlumberger electrode configuration. Five groundwater samples collected from different tube wells across the study area were also analyzed using Atomic Absorption spectroscopy (AAS) to evaluate arsenic level and to draw correlation with aquifer contamination.

Geophysical technique has been applied in many studies to investigate impact of groundwater contamination [1,2]. Many studies have also established the viability of combined geophysical and hydro-geological methods in the study of groundwater contamination [3].Physicochemical analysis was adopted in many studies to investigate groundwater contamination and its subsequent impact on plants and animals [4,5,6]. Aquifer contamination by heavy metals and general groundwater contamination were investigated by many studies [7,8,9,10]. Vertical electrical resistivity method has been proved effective in groundwater exploration [11,12,13]. In particular, Schlumberger electrode configuration is good for groundwater investigation, especially because of its vertical and horizontal coverage [14,15,16,17]. In general, groundwater contamination due to irrigated environment could be caused by agrochemicals infiltration [18]. Many studies have reviewed the impact of Arsenic contamination in groundwater with respect to irrigated environment [19,20]. The present study combined geophysical and physicochemical techniques and evaluated the toxicological effects of agrochemicals runoff in groundwater aquifer system in Dikumari, the study area.

Study Area

Dikumari is an irrigated environment, about three kilometers west of Damaturu in Yobe State, Northeast Nigeria. Like Damaturu and most parts of Yobe State, Dikumari's source of water for drinking and irrigation activities are tube and hand-dug wells of relatively shallow depth. This implies that groundwater remains the main source of water in and around the study area. Dikumari lies between latitude 11^0.42'40"N and 11^0.44'60"N, and longitude 11^0.53'80"E and 11^0.56'80"E. The reference map of the study area (**Fig.1**) shows the positioning of the ten VES points – D1 to D10. The area has two seasons – the rainy season April to October, and dry season March to April. However, there also exist a session of Harmattan between the months of December and January.

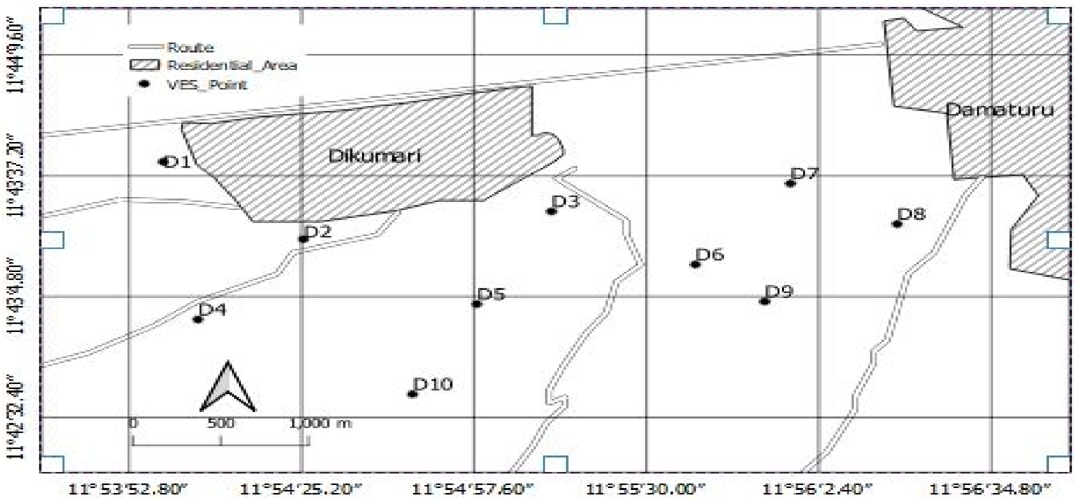

Figure. 1: Reference Map of Dikumari showing the locations of VES Points across the area

Materials and Methods

The materials used in the present study constituted hard and soft wares. For the hard ware components of the study, a laptop, GPS devices, and Resistivity meter (ABEM SAS1000 Terrameter) gadget. Others include steel rod electrodes and external power source (Battery). The soft waresused are open source IX1D Interpex and Surfer 13 by Golden Software. The hard wares used in this study were mainly for geophysical (resistivity) field data collection, while the soft wares (IX1D) were used for forward and inverse modeling of the resistivity data generated in the field, and (Surfer) was used for Contour gridding and 3-D surface mapping.

Vertical Electrical Sounding

A total of ten (10) VES points were measured using the Schlumberger electrode configuration with current electrode spacing (AB/2) ranged from 2 to 100 m, and potential electrode spacing (MN) from 0.5 to 32 m. The AB/2 adopted is 2, 4, 6, 8, 10, 13, 16, 20, 25, 30, 35, 40, 45, 50, 60, 80, and 100 m. Thus each VES point stretches across about 200 m of horizontal coverage. Current, I, was injected into subsurface from the external power source and via the steel rod current electrodes (AB/2). Potential difference, V, was then recorded from the Terrameter across MN (potential electrode spacing). Resistance and apparent resistivity were computed. The recorded apparent resistivity was then modeled using the computer software, IX1D Interpex.

