ZEAL SCIENTIFIC PUBLICATION

World Journal of
Advanced Science and Tehnology

Journal homepage: https://zealjournals.com/wjast/

(Research Article)

Check for updates

Time series investigation on spatial and temporal disparity of sodium in groundwater within Abuja, Northern Nigeria

Lucia OmolayoAgashua [1,*], Bamitale Dorcas Oluyemi-Ayibiowu [1] and Igibah Christopher Ehizemhen [2]

[1] *Civil Engineering Department, Federal University of Technology Akure, Ondo State, Nigeria.*
[2] *Civil Engineering Department, Federal University Oye-Ekiti, Ekiti State, Nigeria.*

World Journal of Advanced Science and Technology, 2022, 01(02), 011–019

Publication history: Received on 02 April 2022; revised on 06 May 2022; accepted on 08 May 2022

Article DOI: https://doi.org/10.53346/wjast.2022.1.2.0028

Abstract

This study revealed case study on how to exploit time series investigation as extracting device to trace the transience of sodium discharge and to forecast the sodium accumulation in groundwater. Abuja North Nigeria, was chosen as study zone, and twenty-five groundwater monitoring boreholes positioned within the domain of sodium discharge were subjected to time series scrutiny. The measured sodium values in groundwater are from 55.98 to 515.45 mg/L, and compare with WHO limit of 50 mg/L. Time series scrutiny is a suitable tool for mining stimulating archetype from well-arranged series of observations. From extorting information from ACF, season model, time series modeler and CCF, the style, interesting patterns, procedures, or models around the original data set were sort out. IBM SPSS Modeller V18.x and Aq.QA time series plot, were engaged to construe the data from the monitoring information of groundwater quality.

Keywords: Sodium; Time Series Investigation; Groundwater Contamination; Data Mining

1 Introduction

Various factors such as human activities, climate, saline water imposition, topography, groundwater recharge, and aquifer lithology could have a substantial effect on groundwater quality as well as reduce its usefulness for water supply [1]. Though, there is establishment of monitoring boreholes to gathered data on trimestral or biannually bases in Nigeria. Data gathered from every single borehole unswervingly imitates groundwater attribute when relating with the synchronized criteria for instance WHO limit, but the sources of contagion and their transience might not be straightforwardly perceived from monitoring data [2,3]. By exploiting statistical kits it is feasible to recognize the geneses of likely groundwater contagion, to apportion the spatial domains of pollutant sources as well as track the transience of a definite pollutant [4]. Abuja and its suburbs maintain position as the African fastest growing metropolis and high quantities of Na^+ may perchance be result of groundwater contamination thru salt accretions erosion, sewage, irrigation because farming is the most substantial profitmaking activity disturbing the changes in groundwater attributes by anthropogenic effect, and sodium-bearing rocks. The findings of erstwhile research papers [5-9], pointed out that quick population growth, agricultural activities, salinization, and industrial leakage are some major factors liable for groundwater pollution. Sodium is an alkali metal, that human being do not need much though human activity for example, human or animal disposal, road salt, contagion from landfill, and releases from water softeners can cause release of sodium to groundwater. It is critical to trace the transience of sodium discharge and to forecast the sodium accumulation in groundwater [10-12]. This research engaged time series scrutiny to anatomize the spatial and temporal dissimilarities of sodium quantity in groundwater. Numerous techniques of time series investigation were examined to institute the style of spatial and temporal dissimilarities on sodium level in groundwater; embracing sequence plot (SP), season model (SM), generalized lower mixed models (GLMM), time series modeler (TSM), and time series plot by Aq.QA. This paper offers showcase to construe the fate of sodium discharge from groundwater monitoring data. Additionally,

*Corresponding author: Lucia Omolayo Agashua
Civil Engineering Department, Federal University of Technology Akure, Ondo State, Nigeria.

finding concerning sodium release in groundwater is valuable for Abuja water management Bureau so as to improve groundwater administration as well as avert groundwater contagion.

2 Materials and method

2.1 Study Area

Borehole water quality investigation was carried out in Abuja North in Federal Capital Territory, Nigeria at the locations in the map shown in Fig. 1. The area lies between latitude 9.4°N and 9.12°N and longitudes 7.39°E and 7.45°E and with an estimated inhabitants of 6,235,880 persons, developing at a rate of thirty-five percent annually, maintain its stand as the African promptest growing urban municipality [3,4]. This metropolis is served thru the Nnamdi Azikiwe International Airport, besides is the political as well as administrative center of Nigeria. Nearby metropolises that share borders with Abuja consist of Kaduna, Mandalla, Lokoja and Keffi.

