Public Health threat caused by sodium and chloride concentration in groundwater: A case study of Abuja, Nigeria.

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Abstract - This paper studies the municipal health threat originated from water used for both consumption and domestic deeds, as this will help in the prevention of water-related sicknesses and maintenance of good healthiness for human being that rely on water to survive. Also, groundwater chemical composition such as sodium and chloride was assessed using multivariate statistical techniques for five cities in Abuja, Nigeria. The quantities of chloride in boreholes water show a discrepancy at various sites, varying from 32.56mg/L to 564.12mg/L with an average value of 236.41mg/L while that of sodium ranged from 55.98mg/L to 515.45mg/L with an average value of 260.19mg/L. The Hierarchical cluster analysis revealed three common clusters in which the samplings can be grouped. The carcinogenic threat was calculated with circumscribed procedures by USEPA considering ingesting and dermal pathways. Total threat Index surpass 1.0 for sodium consumption in the scrutinizedlocalities was obtained from all locations.

Keywords: sodium, groundwater, elements, chloride, health, Abuja.

1. Introduction

On earth the issue about clean water distribution is of specific significance since water served as one of the fundamentalecologicalconstituentspreordained forlong-lasting contact with humansbody (Achieng et al. 2017). The mainportions of various substances, such that are crucial to life as well as poisonous ones come into human beings physiquethrough drinking water, thougharchetypes of human contact factors that infect the environsprincipally at low proportions arestill scantilyexamined, which can be either direct or indirect (Bamuwamye 2017; Assubaie 2015). Approachtothreat assessment permits is via estimatingthe genuine dose risk for humans as well as taking into consideration the exposure factors such as exposure of human lifetime, duration, and dosage.The most frequentlyutilized substitutionconsist of: lakes, rivers, boreholes, streams, seas,oceans, etc (USEPA 2011). Majority of these numeroussubstitution sources areprone to water contagion, which can be from most common sources of contaminationfor examples expulsion of domestic agrarian, and industrial wastewater into riverphysiques (Emenike et al.2018; Fijani et al.2017; Etteieb et al.2017).Groundwater is an essentialelement to human's life since is one of the natural resources that possess ostensiblegood microbiological attribute in the natural formwhich also served as fancied source of cleanwater distribution as treatment is restricted to disinfection. Visually,it appearsspotless as well as acceptable to numerousfamiliesas it is habitually free from odour besidesfrom time to time do possess apleasant taste (Igibah and Tanko 2019; Enitan et al. 2018). In spite of the professed safety connectedwith groundwater ingestion, numerous researches haveexposed that groundwater might also be amenable to contagion(Igibah and Tanko 2019; Emenike et al. 2018; Jan et al. 2010).Some features that affect the attributeof groundwater encompasses climate, geology of the aquifer, andhuman-relateddeeds(Khan et al. 2016; Assubaie 2015; Jalal et al. 2012).Majority of the public that hang onboreholes water sources don't aware of the attribute of waterthey ingest as they often guess that boreholes water has good water attribute. In some part of Nigeria, groundwater (boreholes water) is a strategiccomponent of the water resources as well as one of the sourcesof water distribution. Report have disclosed that roughly two-thirdsof South African inhabitantsrely on boreholes waterfor drinking with almost 65% of the total distributionin the rustic districts(Khound and Bhattacharyya 2016; Kolawole and Obueh 2015). Inthe rustic and peri-urban districts, most of the groundwaterdistributed are usually untreated, despite the fact that majority of the boreholesare positioned either close to a pit toilette, downstream ofsoakaway pits,adjacent landfills or dumpsites (Odukoya et al. 2017; Pawekzyk 2013; WHO 2011).Utilization of groundwater of unknown attribute putsthe users at threat to possible waterborne illnesses.The current study displays the qualified analysis of Abuja water attribute and estimation of itsportabilityvia the threat assessment technique.This research is carried outonAbuja district which comprises of 5 settlements, which is built-up, its zoneencompasses the administrative center with big industrialfirms that are answerable to high human-relatedeffect on the ecosystemtogether withunderground hydrosphere. Some part of the settlements (Gwagwalada, Kubwa and Bwari) are supplied with water from both central water board withpreliminary water treatment plus individual borehole wells with almost 42.8% of the borough population possessindividual water sources (Rasool et al. 2016; Wei et al. 2015). From the result of long-term surveillance ofchemical values in groundwater, it is perceived that a number of elements are discoveredfrom the increased concentrations which often surpassing the maximum admissible concentration that is explicatedthru some objective as well assubjective factors.

2. Materials and methods

Study region

The case study for this study is Abuja, the capital as well as center of Nigeria. This location is well explained thru Aso rock, a four hundred (400) meter megalith at the midpoint, and close by Zuma Rock, a seven hundred and ninety-two (792) metre megalith, northern part of the metropolis on Kaduna artery. It located within latitude 9.4° N as well as longitude 7.29° E. The inhabitants of Abuja is approximately 6,000,000 with a yearly advance speed of 35%, maintain its position of African rapidest developing metropolis. Abuja municipal double as the political and administrative center of Nigeria besides served via Nnamdi Azikiwe International Airport. Other contiguous metropolises that borders Abuja comprise of Mandalla, Keffi, Kaduna and Lokoja.