Physicochemical Analysis

Five samples of groundwater (G1 – G5) were collected from carefully selected tube wells to adequately cover the study. Only one of the five selected wells is located away from irrigation site to serve as control point. The four other tube wells were located right on farmland where agrochemicals are applied throughout farming session. Three chemical parameters, namely Arsenic (As), Lead (Pb), and Nitrate (NO_3) were analyzed using atomic absorption spectroscopy (AAS) and in accordance with the Nigerian Standard for Drinking Water Quality (NSDWQ) guideline. The chemical parameters were so selected because of their quantity in most pesticides used in Nigeria. The maximum permissible limit for Arsenic, Lead, and Nitrate are 0.01 mg/L, 0.01 mg/L, and 50 mg/L respectively [21].

Results and Discussions

Geophysical survey

The results of the ten VES points as processed using the IX1D Interpex is presented in **Table 1**. The results revealed that with the exception of VES points

D1, D6, and D7, all the VES points exhibited four (4) layers, namely h1, h2, h3, and h4. The three VES points D1, D6, and D7, each exhibited three (3) layers. The topmost layer h1 showed resistivity variation 97 Ωm in D8 and 388 Ωm in D1 with thickness variation from 1.7 m in D10 to 5.5 m in D3. The second layer which appeared to be the shallow aquifer showed resistivity variation ranging from 7.5 Ωm in D6 to about 173 Ωm in D2 with thickness variation ranging from 6.9 m in D3 to about 11.0 m in D6. From this layer (aquifer), region of low resistivity occurred mostly away from residential area, and on irrigated site. This could account for contamination (high conductivity) due to application of agrochemicals on the irrigated sites. The third layer revealed resistivity variation ranging from 65 Ωm in D2 to about 881 Ωm in D6, with thickness variation ranged from about 5.1 m in D4 to about 10.0 m in D2 and D9. The high resistivity at this point could account for less contamination at the point. The fourth layer runs to infinity with resistivity variation ranging from about 53 Ωm in D10 to about 231 Ωm in D8.**Figures 2** and **3** showed the contour and 3-D surface maps of the second layer (aquifer), respectively as processed using Surfer 13 Golden Software.

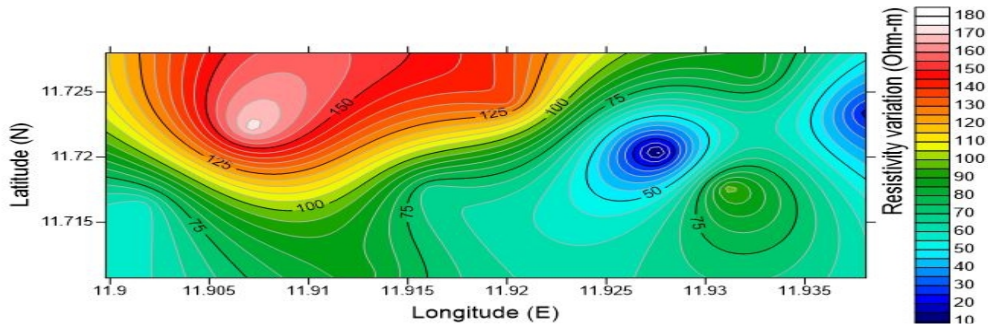

Figure 2: Contour map showing resistivity variation from shallow aquifer

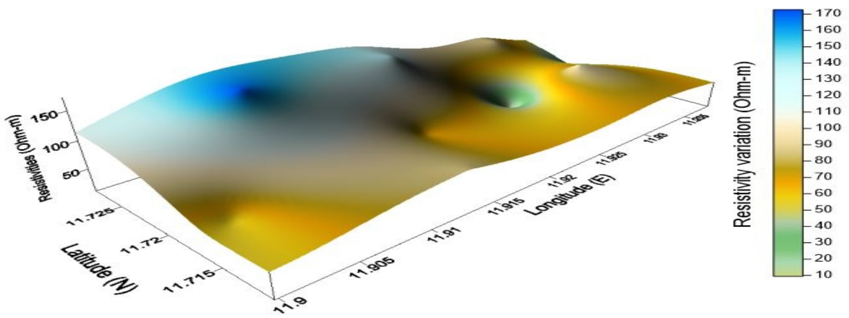

Figure 3: A 3-D representation of the resistivity variation in aquifer layer

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Table 1: Geophysical analysis revealing layers' thickness and resistivity