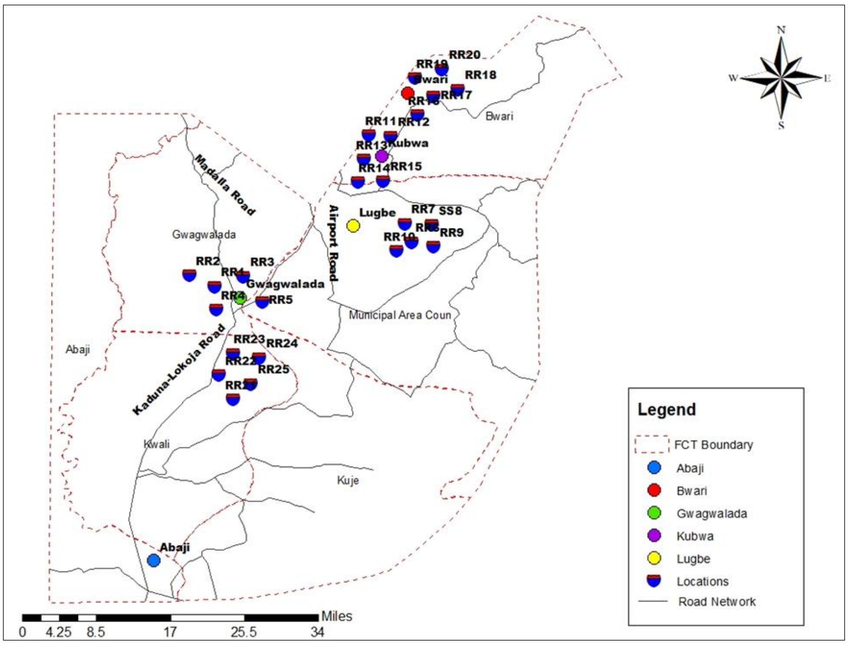

Figure 1 The map of sodium discharge and the spots of dispersion monitoring boreholes within study zone

2.2 Groundwater Data Monitoring

For adequate groundwater fortification, there are 25 boreholes were analyzed within Abuja and it's environ. The analyzed parameters of groundwater quality consist of pH (hydrogen ion concentration), total hardness (TH), total dissolved solids (TDS), electrical conductivity (EC), alkalinity (Alk), temperature (Temp), dissolve silica (SiO_2), and substantial cations for example sodium (Na^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), potassium (K^+), and iron (Fe^{2+}) as well as anions for instance sulphate (SO_4^{2-}), nitrates (NO_3^-), carbonates (CO_3^{2-}), fluoride (F^-), chloride (Cl^-), bicarbonates (HCO_3^-), and heavy metal (Mn)[13-15]. By using Hierarchical cluster analysis (HCA), EC, $SO4^{2-}$, HCO_3^-, Na^+, and TH were within cluster 3 as shown in Table 1. The field of the equivalent PC was determined thru connecting the localities of the categorized monitoring wells in every cluster.

As displayed in Fig. 1, there are 25 monitoring boreholes ordered in the purview of sodium discharge.

From the outcomes of Principal Component Scrutiny (PCS) on groundwater data monitoring, sodium discharge were identified as the 0.74 first principal component influencing 30.5% of the total variance and has extreme positive loading in the original data set as shown in Table 2. By using Hierarchical cluster analysis (HCA), EC, $SO4^{2-}$, HCO_3^-, Na^+, and TH were within cluster 3 as shown in table 2. The analogous PC field was ascertained thru connecting the localities of the classified monitoring wells in every cluster. Additionally, descriptive statistics were employed to analyze Physical parameters (Na^+) of the boreholes water and graphically illustrated in Fig. 2a, while spatial group scrutiny was engaged to the water attribute data set to ascertain the spatial likeness groups amongst the sampling stations as displayed in Fig. 2b.