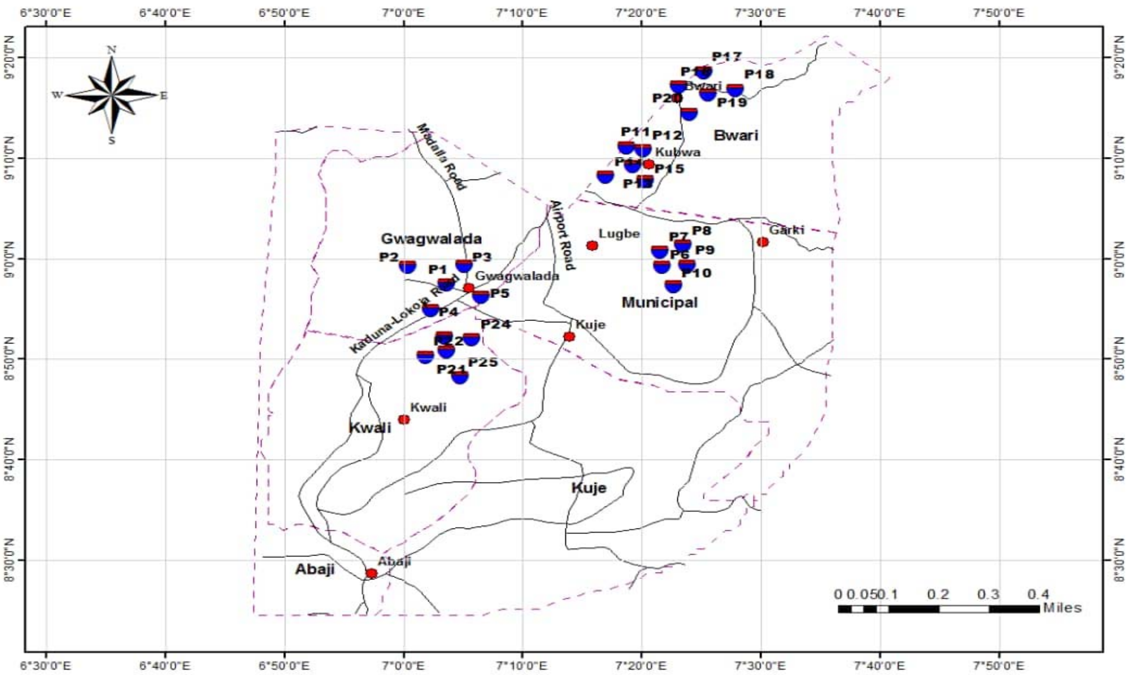


Fig. 1. Map of study district signifying the sampling locations.

Analytical methods

The on-site measurements were carried out on Twenty-five groundwater samplings collected from Abuja (Fig. 1) during March and July 2018 from boreholes taps situated in 25 dissimilar locations (P1–P25) via multiparameter Hanna HI98194 TDS/salinity meter / E. cond and Hanna HI2030 probe, besides scrutinized and compared with WHO(2011) water attribute standards.Exposure dose for human healthiness threat via these two paths could be work out using Equations 1plus 2as revised from the USEPA (2011),threat appraisal control for superfund approach. The parameters were slot in the Equations (1 and 2) to estimate the exposure threat connected with sodium and chloride accumulation cogitating consumption (EDD_{ING}) as well as dermal (EDD_{derm}) pathways correspondingly.

$$EDDing \quad = (Cw\ x\ \ WR\ x\ ER\ x\ ED) \div (MT\ x\ BW) \tag{1}$$

$$EDDderm = (CW\ x\ ER\ x\ EP\ x\ SR\ x\ ED\ x\ CF) \div (MT\ x\ BW) \tag{2}$$

where Cw is trace element concentration; WR is rate of water digestion (taken as 2 L/day and 1L/day for adults as well as children correspondingly) USEPA 2011; ED is exposure duration (taken as 30 years and 6 years for adult and child correspondingly); ER is the exposure rate (taken as 365days); BW specifies body weightiness (taken as 32.5kg and 72kg for child and adult correspondingly); MT specifies mean time (taken as 10,950 days as well as 2190 days for adult and child correspondingly); SR denotes skin apparent region (taken to be 6365cm^2 and 19,652cm^2 for child as well as adult correspondingly); EP signifies exposure period (taken as 350days); Kp is the skin observance feature (taken as 1/100); CF denotes conversion factor (taken to be 1/100). DI represents average daily intake (taken to be 2.2L/day).

To estimate the chronic health risks TI, Equations 3 and 4 was used

$$CDI = CW\ x\ (DI \div BW) \quad (3)$$

$$TItotal = (EDDing + EDDderm) \div RfD \quad (4)$$

$$TItotal = HQin + HQde$$

Where RfD is the oral reference dose, children and adult (taken as 400 µg/kg-day and 500 µg/kg-day respectively for sodium), as stated by ITIS (Integrated Threat Information System) databank of the USEPA. RfD of chlorideis100µg/kg-day. A major threat may ensue for cancer impact if the Threat index is above one (>1). The Threat index value below one (<1) implies that there is no cancer coincidental effect occurring. Meanwhile, The figures in Tables 5 and 6 shows the EDD_{ING}in addition to HQ_{IN} of chloride and sodium accumulation in the water samplings correspondingly. Also, deliberates on the TI for adults and children acquired from various sampling sites (P1−P25). Additionally, the figures in Tables 7and 8 indicates the EDD_{DE} in addition to HQ_{DE} of chloride and sodium correspondingly, whereas Table 9 shows chronic daily intake (CDI) calculated using equation (3). The data acquired from Tables 5 -9, were utilized to compute the total Threat Index (TI) values (Table 10) for sodium in addition to fluoride. The total Threat index (TItotal) was computed for carcinogenic threat based on Equation (4). The TI value not more than one is considered to be safe for the users.

Statistical analysis

The descriptive statistics charts of the collected boreholes water samplings are displayed in Fig. 2(a-r). To checked likely connections, degree of likeness as well as discrepancy that exist between the various localities, Hierarchical Cluster scrutiny (HCS) method was employed. Fig. 3 and 4 reveals the Ward linkage dendrogram that categorized the parameters and observed samplings. The vital parameters utilized for computing the exposure threat connected with sodium and chloridecontagion in children and adults, provided by the USEPA (2011) was utilized to calculate the Exposure daily dose (EDD) of each pollutant.

3. Results and discussion

Table 1indicates the average values of Chloride (Cl)gotten during the course of the evaluation varied from 32.56 to 564.12 mg/L (milligram per litre), and were further than the suggested concentration from < 0.1 as well as 250 mg/L submit by WHO, for domestic (Housing) water usage while, sodium mean values ranged from 55.98 mg/L to 515.45mg/L as well as beyond Who suggested limit of < 0.1 and 50 mg/.L. Pearson's correlation constants were computed for every single hydrogeological variables as exhibited in Table 2. A negative correlation was perceivedamongst Na in addition to Cl (α = 0.05, r = -0.65). The rate of violation of water attribute parameters versus WHO clean water attribute

Table 1. Descriptive statistics of water samples collected from the study site

Variables	F^- (mg/l)	TDS (mg/l)	EC (µS/cm)	Cl^- (mg/l)	$SO4^{2-}$ (mg/l)	Na^+ (mg/l)
Mean	1.281068.24	1796.87	236.41	447.23	260.19	
Min	0.47468.40	497.34	32.56	34.56	55.98	
Max	1.842122.32	3310.11	564.12	890.65	515.45	
SD	0.45577.44	857.13	178.23	307.84	195.77	
V	0.21333431.44	734672.28	31764.28	94764.32	38324.82	
Kurtosis	-0.96	0.74	-0.10	0.88	0.03	-1.78
Skewness	-0.32	-0.62	-0.82	-0.48	-1.35	0.27
Q1	1.02493.78	1162.40	169.01	172.40	57.40	
Q3	1.771178.77	2352.98	323.73	765.71	483.39	
WHO	1.5	1000	1500	250	250	50

