CEDTECH International Journal of Environmental Science & Biotechnology
Volume 2, Number 1, March 2021
http://www.cedtechjournals.org
ISSN: 2756-4541

DETERMINATION OF TRACE ELEMENTS FROM VARIOUS WATER SOURCES IN KADUNA METROPOLIS, NIGERIA

A. Dadan Garba[1], S.K. Ouki[2], S.J. Hughes[2], N.I. Ward[3], G Lord[3]
[1]Department of Geography, Nigerian Defence Academy, Kaduna, Kaduna State, Nigeria
[2]Centre for Environmental Health Engineering, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, GU2 7XH, United Kingdom
[3] ICP-MS Facility, Department of Chemistry, Faculty of Engineering and Physical Science, University of Surrey, Guildford, GU2 7XH, United Kingdom
Email: adgtonga@gmail.com,

ABSTRACT
The study assessed the concentrations of trace elements from various water samples collected from groundwater (hand- dug wells), surface water (streams and rivers) and public tap water in the study area. Trace elements in water samples were analysed using Inductively Coupled Plasma Mass- Spectrometry (ICP-MS). Elemental concentrations in the water samples were compared with WHO guidelines and Nigerian standards. Trace elements (Arsenic, Molybdenum, Selenium, Chromium, Copper& Lead) concentrations were found to be generally below the guideline limits of the regulatory bodies with the exception of some elements which were raised at various sampling sites in the industrial areas (Manganese near textile industries; Nickel near vehicle assembly plant) whilst Copper& Zinc were higher in tap water, probably due to pipe aging.. Other than these, tap water sources had the least concentrations perhaps due to water treatment. Generally, trace elements were found in groundwater sources in residential and commercial areas and surface water sources in industrial and refinery areas.

Keywords: *Trace Elements, Groundwater, Surface Water and Tap Water Sources, WHO Guidelines, Nigerian Standards, Kaduna Metropolis.*

INTRODUCTION
Heavy metals and trace elements are emitted into the environment through natural and anthropogenic processes and pathways. These include air via combustion, extraction and processing; surface water via runoff, releases from storage and transport as well as through the soil, groundwater or crops (Jarup, 2003). Trace elements are found at levels of 0.01- 10mg/L (body content- 0.01 to 10 mg/kg) (O'Reilly, 2010). The main trace elements found in water are Al, As, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, V and Zn (Ward, 2000).

Water contamination by trace elements may be due to rock weathering causing an excess of water hardness and the presence of Fe, Mn and other dissolved solids (Purcell, 2003). Furthermore, water quality can be influenced by anthropogenic factors, such as the still felt consequences of the 1953 methyl mercury pollution in Minamata, Japan (Sakamoto *et al*., 2001 and Ekino et al., 2007). Regarding specific trace elements Arsenic (As)- in groundwater may result from mineral dissolution due to volcanic activity (Christodoulidou *et al.,* 2012) and in surface runoff from mining waste tips or areas with certain types of metalliferous ores and from the use of As containing pesticides (Ratnayaka *et al.,* 2009). Cadmium (Cd) arises from the use of zinc to galvanise pipes or other metal fittings and their eventual deterioration (Ratnayaka *et al.,* 2009). Cadmium fumes could cause life threatening illnesses such as acute pulmonary condition, kidney damage and renal lesion (Jarup, 2003).

The presence of chromium (Cr) in natural water may be due to weathering of Cr containing rocks, leaching of soils and from industrial operations and can be carcinogenic (Kimbrough *et al*., 1999, (Sawyer *et al.*, 2003). Cobalt (Co)normally occurs at levels around 10 µg/L in natural waters but the concentrations may be higher in wastewaters (APHA, 2005). Cobalt is an essential element in minute amounts, around 20 mg. However, in excess it can cause dermatitis and is considered carcinogenic. Copper (Cu) trace amounts of copper can be found in soft, acid moorland waters. The most usual source of copper in drinking water is from the corrosion of Cu and Cu containing alloys used in domestic plumbing systems.