Table 1 Cluster categorizing of the water attribute parameters

Cluster 1	Cluster 2	Cluster 3	Cluster 4
pH	TDS	EC	Cl^-
Temp	-	$SO4^{2-}$	-
AlK	-	HCO_3^-	-
CO_3^{2-}	-	Na^+	-
NO^{3-}	-	TH	-
F^-	-	-	-
K^+	-	-	-
Fe^{2+}	-	-	-
Ca^{2+}	-	-	-
Mg^{2+}	-	-	-
Mn	-	-	-
SiO_2	-	-	-

Table 2 Principal components of borehole water parameters

Parameter	Components				
	PC1 (30.5%)	PC2 (19.67%)	PC3 (17.33%)	PC4 (7.74%)	PC5 (7.16%)
pH	0.52	0.34	0.08	-0.29	-0.69
Temp	0.64	0.52	-0.09	0.03	0.26
AlK	-0.83	0.13	-0.30	0.06	0.31
TDS	-0.57	-0.61	0.32	0.10	0.14
EC	-0.77	0.38	0.37	-0.04	-0.01
Cl^-	-0.92	-0.19	-0.04	-0.05	0.21
SO_4	-0.22	0.60	-0.53	0.22	0.01
CO_3^{2-}	0.14	-0.45	-0.69	-0.38	0.07
NO^{3-}	0.64	0.21	0.27	0.31	0.22
HCO_3^-	0.38	0.52	-0.50	0.22	0.31
F^-	0.67	0.33	0.27	-0.39	0.05
K^+	-0.59	0.73	0.18	-0.16	-0.02
Na^+	0.74	0.12	-0.44	0.12	0.24
Fe^{2+}	0.64	-0.30	0.52	-0.13	0.20
Ca^{2+}	0.28	-0.63	0.42	0.15	-0.02
Mg^{2+}	0.14	0.24	0.83	0.37	-0.65
Mn	0.08	-0.32	-0.16	0.80	-0.33
TH	0.13	0.34	0.61	-0.11	0.52
SiO_2	0.42	-0.77	-0.19	0.11	0.18

Time and series chart, are data picturing kits that shows data spots at continuous time intervals. The horizontal as well as vertical points on the graphic representation corresponds to time as well as quality respectively, in addition it can quickly pinpoint spot, trend in recurrent prototype over a given time [15,16]. Water scrutiny outcome from the research region is charted in (Fig. 3, 4 & 5).

2.3 Method

Time series investigation is recognized as a potent device for summarizing categorizations of observations with different correlations degrees over time by means of engaging the notions of stochastic technique for dynamic methods. Time series investigation is an eminent method of economic predicting, having serviceable application that spreads from astrophysics to neurophysiology. Characteristically, time series investigation is based on the supposition that the data comprise of universal pattern as well as arbitrary error. Through extracting data from PACF (partial autocorrelation functions) and ACF (auto correlation functions) and, it could sift out sound so as to achieve more significant shape. The first phase in analyzing time series is via carrying out certain preliminary treatment on the unprocessed data for suitability purposes before further scrutiny. In this paper, all the scrutiny was computed by the SPSS (Statistical Package for Social Sciences) -23.0 software. Two prototypes of time series investigation including IBM SPSS Modeller V18.x and Aq.QA time series plot were engaged to reconnoiter the relationship between sodium accumulation and groundwater specimen time.

3 Results and discussion

Based on Hierarchical Cluster investigation, 25 boreholes were assigned to the domain of sodium discharge. From the descriptive statistics the following data was obtained for Na (mg/l); Mean (260.187), Std. Deviation (195.767), Variance (38324.82), Skewness (0.27), Kurtosis (-1.78), minimum (55.98) and Maximum (515.45). The spatial variation of water attribute was ascertained through typical weather (rainy and dry). Because, seasonality has significant influence on hydrochemistry [15, 17]. A lot of rain from May to June was observed, but there is no rain from April to middle of May. The season-correlated variables could be presumed to be demonstrating as the key source of dissimilarity in water attribute [18]. Meanwhile, significant dissimilarities were detected among the 25 boreholes data units for dry and rainy seasons. For Na, high values were beheld in raining season (176.56 – 515.45mg/L) and low quantities in dry season (55.98 – 193.56mg/L).