Table 2. Pearson coefficient

P	TDS	EC	Cl^-	SO_4^{2-}	HCO_3^-	F	K	Na^+	Ca
TDS	1.00								
EC	0.29	1.00							
Cl	0.67	0.64	1.00						
$SO4^{2-}$	-0.23	0.07	0.08	1.00					
HCO3	-0.65	-0.31	-0.40	0.56	1.00				
F	-0.53	-0.23	-0.57	-0.24	0.17	1.00			
K	-0.05	0.77	0.40	0.46	0.06	-0.09	1.00		
Na	-0.54	-0.69	-0.65	0.18	0.64	0.38	-0.47	1.00	
Ca	0.28	-0.34	-0.15	-0.63	-0.27	0.07	-0.55	-0.06	1.00

criterions was computed as a percent of the over-all number of times a variable surpassed set standards as presented in Table 3. It was discovered that Na^{2+}, SO_4^{2+}, EC, Mg^{2+}, TDS, HCO_3^-, F^-, Fe^{2+}, TH, and Cl^- indicated the worstnon-conformity of drinking water standards with percentagenon-compliance of 100, 76, 64, 56, 56, 44, 40, 40, 36, and 24 %, correspondingly. Health studies have shownthat water with high contents of Na^{2+} and Cl^-can be ascribed to expansionof industrial water effluence most likely from unrestrained expulsion of industrial waste (Emenike et al. 2018; Assubaie 2015). Nevertheless, above 50and 250mg/L was revealed in water samplings taken from taps waterP1–P25 and P6-P10 respectively, during the months of April to September. Also, with reverence to the study region, Na^{2+} and Cl^- may have been initiated into groundwater from septic tank discharge,urban solid waste leachate, industrial bilge water, animal, as well as agricultural waste. The high connection coefficient between Na^{2+} and Cl^-in boreholes water samplings is frequently testified in the literature and could be ascribed to the suspension of halite, anhydrite, as well as gypsum, (Emenike et al. 2018;Fijani et al. 2017). Likewise, both Na^{2+} and Cl^- are broadlystrewn in nature as NaCl, these ions mightcome into the water viaanimal waste, saltwater,path deicers, weathering of rocks, septic tank discharge,agrarian chemicals, municipal landfill leachate, basin saline, and irrigation acquittal (Emenike et al. 2018;Achieng et al.2017).

Table 3: Different samples violation values

Parameter	Unit	WHO Limit	Violation Number	Violation %	Within %
pH		6.5 - 8.5	0	0%	100%
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%
HCO_3^-	mg/l	500	10	40%	60%
F^-	mg/l	1.5	10	40%	60%
Na^+	mg/l	50	25	100%	0%
Fe^{2+}	mg/l	0.3	11	44%	56%
Mg^{2+}	mg/l	50	14	56%	44%
TH	mg/l	500	9	36%	64%

Multivariate analysis

The interactions amongst the metals were determined thru HCA and they were clustered based on the dissimilarities as well as similarities between disparate metals. Dendrogram scrutiny formed 3 clusters based on the metals spatial dispersal within five months (Fig. 3&4). Cluster 1 contained P1-P4 and P20-P25, cluster 2 comprisesof P5-P10 and cluster 3 has P11 –P19 (Table 2). Cluster 1 in the dendrogram created for Gwagwalada and Kwali town is analogous with the aforesaid cluster 1, whereas cluster 2 comprises of Lugbe satellite town and cluster 3 is Bwari satellite town of Abuja (Fig. 1). Cluster 1 was found to have the best hydrochemical attributethen cluster 2 with percentage non-comformity of 0.00 and 10.0%, correspondingly. The decreasing direction of water attribute was cluster 3> cluster 2 > cluster 1. The outcomes of cluster scrutiny buoyed the correlation results, which recommended that the chosen metals are from natural as well as anthropogenic sources. Fertilizers excess or fungicides from the farming, leachates into groundwater through the aquifer could also affect water attribute.