Iron (Fe) is found in most natural waters either in solution or suspension as a colloid. Iron salts are used as coagulants in water treatment. Over time it will accumulate significant amounts in the distribution system. Iron is an essential element in the human diet with no adverse health effects except water containing iron can cause brown stains on laundry and plumbing fixtures and can have a bitter taste when present above 1 mg/L (Ratnayaka *et al., 2009*). Iron is found in high concentrations in waters that are in anaerobic conditions (Fawell and Nieuwenhuijsen, 2003). Exposure to lead (Pb) can cause brain and kidney damage, mental retardation and even convulsions in later life (Sawyer *et al.*, 2003) as well as learning and behavioural problems in children (Ratnayaka *et al*., 2009). Sources of lead in waters arise when soft acidic waters come in contact with galena or other lead ores. Other potential sources of lead in water supply are industrial operations, mine and smelter discharges and dissolution of plumbing pipes (APHA, 2005) as well as automobile exhaust and leaded petrol still used in Nigeria and some developing countries (Maduabuchi *et al*., 2006); in locally manufactured and sold paints (Eriyamremu *et al*., 2005) and in lead acid battery factories (Adebamowo *et al*., 2006).

Manganese (Mn) usually occurs in groundwaters subject to anaerobic conditions (Fawell and Nieuwenhuijen, 2003). It may also occur in domestic wastewaters, industrial effluents and receiving streams (Sawyer *et al.,* 2003). Manganese is an essential element in the human diet but levels as low as 0.1 mg/L can cause staining of laundry and sanitary wares. There are no toxicological considerations regarding manganese in water (Ratnayaka *et al.,* 2009).

Nickel (Ni)is used in electroplating and the rinse waters from these operations constitute the main avenues by which salts gain access to the aquatic environment (Sawyer *et al*., 2003). It appears to be of low toxicity to humans but it can cause skin sensitisation and the ingestion of high levels via food or drinking water may cause dermatitis (Ratnayaka *et al*., 2009).The concentration of vanadium (V) in water increases by discharges from industrial application of vanadium such as dyeing, ceramics, ink and catalyst manufacture (APHA, 2005). Vanadium is also found in groundwaters associated with volcanic activity and has been found at raised levels in Argentine waters having high arsenic levels (O'Reilly *et al*., 2010 and Farnfield *et al*., 2012. Zinc (Zn) most commonly enters the domestic water supply from the deterioration of galvanised iron and dezincification of brass with lead and cadmium as other impurities (Sawyer, 2003).

Several studies have revealed industrial effluents and domestic wastewater as being responsible for high quantities of trace elements such as Na^{+}, Ag^{2+}, Fe^{2+}, Cr^{3+}, Mn^{2+}Flame Atomic Absorption Spectrometry (FAAS) was used by Jinwal *et al*., 2009 to determine the levels of Cu, Fe, Mn, Zn, Cr and Pb in the groundwater of Sehore and Bhopal, India. Results showed that with the exception of Ni and Pb water samples contained levels of the trace elements generally within the WHO guidelines.

Nazir *et al*., 2015 used FAAS to assess the levels of Cd, Zn, Fe, Cu, Ni, Cr and Pb as well as pH and electrical conductivity (EC) in Tanda Dam

Kohat, Pakistan. The results revealed concentrations of Cd, Cr, Fe and Pb above WHO guidelines. Ni was not detected in all the samples whilst pH levels were low and EC levels were above WHO guidelines. Perera *et al*., 2016 investigated the concentrations of some trace elements in River Malwathu Oya, Sri Lanka. Results showed elemental levels to be higher during the paddy cultivation season. In Hueihe, Anhui, China Wang *et al*., analysed 53 samples using Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP – AES). Results revealed concentration to be higher than national regulations (CSEPA) as well as WHO and US EPA limits.

Outa *et al*., 2019 determined trace elements in the water of the Kenyan part of Lake Victoria. Samples were analysed using total x-ray reflection fluorescence and FAAS. Results revealed significantly higher levels of Cr, Cu, Cd, Pb and Zn in a site near Kisumu city, indicating increased pollution over the past 15 years due to anthropogenic activities. Asante *et al*., (2007) investigated the impact of mining on the groundwater of Tarkwa, Ghana. The study showed the presence of As^{3+}, Mn^{2+}, Hg^{2+} and Pb^{2+}at levels above the World Health Organisation (WHO, 2011a) guideline limits and the limits imposed by the country's capital Accra as established for areas with no mining activities. In Nigeria, Mustapha (2008) has found limits of Si^{2+}, Ca^{2+}, and Mg^{2+} below WHO Guidelines in Ogun reservoir, Offa, Kwara State. In areas near Warri refinery host community, the refinery effluents were responsible for high levels of Cr^{3+}, Mn^{2+}, Pb^{2+}, Cd^{2} (Nduka and Orisakwe, 2009). Crude oil production was found to be also responsible for high levels of polycyclic aromatic hydrocarbons (PAHs), Fe^{2+}, Cr^{3+}, As^{2+}, Pb^{2+}, Ba^{2+}, Zn^{2+}, (Nriagu, 2011).