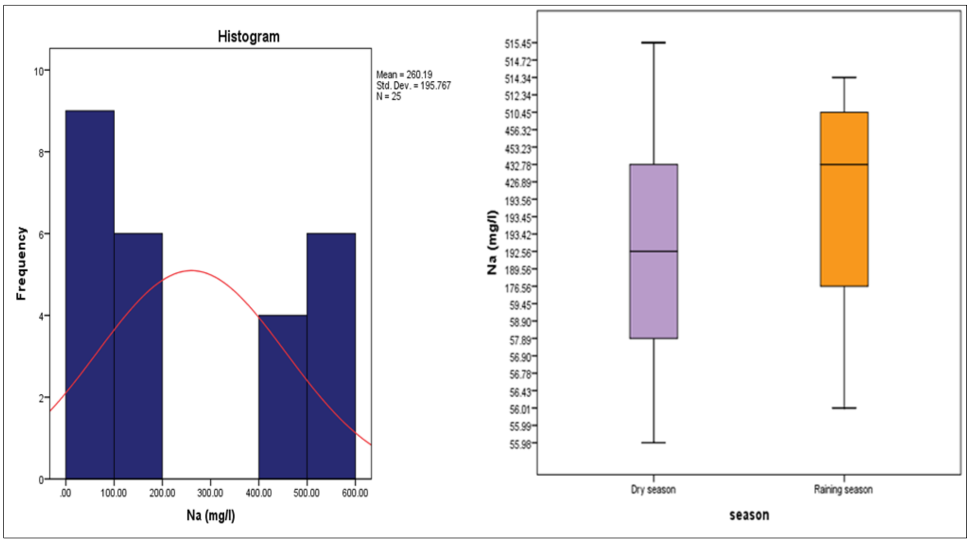

Figure 2a. Sodium frequency distribution. **b.** spatial variation

The time series data of sodium concentration, Sodium sequence plot and season model in each boreholes was given in Figure 3 and 4 respectively. The measured sodium levels in groundwater range from 55.98 to 515.45 mg/L, compare with WHO limit of 50 mg/L as shown in Table 3.

Time and series plots, are data picturing equipment that exhibits data spots (points) at consecutive time intervals. The horizontal as well as vertical points (spots) on the diagram corresponds to time and quality correspondingly, as well as hastily pinpoint spot, style in cyclic archetype over a specified period of time. According to the piper diagram analysis, sodium concentration line was within 500 mg/L, which is relatively high when compare to WHO limit. Plots of correlation function (CCF) for ground water levels time series for Abuja locality are displayed in Fig. 5a-d. The unbroken line beyond and under the x- axis in the charts signifies the confidence limits. The affirmative or positive indicator advocates that groundwater states are deteriorating with respect to the ground surface. The result showed that Na with HCO_3 has the highest CCF value (0.75 mg/l) and followed by Na and temp (0.74⁰C) while Na plus Ec recorded the lowest (- 0.73 mg/l).