VES Point	Thickness of layer (m)			Resistivity of layer (Ωm)			
	h1	**h2**	**h3**	**ρ1**	**ρ2**	**ρ3**	**ρ4**
D1	2.3	10.3	-	388	114.11	112	-
D2	3.5	8.2	10.0	213	173	65	200
D3	5.5	6.9	9.0	117.3	138	87	123
D4	1.8	7.4	5.1	100	56.4	213	89
D5	2.9	8.0	8.0	200	66	467	99
D6	3.0	11.0	-	283	7.5	881	-
D7	4.0	10.6	-	182	88	101	-
D8	4.7	9.4	9.7	97	22.4	382	231
D9	2.6	7.7	10.0	88.6	98	151	87.4
D10	1.7	8.3	8.8	267	87.3	133.6	53

*Field data processed using IX1D Interpex

Physicochemical analysis

Five (5) groundwater samples were collected four times every month from January to Decemberin the year 2020 (year under review) for the atomic absorption spectroscopy (AAS) on the selected chemical parameters – As, Pb, and NO_3. Results of physicochemical analysis were recorded each month, and the mean in each month was taken (**Table 2**). Arsenic (As)distribution throughout the year under review showed variation ranged from 0.001 mg/L in February to about 0.008 mg/L in June. The peak of arsenic distribution occurred around June/July (**Fig. 4**), which may be attributed torunoff due to rainfall. Lead

(Pb) distribution showed variation ranging from 0.002 mg/L in December to about 0.009 mg/L in July, while Nitrate (NO_3) revealed variation ranging from about 11 mg/L in April and October, to about 43 mg/L in July (**Table 2**).

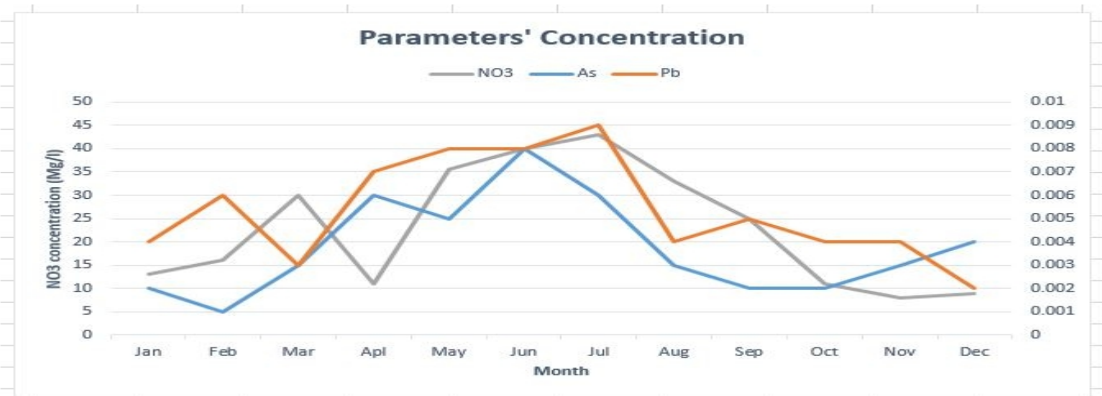

Figure 4: Graphical representation of As, Pb, and NO_3concentration from Jan to Dec.

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Table 2: Physicochemical survey of selected parameters between January and December, 2020.

Parameter (mg/L)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
As	0.002	0.001	0.003	0.006	0.005	0.008	0.006	0.003	0.002	0.002	0.003	0.004
Pb	0.004	0.006	0.003	0.007	0.008	0.008	0.009	0.004	0.005	0.004	0.004	0.002
NO_3	13	16	30	11	35.5	40	43	33	25	11	8	9

*AAS analysis from Laboratory

Conclusion

Many persons living in Dikumari, an irrigated area, rely on water sources (groundwater) that are not so regulated under the Nigerian Standard for Drinking Water Quality (NSDWQ).Agrochemical infiltration of groundwater in the area mostly depends on amount of the chemicals applied per area and per season, as evident from the geophysical and the physicochemical analyses of groundwater and groundwater aquifer across the study area.The shallow aquifer layer revealed resistivity variation ranging from 7.5 Ωm in D6 to about 173 Ωm in D2 with thickness variation ranging from 6.9 m in D3 to about 11.0 m in D6. Low resistivity variation occurred mostly away from residential area, and on irrigated site, which accounted for contamination (high conductivity) due to application of agrochemicals on the irrigated sites.Groundwater contamination due to agrochemical runoff in Dikumari does, at present not constitute public health concern, since all checked chemical parameters were within accepted limit by NSDWQ, but may expose people to health risk, should pesticides containing highly toxic chemical compounds continue to have field day in and around the study area.Geophysical technique could be a reliable method to assess toxicity of agrochemical in groundwater aquifers, especially when combine with physicochemical analysis.

Declaration of conflicting interests

The authors declared no potential conflicts of interest

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Cite this article

Babagana S.M. and . Kolo A.. (2021). Geophysical Assessment of Toxicological Effects of Agrochemical Runoff in Groundwater: A Case of Dikumari, Yobe State. *FUAM Journal of Pure and Applied Science*, **1**(**1**): 1-6