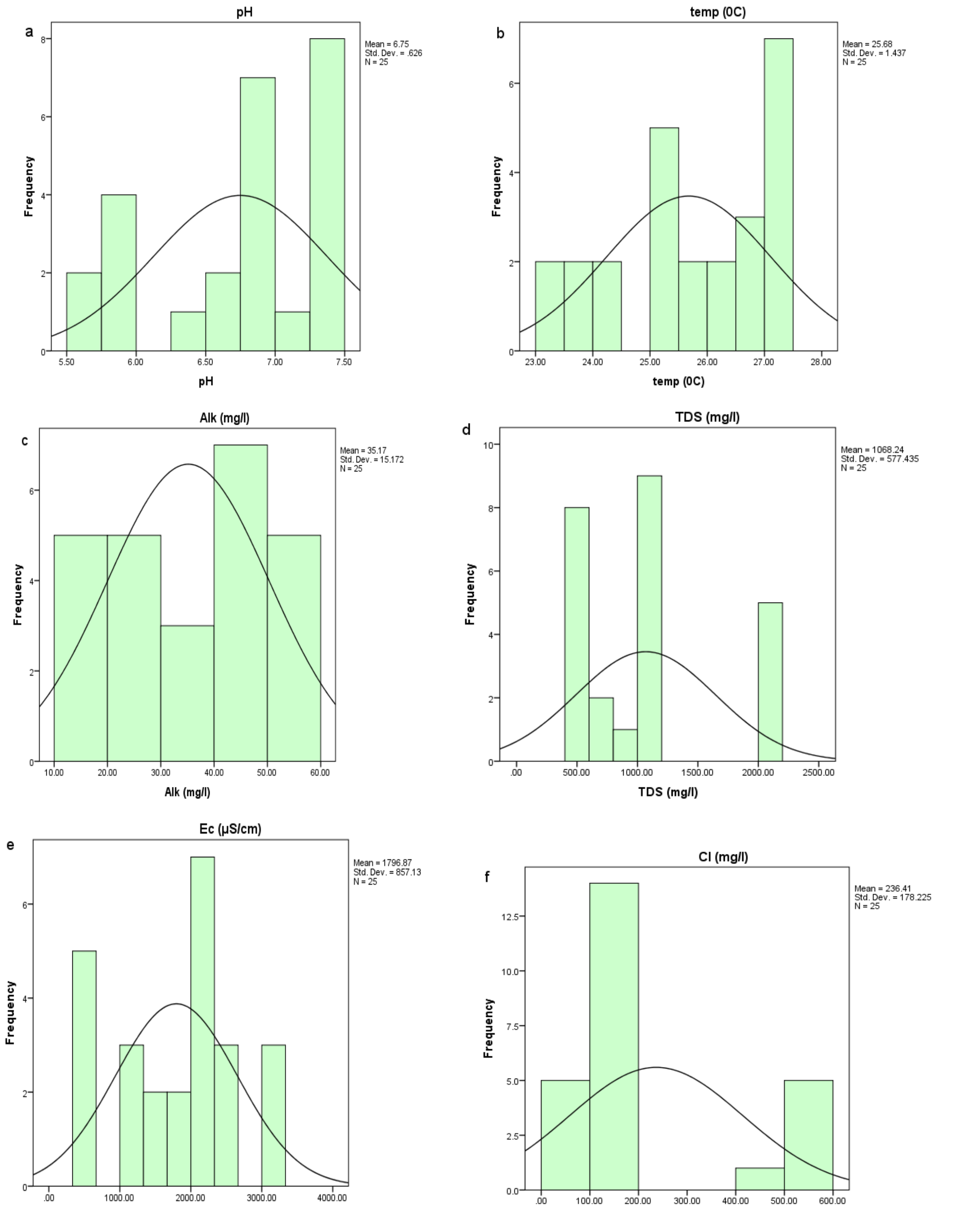


Fig. 2. Histogram shown normal curve of (a) pH (b) Temperature (c) Alkalinity (d) TDS (e) EC (f) Cl^- : Histogram shown normal curve of (g) SiO_2 (h) CO_3^{2-} (i) NO_3^- (j) HCO^{3-} (k) F^- (l) K^+ : Histogram shown normal curve of (m) Na^+ (n) Fe^{2+} (o) Ca^{2+} (p) Mg^{2+} (q) Mn (r) SiO_2.

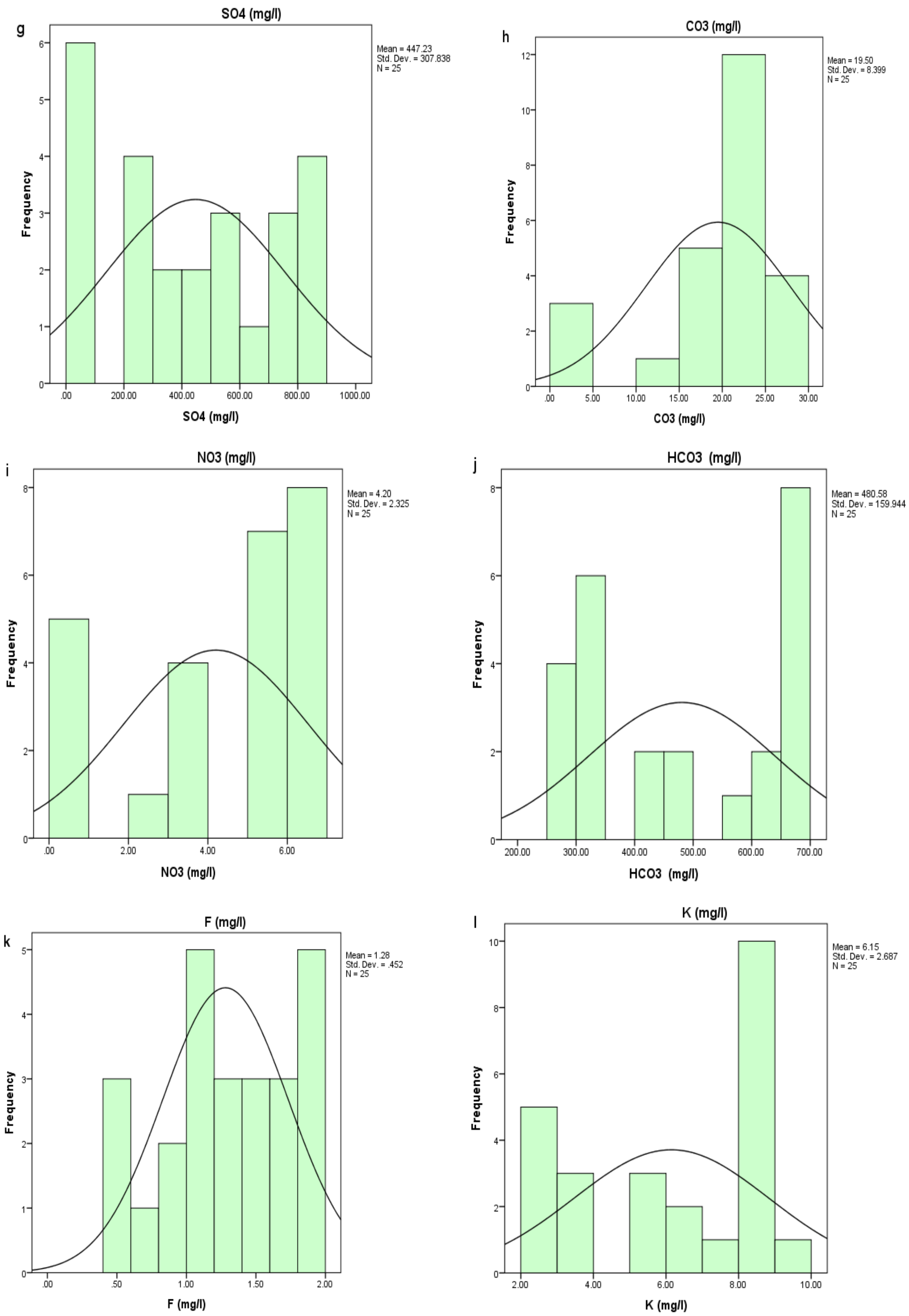
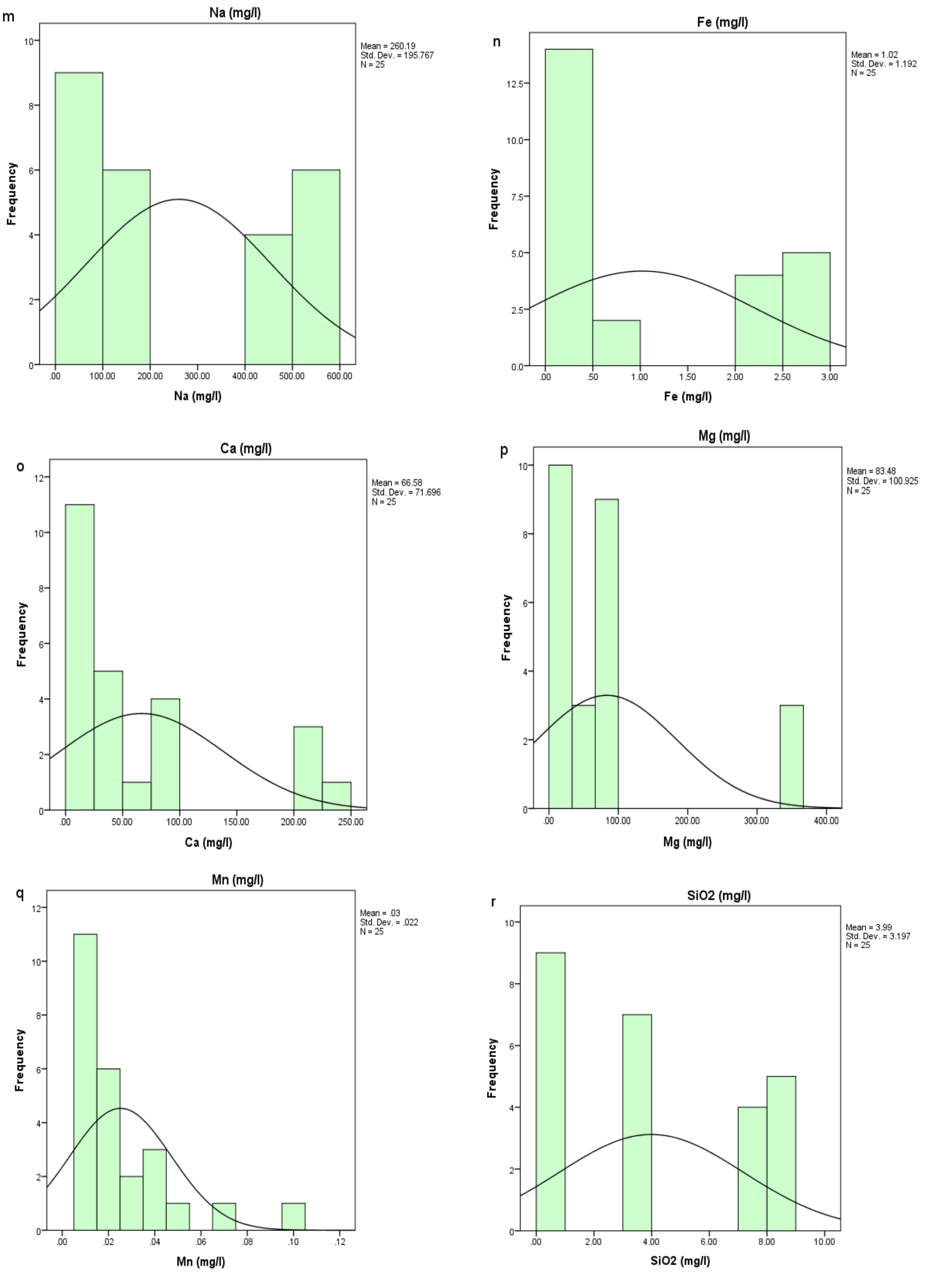