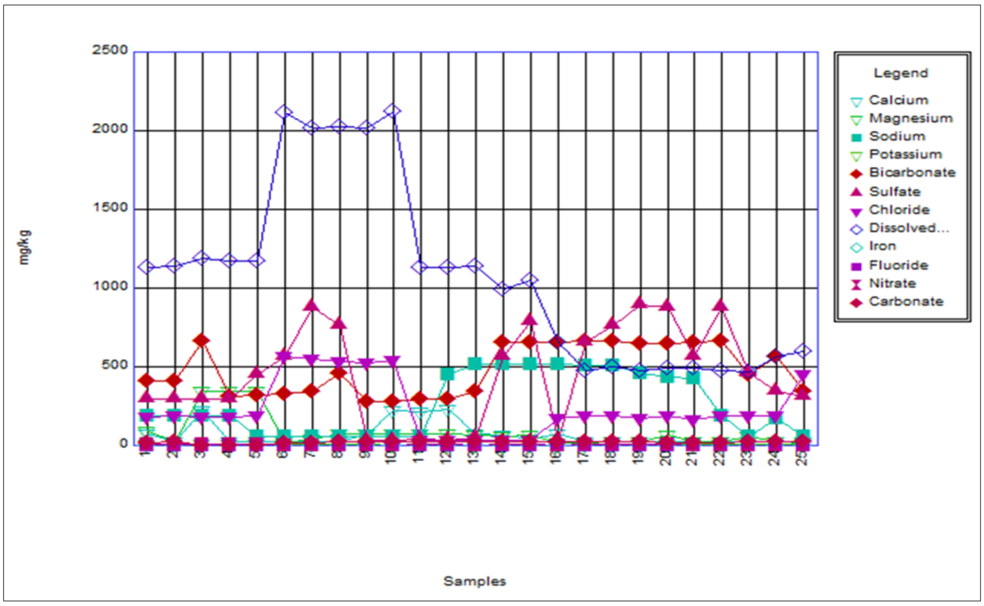

Figure 3 Time series signifying samples and time variation in the study area

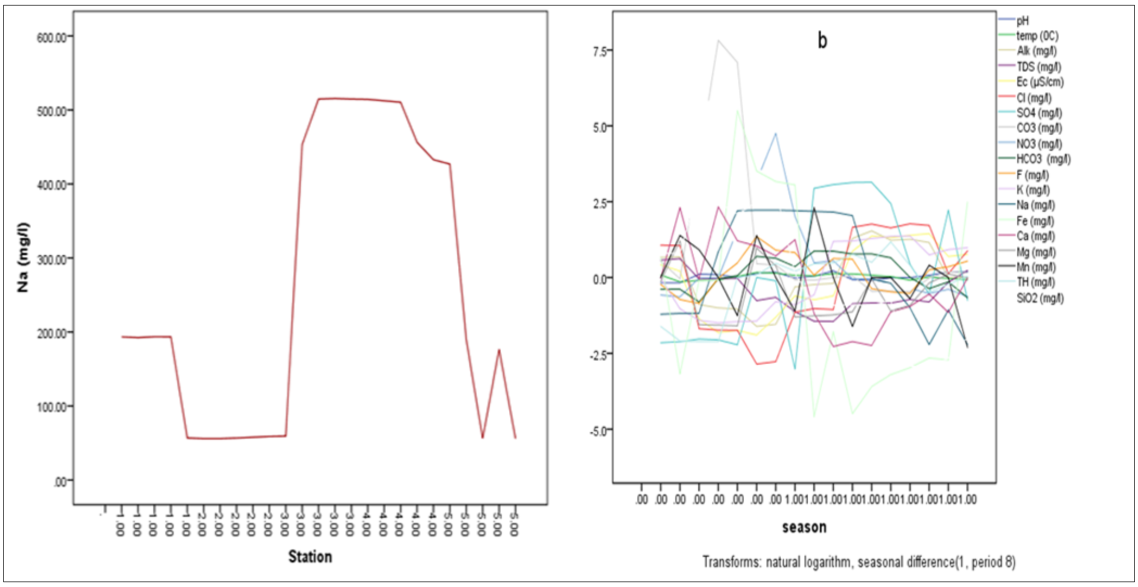

Figure 4 Sodium sequence plot and season model

Hence, it can be stated that the usual groundwater pumping in Abuja locality during rainy season is higher than drying season. This could be as result of the enhanced zone under rice farming over the years.

Table 3 Different samples violation values

Parameter	Unit Limit	WHO Number	Violation	Violation	Violation
pH		6.5 - 8.5	0	0	100
Temp	°C	NA			
AlK	mg/l	NA			
TDS	mg/l	1000	14	56	44
EC	μS/cm	1500	16	64	36
Cl-	mg/l	250	6	24	76
SO_4	mg/l	250	19	76	24
CO_3^{2-}	mg/l	NA			
NO_3^-	mg/l	50	0	0	100
HCO_3^-	mg/l	500	10	40	60
F^-	mg/l	1.5	10	40	60
K^+	mg/l	12	0	0	100
Na^+	mg/l	50	25	100	0
Fe^{2+}	mg/l	0.3	11	44	56
Ca^{2+}	mg/l	300	0	0	100
Mg^{2+}	mg/l	50	14	56	44
Mn	mg/l	0.4	0	0	100
TH	mg/l	500	9	36	64
SiO_2	mg/l	NA			