Yusuf (2007) investigated rivers in Lagos State. The levels of total dissolved solids, NO_3^-, PO_4^{3-}, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, Na^+, Pb^{2+} and Zn^{2+} were found to be above WHO drinking water guideline limits due to sewage and industrial effluents. In a similar study in Warri, Delta State Nduka and Orisakwe (2007) examined groundwater levels of Cd^{2+}, Cr^{3+}, Pb^{2+} and Mn^{2+}. The study found showed the trace elements levels to be lower in bore-hole than in shallow well water samples. Olaoye and Onilade (2009) found low levels of Fe^{2+} and non-detection of Pb^{2+} and Mn^{2+} in water samples from various parts of western Nigeria. Oluwo *et al*., (2010) examined the levels of Zn^{2+}, Ni^{2+} and Fe^{2+} in the Epe and Badagry lagoon in Lagos State. The study found more contamination in the former than the latter but both less contaminated than the Nile in Egypt. This paper therefore, sought to determine the concentrations of trace elements from various water sources and their possible contamination in Kaduna metropolis, Nigeria.

Study Area and Description of Sample Points

The study area- Kaduna Metropolis, Nigeria, is the capital city of Kaduna State, Nigeria. It lies between Latitudes 10 24.447N and 10 35.004N and Longitudes 7 24.245E and 7 28.886E (Figure 1). It is underlain by basement complex comprising high grade metamorphic and igneous rocks (du Preez and Barber, 1965; Olugboye, 1975; Offodile, 1992 and Akujieze *et al.,* 2003). It is characterised by guinea savannah with mean annual temperature of $25^{o}C$ and about 1200 mm of rainfall (Mallo, 2000). According to 2006 national population census about 1.45 million people reside in the study area (NPC, 2006). The study area comprises of two local government areas (Kaduna North and Kaduna South) and parts of Chikun and Igabi Local Government Areas. There are different types of land use ranging from residential areas, educational (schools and universities) to commercial areas and industrial establishments most of which are currently not in operation.

Sampling and Analytical Procedures

Water samples were collected in March, 2019 from different water sources in the study area. They comprise groundwater (hand-dug wells), surface water (streams and rivers) and tap water sources. Samples were collected from different parts of the study area representing various types of activities ranging from industrial and refinery areas to residential, commercial and agricultural areas. Summary of sampling programmes is shown in Table 1 while details are presented in Appendices 1 and 2.

Table 1. Summary of Sample programmes

Code	Number of samples	Name of water sample source
GWRA	10	Groundwater from residential areas
SWRA	10	Surface water from residential areas
TWRA	10	Tap water from residential areas
GWAA	05	Groundwater from agricultural areas
SWIN	60	Surface water from industrial areas
SWRF	12	Surface water from Refinery area
GWCM	03	Groundwater from commercial areas
SWCM	04	Surface water from commercial areas

All laboratory procedures were analysed in accordance with the Standard Methods for the examination of water and wastewater (APHA, 2005, 21st Edition).Parameters that were analysed *in situ* were pH, temperature, electrical conductivity and total dissolved solids. They were analysed using HANNA HI 991300. Calibration for each was done prior to measurement in accordance with Manufacturer's manual. Elemental analyses were carried out using the ICP-MS Agilent 7700 series instrument with an ASX-500 series auto sampler. Helium and no gas modes were used in these analyses.