Fig.2. (continued)



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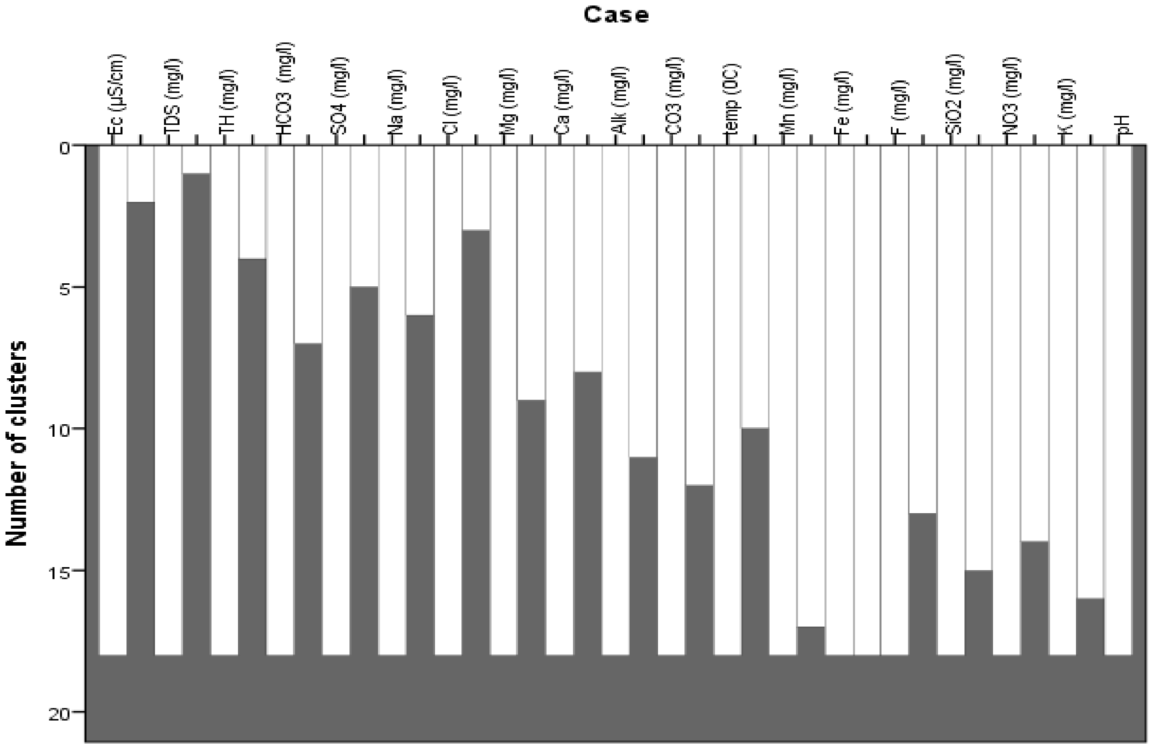