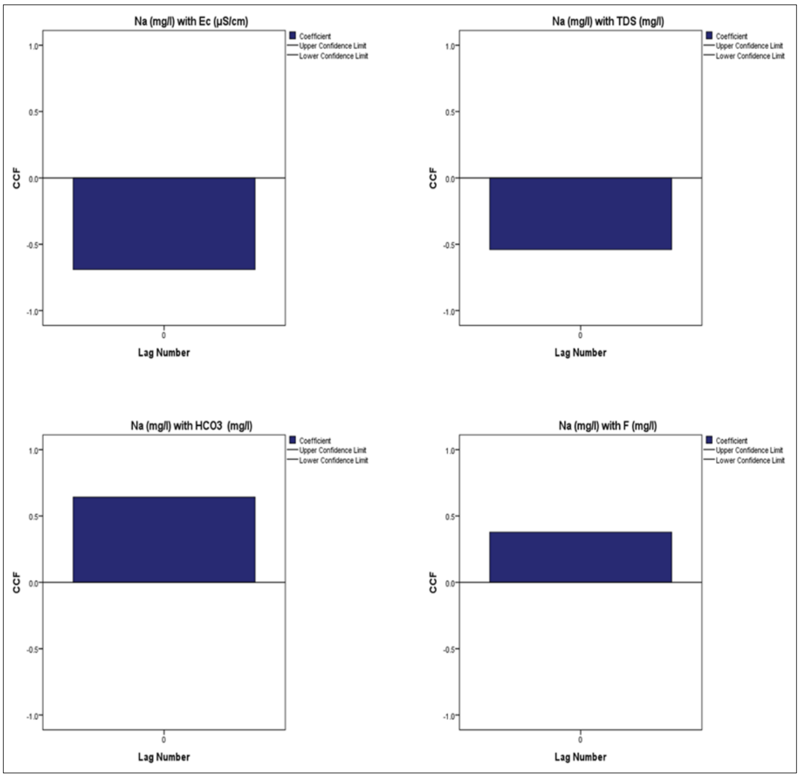

Figure 5 a CCF of Na^+ with Ec, and TDS. **b** CCF of Na^+ with $HC0_3$, and F^-

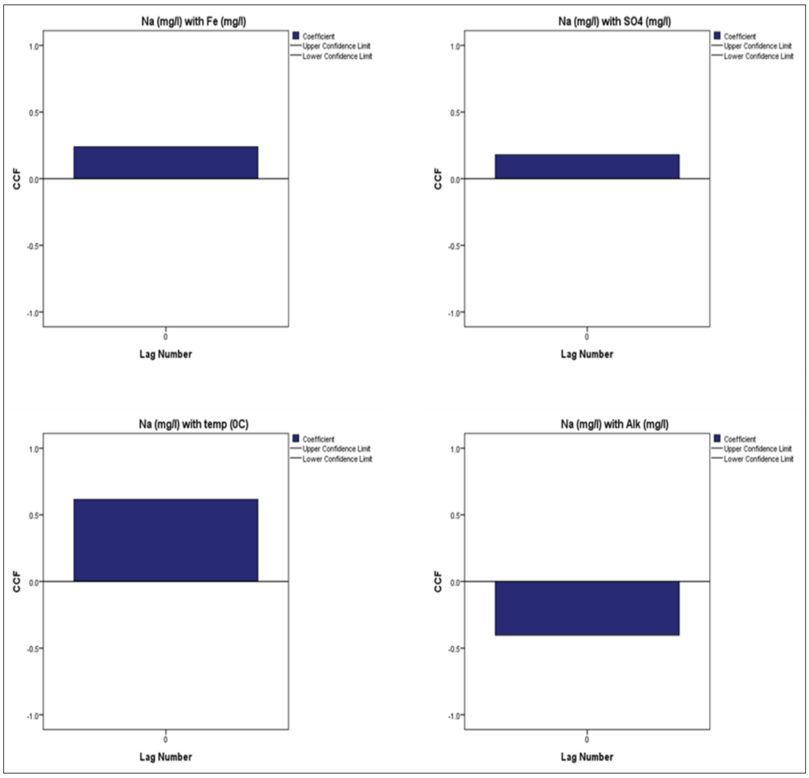

Figure 5 c CCF of Na^+ with Fe, and SO_4. **d.** CCF of Na^+ with temp, and Alk

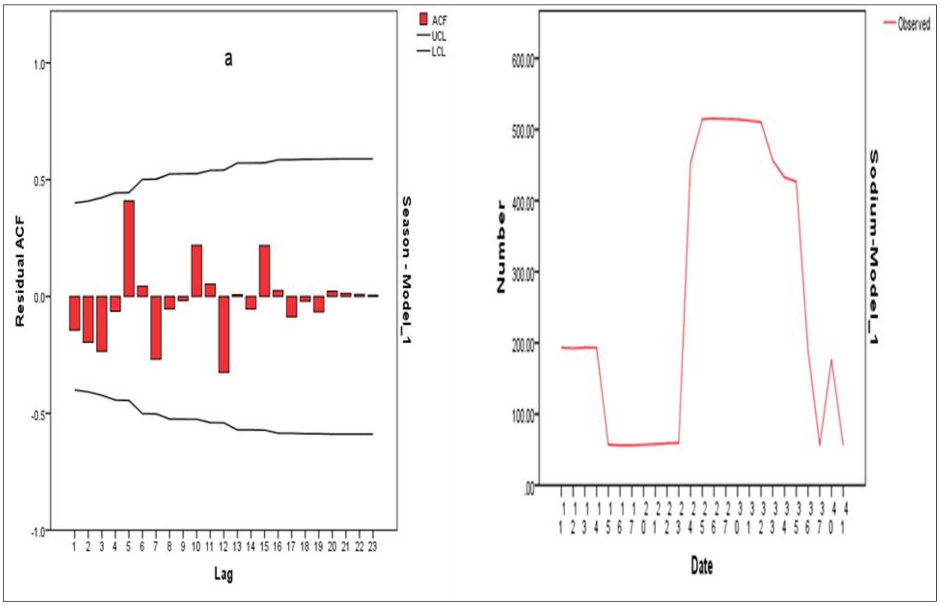

Figure 6 a ACF Season model. b sodium time model

The plot of autocorrelation function (ACF) and sodium model for time series of groundwater levels are displayed in Fig 6a & b respectively. From Na (mg/l)-Model_1 summary, Stationary R-squared is -0.003, Statistics of 14.40, DF equal to 17 and Sig. of 0.639, this means that significance > 0.5; if not, the data set would not be pertinent for the time model. Sodium sequence plot and season model using Transforms natural seasonal difference (1, period 8) are graphically illustrated in Fig 4.. This were exploit to further scrutinize if the water table degenerated was as a result of climate change or augmented groundwater propelling caused by crop evapotranspiration, farming intensification or reduction, and rain trends during rainy and drying season were strictly scrutinized. It was clinched that crop evapotranspiration has not intensified during the season despite there is substantial change in seasons style line. The foremost impact of climate change is predictable on groundwater revitalize and crop evapotranspiration. Both positive and negative changes of Na^+ with other parameters during the seasons, suggestively denoting that the debility, variation in groundwater altitude and its physicochemical properties is mostly as a result of increased groundwater pumping because of spiraling and extensification of farming in the region as gap also indicated decrease during dry season to nearly zero which is in agreement with research work by Emenike et al.[4],Achieng et al. [1] and Fijani et al. [8].

4 Conclusion