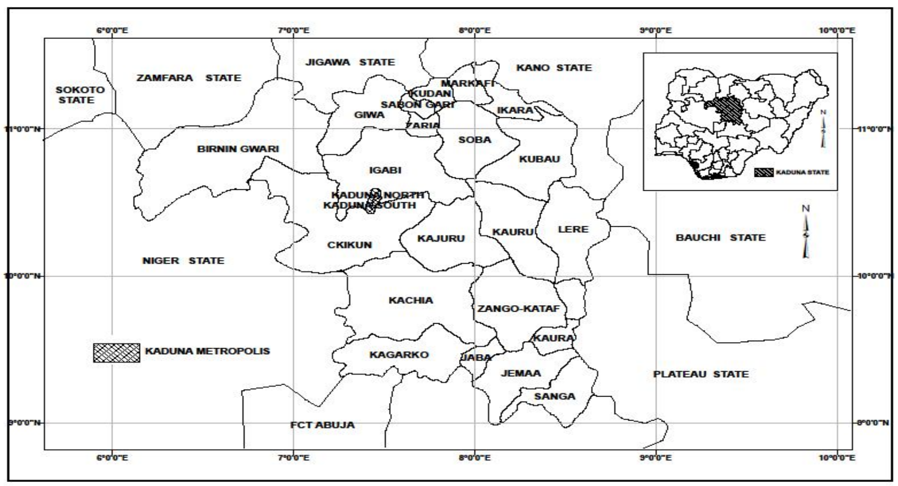

Figure 1: Study area (shaded) in Kaduna State with Nigeria as inset.

RESULTS AND DISCUSSION

The results showed that the concentrations of trace elements to be generally within the drinking-water guideline limits for the World Health Organization (WHO) and Nigerian Standards for drinking water quality (NSDWQ). The detailed trace elements and physicochemical data are presented for the Kaduna Metropolis in Tables2& 3 obtained from groundwater from residential, commercial, agricultural areas and tap water while Table 4 is the summary of the concentrations obtained from Tables2 & 3. On the other hand, Tables 5 & 6 present the data collected from surface waters from residential, commercial and industrial and refinery areas while Table 7 is the summary derived from Tables 5 & 6.

The results of groundwater samples showed mean pH values were generally within the limits of the regulatory bodies. The levels for electrical conductivity (EC) and total dissolved solids (TDS) were highest at commercial areas with the values being for lowest values found in tap water sampled from residential areas (Table 4).