Fig.3. Dendrogram demonstrating all parameters analysed

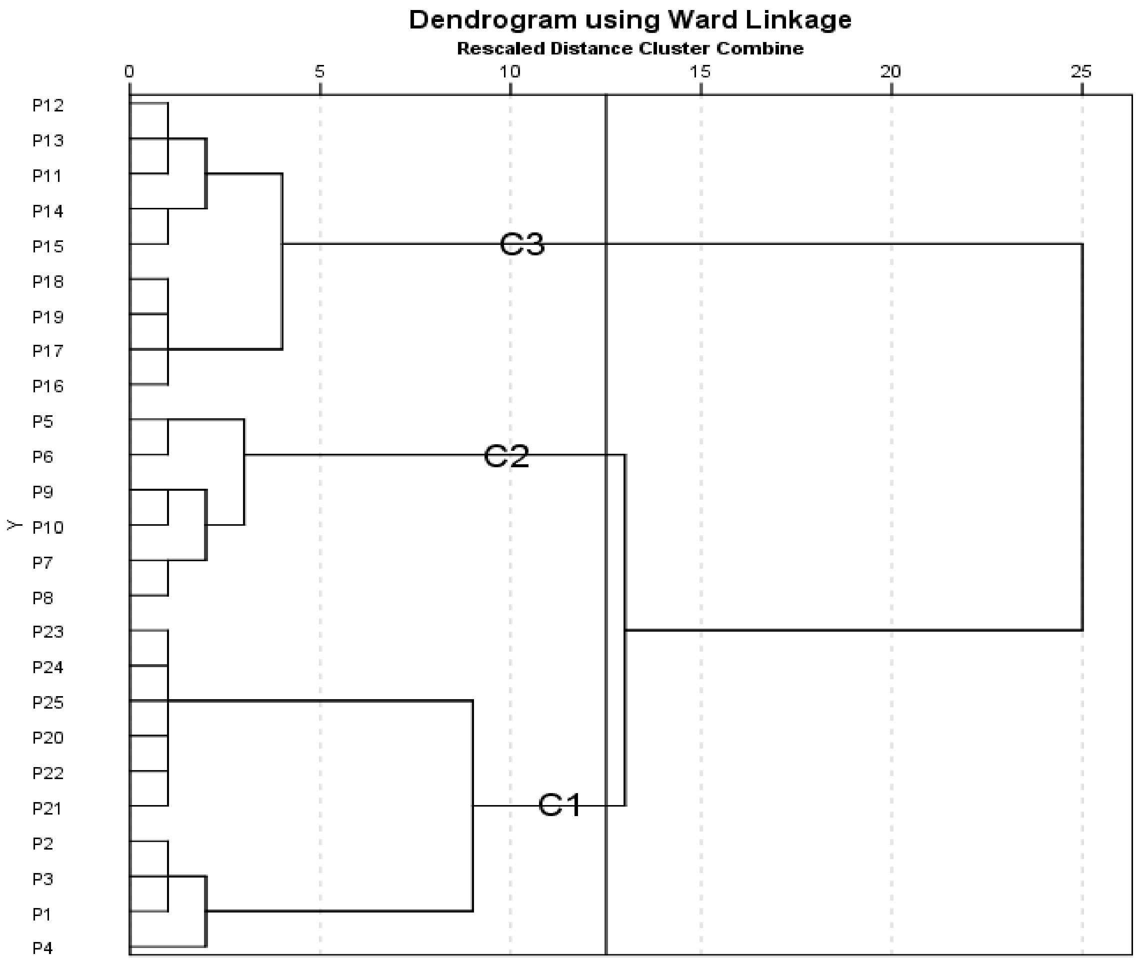

Fig.4. Dendrogram indicating all water samples from study locations

Table 4. Cluster group of the water attribute parameters

Cluster 1	Cluster 2	Cluster 3
P1	P5	P11
P2	P6	P12
P3	P7	P13
P4	P8	P14
P20	P9	P15
P21	P10	P16
P22		P17
P23		P18
P24		P19
P25		

Appraisal of human health threat due to heavy metalsin groundwater samplings

Health threat appraisal archetypal by the USEPA were utilized to compute the healthiness threats that heavy metals can impose on human being thru digestion in addition to dermal ingestion of groundwater in Abuja settlement. The exposure state thru EDD_{ing} and EDD_{derm} were appraised for the months of April to September. The end results propounded that impurities from the boreholes within Abuja vicinity thru absorption as well as dermal passageways were the main exposure means to people in this settlement. Health correlated threat linked with the exposure via absorption hang on lifetime, weightiness as well as groundwater capacity ingested by an individual,which was computed by means of the quantified minimum and maximum accumulation of Cl^- and Na^{2+}. The TQ (threat quotient) which is numeric approximation of the widespread toxicity prospective modelled via single element insidesole track of exposure were work out, both HQ_{in} as well as $HQ_{DE}$from April and September were below one unit (Table 5 - 8) for adults as well as children. This postulates slight or no antithetical healthiness impact are likely to be initiated through these metals when the boreholes water is swigged thru dermal consumption for all ages. The outcomes are closely related to the discoveries of Emenike et al. 2018, in which HQ_{ing} for Cl^- and Na^{2+}accumulationfrom tested groundwater for children were higher than one unit.The major instigators for carcinogenic healthiness threat in both paths were Cl^- and Na^{2+}. The valued of cumulative threat quotients (TI) via metal functioned as a predictable assessment instrument to guesstimate high-end threat instead of low end- threat so as to safeguard the societies (Table 9). This helped as exhibitpictogram to discover any majorsignificanthealthinessthreat that heavy metals contact in the groundwater couldenforce on the humankinds and if there is any divergence in total health threat all through the study period. The computed total HQ values were below one unit (Table 5 - 8), along these lines, exposure to these variables via mouth absorption as well as dermal ingestion thru the skin might possibly not wield harmful or collective adversarial threat on the occupiers of this settlement. As a whole, health threat evaluation index by means of the global arcinogenic threat evaluation (TI), CDI and HQthru absorption and dermal ingestion paths were below one. This demonstrates that groundwater possess a reduced amount of significant healthiness endangerments to both adults as well as children thru the paths, contrariwise measures must be invent so as to evade heavy metals accumulation that might pose any healthiness complications specifically in children.Carcinogenic threat (CT or TTI) can be expressed as the incrementalodds that humans will develop cancer duringone's life time which isattributable to exposure below particular conditionswere work out for the selected metals in this paper (Fijani et al. 2017; Odukoya et al. 2017; Kolawole and Obueh 2015). Carcinogenic threat of Na and Cl for Abuja groundwater were work out for both children and adults (Table 9). Only sodiumvalues from location P5, P6, P7, P8, P9, P10, P11, P23 and P25 of all the water samples examined for children are within unity, whereas all sodium values of all location for adults are above unity and though the rule state that value higher than unity is great concern.Nevertheless, all chloride values for both adults as well as children for all location is below unity except P12 to P14 for adults.Hence,appropriate control measures to safeguard human's health within the study region must be put in place so as toensure security of users. Likewise, rigorous efforts arevital for feasibility of the groundwater by eliminatingthese metals.

Conclusions

The carcinogen threat for human healthiness in Abujaprovince conditioned by groundwater ingestionfrom diverse aquifer structures without preliminary treatment is tolerable. Though, to generate good clean and drinking water, it is indispensable to treat for higher chemical quantitiesremoval including sodium and chloride.Only 76.0% boreholes possess perfect water attribute in terms of Na^{2+} and Cl^- concentration with 0% found to be in the peripheral water attribute group, whereas 100% fell in the unsuitable water attribute category. In respect to chemical properties, it is hazardous for occupierwithin the examined province to use the taps water for domestic deeds without treatment. The measured quantities of Na^{2+} and Cl^{-} for some of the examined boreholes water were noticed to be greater than the suggested limits by WHO. The HQ and the overall carcinogenic health threat indices (HI) through the absorption as well as dermal ingestion of the taps water were below one. Nevertheless, the results indicated the likely threat of some of the picked metals on human, specifically children. Thekey contributors to carcinogenic threat were Na^{2+} for both pathways. It is hence suggested that water attribute studies must be prioritize by adding it into the integrated growth plans (IGPs), and to be appraised on a consistent basis so as to evaluate contagion threats. Healthiness and hygiene talk is extremely required for people in rustic regions on account of poor hygiene and water management practices. Additionally, advance studies are suggested to examine the point sources of contagion and potential causes of high quantities of sulphate, TDS and Bicarbonate level in the boreholes around Lugbe-Abuja town.