The source of High levels of sodium (Na+) in groundwater can be most likely ensued from outcome of groundwater contamination by irrigation, sewage as well as salt deposits erosion and sodium-bearing rocks. Using of the time series investigation specified interpretation and predicting the sodium quantity in groundwater as referring to the erstwhile information. This model hesitantly revealed the temporal and spatial style of the sodium level in groundwater, besides the anticipated sodium level shown that the underlying processes for instance, diffusion and transmission might efficiently mitigate the sodium level in groundwater. Conclusively, it can be convinced that the drop in groundwater levels was principally attributable to groundwater pumping escalating and physicochemical reaction between sodium and other parameters. The study has productively revealedshowcase of engaging time sequence investigation to trace the impermanence of sodium discharge and to envision the sodium absorption in groundwater. With the help of time series scrutiny, the enhancement of groundwater administration as well as pollutant control is in progress in Abuja, Northern Nigeria.

Compliance with ethical standards

Acknowledgments

We are very indebted to University of Abuja and Abuja Municipal Water Board, Nigeria management for permitting us to conduct the laboratory scrutiny and providing the necessary preliminary information while conducting this study. We do wish to extend our gratitude to the study participants, supervisor and data collectors.

Disclosure of conflict of interest

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

Authors' contributions

LOA AND ECI participated in designing the study and performed the data collection, LOA statistical analysis, and was the lead author of the paper, BDA and ECI participated in data analysis, and BDA, LOA, ECI revised subsequent drafts of the paper. All the authors read and approved the final manuscript.

Funding

The authors have not declared a specific grant for this research from any funding agency in the public, commercial, or not-for-profit sectors.

References

[1] Achieng A; Raburu O; Kipkorir E; Ngodhe S; Obiero K; Ani-Sabwa J. Assessment of water quality using multivariate techniques in River Sosiani, Kenya. Environ Monit Assess. 2017; 189(1): 280- 289. https://doi.org/ 10.1007/s10661-017-5992-5.

[2] Bamuwamye M; Ogwang P; Tumuhairwe V; Eragu R; Nakisozi H; Patrick E. Human Health Risk Assessment of Heavy Metals in Kampala (Uganda) Drinking Water. Journal of Food Research. 2007; 6(3): 6-16. http://dx.doi.org/ 10.5539/jfr.v6n4p6.

[3] Enitan I; Enitan A; Odiyo J; Alhassan M. Human Health Risk Assessment of Trace Metals in Surface Water Due to leachate from the Municipal Dumpsite by Pollution Index: A Case Study from Ndawuse River, Abuja, Nigeria. Open Chem. 2018; 16(1):214–227.https://doi.org/10.1515/chem-2018-0008.

[4] Emenike C; Tenebe T; Omole D; Ngene B; Oniemayin B; Maxwell O; Onoka B. Accessing safe drinking water in sub-Saharan Africa: Issues and challenges in south-west Nigeria. Sustainable Cities and Society. 2017; 30(2): 263–272. https://doi.org/10.1016/j. scs.2017.01.005.

[5] American Public Health Association, (https://books. google.co.uk/books/about/Standard Methods_for_the_Examination_ of.html?id=buTn1rmfSI4C&redir_esc=y. (Accessed 20 October 2018).

[6] Assubaie F. Assessment of the levels of some heavy metals in water in Alahsa Oasis farms, Saudi Arabia, with analysis by atomic absorption spectrophotometry, Arab. J. Chem. 2005; 89(2): 240–245. http://dx.doi.org/10.1016/j.arabjc.2011.08.018.

[7] Etteieb S; Cherif S; Tarhouni S. Hydrochemical assessment of water quality for irrigation: a case study of the Medjerda River in Tunisia. Applied Water Science. 2015; 7(2): 1–12. https://doi.org/10.1007/s13201-015-0265-3.

[8] Fijani E; Moghaddam A; Tsai F; Tayfur G. Analysis and assessment hydrochemical characteristics of Maragheh-Bonab plain aquifer, northwest of Iran. Water Resources Management. 2017; 31: 765–780. https://doi.org/10.1007/s11269-016-1390.

[9] Jalal A; Al-Tabbal; Kamel K. Suitability Assessment of Groundwater for Irrigation and Drinking Purpose in the Northern Region of Jordan. Journal of Environmental Science and Technology. 2012; 5(1): 274-290.https://doi.org/10.3923/jest.2012.274.290.

[10] Khound N; Bhattacharyya K. Multivariate statistical evaluation of heavy metals `in the surface water sources of Jia Bharali river basin, North Brahmaputra plain, India. Applied Water Science. 2016; 7(3): 2577–2586. https://doi. org/10.1007/s13201-016-0453-9.

[11] Kolawole S; Obueh H. Evaluation of the minerals, heavy metals and microbial compositions of drinking water from different sourcesin Utagba-Uno, Nigeria. ISABB-Journal of Health and Environmental Sciences. 2015; 2(1): 6-10. http://dx.doi.org/10.5897/ISAAB-JHE2015.0017.

[12] Odukoya A; Olobaniyi S; Oluseyi T; Adeyeye U. Health risk associated with some toxic elements in surface water of Ilesha gold mine sites, south west Nigeria, Environ. Nano technol. Monit. Manag. 2017; 8(1):290–296. http://dx.doi.org/ 10.1016/j.enmm.2017.10.005.

[13] US Environmental Protection Agency, Exposure Factors Handbook: (2011) Edition, U. S. Environ. Prot. Agency 1–1466 (doi:EPA/600/R-090/052F).

[14] APHA. Standard methods for the Examination of Water & Wastewater, 21st edition, 2005.

[15] WHO, WHO Guidelines for Drinking-water Quality, 4th Edition, 2011. ⟨http://dx.doi.org/10.1016/S1462-0758 (00)00006-6https://doi.org/10.1016/S1462-0758(00)00006-6⟩.