Acknowledgments

The authors wish to express gratitudeto the management of Geography Department, University of Lagos for the enabling atmosphere for the study.

References

[1] Achieng A. O.,Rabur E., Kipkorir S., Ngodhe K., Obiero J.& Ani-Sabwa. 2017 Assessment of water quality using multivariate techniques in River Sosiani, Kenya.Environ Monit Assess., 189(6), 280- 289. https://doi.org/ 10.1007/s10661-017-5992-5.

[2] Assubaie F. 2015 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., 8(3) 240–245.http://dx.doi.org/10.1016/j.arabjc.2011.08.018.

[3] A.W.W.A. 2005APHA, Standard methods for the Examination of Water & Wastewater, 21st edition, 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).

[4] Bamuwamye M., Ogwang P., Tumuhairwe V., Eragu R., Nakisozi H. & Patrick E. 2017 Human Health Risk Assessment of Heavy Metals in Kampala (Uganda) Drinking Water. Journal of Food Research, 6(2), 6-16. http://dx.doi.org/ 10.5539/jfr.v6n4p6.

[5] Enitan I., Enitan A., Odiyo J. & Alhassan M. 2018Human 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.,16(5),214–227.https://doi.org/10.1515/chem-2018-0008.

[6] Emenike P.C., Nnaji C.C. & Tenebe I.T. 2018 Assessment of geospatial and hydrochemical interactions of groundwater quality, southwestern Nigeria. Environ Monit Assess., 190(3), 440-457. https://doi.org/10.1007/s10661-018-6799-8.

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

[8] Fijani E., Moghaddam A., Tsai F. & Tayfur G. 2017 Analysis and assessment hydrochemical characteristics of Maragheh-Bonab plain aquifer, northwest of Iran. Water Resources Management. 31(2), 765–780. https://doi.org/10.1007/s11269-016-1390.

[9] Igibah E., Tanko J. 2019. Assessment of Urban groundwater quality using Piper trilinear and multivariate techniques: a case study in the Abuja, North-central, Nigeria. Environmental Systems Research, 8(14), 1-17. doi.org/10.1186/s40068-019-0140-6.

[10] Jan F., Ishaq M., Khan S., Ihsanullah I., Ahmad I. &ShakirullahM. 2010 A comparative study of human health risks via consumption of food crops grown on waste water irrigated soil (Peshawar) and relatively clean water irrigated soil (lower Dir), J. Hazard. Mater. 179(4), 612–621. http://dx.doi.org/10.1016/j.jhazmat.2010.03.047.

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

[12] Khan K., Lu Y., Khan H., Zakir S, Ihsanullah., Khan S., Khan A, Wei L. & Wang T. 2013 Health risks associated with heavy metals in the drinking water of Swat, northern Pakistan, J. Environ. Sci., 25 (2) 2003–2013. http://dx.doi.org/10.1016/ S1001-0742(12)60275-7.

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

[14] Kolawole S. & ObuehH. 2015 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, 2(2), 6-10. http://dx.doi.org/10.5897/ISAAB-JHE2015.0017.

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

[16] Pawełczyk A. 2013 Assessment of health risk associated with persistent organic pollutants in water. Environmental Monitoring and Assessment. 185(5), 497-508. http://dx.doi.org/10.1007/s10661-012-2570-8.

[17] Rasool A., Xiao T., Farooqi A., Shafeeque M., Masood S., Ali S., Fahad S. & NasimW. 2016 Arsenic and heavy metal contaminations in the tube well water of Punjab, Pakistan and risk assessment: a case study.Ecol. Eng., 95(3), 90–100. http://dx.doi.org/ 0.1016/j.ecoleng.2016.06.034.

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

[19] Wei H., Le Z., Shuxian L., Dan W., Xiaojun L., Lan J. & XipingM. 2015 Health risk assessment of heavy metals and polycyclic aromatic hydrocarbons in soil at coke oven gas plants. Environmental Engineering and Management Journal, 14(1), 487-496. http://omicron.ch.tuiasi.ro/EEMJ.

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

Table 5: EDD_{ING} and HQ_{IN} values via ingestion pathway for sodium

Sample points	EDD_{IN} (Children)	EDD_{IN} (Adult)	HQ_{IN} (Adults)	HQ_{IN} (Children)
P1	5.95	5.37	1.12E-02	1.49E-02
P2	5.92	5.35	1.19E-02	1.48E-02
P3	5.96	5.38	1.19E-02	1.49E-02
P4	5.95	5.37	1.19E-02	1.49E-02
P5	1.75	1.58	3.50E-03	4.38E-03
P6	1.72	1.56	3.45E-03	4.31E-03
P7	1.72	1.56	3.45E-03	4.31E-03
P8	1.75	1.58	3.49E-03	4.37E-03
P9	1.78	1.61	3.56E-03	4.45E03
P10	1.81	1.64	3.62E-03	4.53E-03
P11	1.83	1.65	3.66E-03	3.49E-02
P12	13.95	12.59	2.79E-02	3.96E-02
P13	15.84	14.30	3.17E-02	3.97E-02
P14	15.86	14.32	3.17E-02	3.96E-02
P15	15.84	14.30	3.17E-02	3.96E-02
P16	15.83	14.29	3.17E-02	3.96E-02
P17	15.76	14.23	3.15E-02	3.94E-02
P18	15.71	14.18	3.14E-02	3.92E-02
P19	14.04	12.68	2.81E-02	3.51E-02
P20	13.32	12.02	2.66E-02	3.33E-02
P21	13.14	11.86	2.63E-02	3.28E-02
P22	5.83	5.27	1.17E-02	1.46E-02
P23	1.74	1.57	3.47E-03	4.34E-03
P24	5.43	4.90	1.09E-02	1.36E-02
P25	1.72	1.56	3.45E-03	4.31E-03

Table 6: EDD_{ING} and HQ_{IN} values via ingestion pathway for chloride

Sample points	EDD_{ING} (Children)	EDD_{ING} (Adults)	HQ_{IN} (Adults)	HQ_{IN} Children)
P1	5.55	5.01	5.01E-02	5.55E-02
P2	5.83	5.27	5.27E-02	5.83E-02
P3	5.57	5.03	5.03E-02	5.57E-02
P4	5.68	5.12	5.12E-02	5.67E-02
P5	5.72	5.17	5.17E-02	5.72E-02
P6	17.36	15.67	0.16	0.17
P7	16.81	15.17	0.15	0.17
P8	16.44	14.84	0.15	0.16
P9	16.12	14.55	0.15	0.16
P10	16.74	15.11	0.15	0.17
P11	1.03	0.93	9.29E-02	1.03E-02
P12	1.00	0.90	9.04E-02	1.00E-02
P13	1.00	0.91	9.06E-02	1.00E-02
P14	1.00	0.91	9.05E-02	1.00E-02
P15	1.05	0.95	9.47E-02	1.05E-02
P16	5.25	4.74	4.74E-02	5.25E-02
P17	5.80	5.23	5.23E-02	5.80E-02
P18	5.83	5.26	5.26E-02	5.83E-02
P19	5.40	4.87	4.87E-02	5.40E-02
P20	5.86	5.29	5.29E-02	5.86E-02
P21	5.15	4.64	4.65E-02	5.15E-02
P22	5.93	5.35	5.35E-02	5.92E-02

P23	5.84	5.27	5.27E-02	5.84E-02
P24	5.96	5.38	5.38E-02	5.96E-02
P25	13.97	12.61	0.13	0.14

Table 7: EDD_{derm} and HQ_{DE} values for sodium

Sample points	**EDD_{derm} (Children)**	**EDD_{derm} (Adults)**	**HQ_{DE} (Adults)**	**HQ_{DE} (Children)**
P1	1325.82	1847.75	2.65	3.32
P2	1319.92	1839.54	2.64	3.30
P3	1336.78	1849.09	2.65	3.32
P4	1326.03	1848.04	2.65	3.32
P5	390.03	543.57	0.78	0.98
P6	383.72	534.78	0.77	0.96
P7	383.79	534.88	0.77	0.96
P8	389.21	542.42	0.78	0.97
P9	396.81	553.03	0.79	0.99
P10	403.74	562.68	0.81	1.01
P11	407.51	567.93	0.82	1.02
P12	3106.72	4329.73	6.21	7.77
P13	3528.21	4917.15	7.06	8.82
P14	3533.21	4924.12	7.07	8.83
P15	3528.21	4917.15	7.06	8.82
P16	3525.60	4913.52	7.05	8.81
P17	3511.89	4894.41	7.02	8.78
P18	3498.94	4876.36	7.00	8.74
P19	3127.90	4359.25	6.26	7.82
P20	2966.54	4134.37	5.93	7.42
P21	2926.17	4078.10	5.85	7.32
P22	1299.36	1810.88	2.60	3.24
P23	386.81	539.08	0.77	0.97
P24	1210.25	1686.69	2.42	3.03
P25	383.93	535.07	0.77	0.96

Table 8: EDD_{derm} and HQ_{DE} values for chloride

Sample points	EDD_{derm} (Children)	EDD_{derm} (Adult)	HQ_{DE} (Adults)	HQ_{DE} (Children)
P1	1236.16	1722.80	7.61E-02	12.36
P2	1299.22	1810.67	2.05E-02	12.99
P3	1241.51	1730.25	0.30	12.42
P4	1264.20	1761.87	0.30	12.64
P5	1274.48	1776.20	0.30	12.75
P6	3866.83	5389.07	1.86E-02	38.67
P7	3743.92	5217.78	3.97E-02	37.47
P8	3661.80	5103.34	6.83E-02	36.62
P9	3590.31	5003.70	6.68E-02	35.90
P10	3729.05	5197.05	6.82E-02	37.29
P11	229.29	319.55	6.29E-02	2.29
P12	223.19	311.05	6.19E-02	2.23
P13	223.53	311.53	6.12E-02	2.24
P14	223.39	311.33	4.90E-02	2.23
P15	233.61	325.57	5.86E-02	2.34
P16	1169.88	1630.42	1.85E-02	11.70
P17	1291.75	1800.27	1.88E-02	12.92
P18	1298.61	1809.93	1.99E-02	12.99
P19	1201.89	1675.03	2.04E-02	12.02
P20	1305.46	1819.38	5.89E-02	13.06
P21	1147.05	1598.61	2.04E-02	11.47
P22	1319.92	1839.54	1.97E-02	13.20
P23	1300.12	1811.93	4.90E-02	13.00
P24	1326.78	1849.09	2.08E-02	13.27
P25	3111.31	4336.13	1.86E-02	31.11

Table 9: Chronic daily intake (CDI) for sodium and chloride

Sample points	CDI Sodium		CDI Chloride	
	Children	Adults	Children	Adults
P1	13.09	5.91	12.21	5.51
P2	13.03	5.88	12.83	5.79
P3	13.10	5.91	12.26	5.53
P4	13.10	5.91	12.49	5.63
P5	3.85	1.74	12.59	5.68
P6	3.79	1.71	38.19	17.24
P7	3.79	1.71	36.97	16.69
P8	3.84	1.74	36.16	16.32
P9	3.91	1.77	35.46	16.00
P10	3.99	1.80	36.83	16.62
P11	4.02	1.82	2.26	1.02
P12	30.68	13.85	2.20	1.00
P13	34.84	15.73	2.21	1.00
P14	34.89	15.75	2.21	1.00
P15	34.84	15.73	2.31	1.04
P16	34.82	15.72	11.55	5.22
P17	34.68	15.65	12.76	5.76
P18	34.55	15.60	12.82	5.79
P19	30.89	13.94	11.87	5.36

P20	29.30	13.22	12.89	5.82
P21	28.90	13.04	11.33	5.11
P22	12.83	5.79	13.04	5.88
P23	3.82	1.72	12.84	5.80
P24	11.95	5.40	13.10	5.92
P25	3.79	1.71	30.73	13.87

Table 10: Total Threat index (TTI) for sodium and chloride

Sample points	**TTI_{total}**			
	Sodium		**Chloride**	
	Children	Adults	Children	Adults
P1	3.33	3.71	12.42	0.13
P2	3.32	3.69	13.05	7.31E-02
P3	3.33	3.71	12.47	0.35
P4	3.33	3.71	12.69	0.35
P5	0.98	1.09	12.80	0.35
P6	0.96	1.07	38.84	0.18
P7	0.96	1.07	37.61	0.19
P8	0.98	1.09	36.78	0.22
P9	1.00	1.11	36.06	0.21
P10	1.01	1.13	37.46	0.22
P11	1.02	1.14	2.30	7.22E-02
P12	7.80	8.68	2.24	7.09E-02
P13	8.86	9.86	2.25	7.02E-02
P14	8.87	9.88	2.24	5.81E-02
P15	8.86	9.86	2.35	6.80E-02
P16	8.85	9.86	11.25	6.59E-02
P17	8.82	9.82	12.98	7.12E-02
P18	8.79	9.78	13.04	7.25E-02
P19	7.86	8.74	12.07	6.91E-02
P20	7.45	8.29	13.11	0.11
P21	7.35	8.18	11.52	6.69E-02
P22	3.26	3.63	13.26	7.32E-02
P23	0.97	1.08	13.06	0.10
P24	3.04	3.38	13.33	7.45E-02
P25	0.96	1.07	31.25	0.15