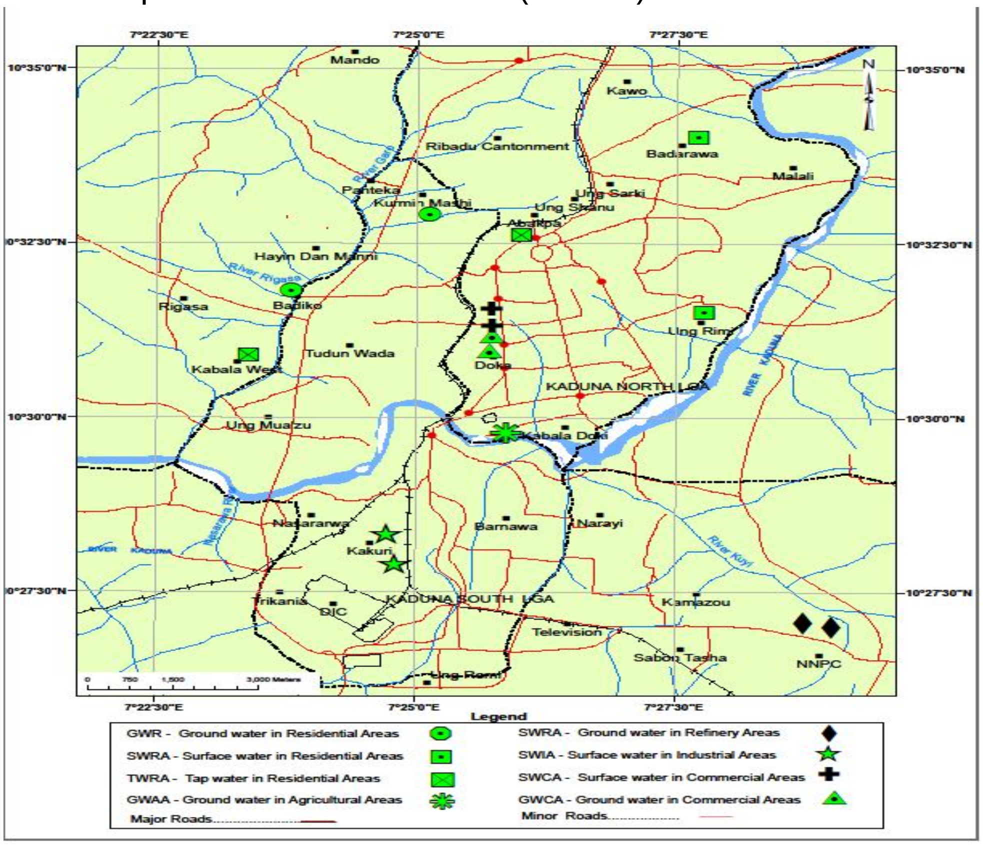

Figure 2: Land use types and sampling points in the Study area.

Table 2: Trace Elements Concentrations of Groundwater from Residential Areas (GWRA) and Commercial Areas (GWCA) in Kaduna Metropolis, Nigeria.

GWRA					GWCA			
n = 10	Median	Min	Max		n = 3	Median	Min	Max
pH	6.3	4.04	7.71		pH	6.5	6.04	6.9
Temp [ºc]	27.5	21.50	29.6		Temp [ºc]	26.1	25.9	26.4
EC [µS/cm]	320.0	108.0	690.00		EC [µS/cm]	340.0	140.0	711.0
TDS [mg/L]	180.0	20.0	640.0		TDS [mg/L]	356.7	200.0	470.0
V	0.01	< dl	0.3		V	0.2	0.2	0.3
Cr	0.01	< dl	1.1		Cr	0.02	< dl	0.2
Mn	1.3	0.02	572.6		Mn	5.5	0.5	16.3
Co	< dl	0.02	6.4		Fe	1.3	< dl	70.4
Ni	0.3	0.1	9.6		Co	0.02	0.01	0.2
Cu	0.2	0.03	0.6		Ni	0.7	0.5	5.3
Zn	2.5	< dl	36.1		Cu	0.4	0.01	1.1
As	0.04	0.01	0.6		Zn	4.6	3.0	8.3
Se	0.03	0.00	3.2		As	0.06	0.04	0.2
Pb	0.02	0.00	0.2		Se	< dl	< dl	0.05
					Mo	< dl	< dl	0.5
					Pb	< dl	< dl	0.02

Key: - GWRA – Groundwater from Residential Areas, GWCA - Groundwater from Commercial Areas, EC – Electrical Conductivity, TDS – Total Dissolved Solids, all trace elements in µg/ L, <dl- less than detection limit, n= no of samples.

Table 3.Trace Elements Concentrations of Tap Water from Residential Areas (TWRA) and Groundwater from Agricultural areas (GWAA) in Kaduna Metropolis, Nigeria.

TWRA					GWAA			
n = 10	Median	Min	Max		n = 5	Median	Min	Max
pH	6.8	6.4	7.3		pH	6.5	6.4	6.8
Temp [ºc]	26.3	22.0	29.8		Temp [ºc]	25.7	24.9	26.9
EC [µS/cm]	150.0	130.0	320.0		EC [µS/cm]	310.0	180.0	320.0
TDS [mg/L]	80.0	70.0	170.0		TDS [mg/L]	170.0	100.0	170.0
V	0.2	0.07	0.8		V	0.2	0.05	0.3
Mn	0.2	0.00	4.9		Cr	0.05	0.04	0.07
Co	0.03	0.00	0.04		Mn	0.8	0.3	0.8
Ni	0.2	0.02	0.3		Fe	1.2	0.04	4.5
Cu	0.4	0.03	3.7		Co	0.1	0.04	0.3
Zn	14.5	0.6	63.2		Ni	0.3	0.2	0.9
As	0.1	< dl	0.2		Cu	0.4	0.2	0.9
Pb	< dl	< dl	0.2		Zn	1.1	0.8	3.6
					As	0.2	0.15	0.3
					Se	< dl	< dl	0.01

					Mo	< dl	< dl	0.3

Key: - TWRA – Tap Water From Residential Areas, GWAA – Groundwater from Agricultural Areas, EC – Electrical Conductivity, TDS – Total Dissolved Solids, all trace elements in µg/ L, <dl- less than detection limit, n= no of samples

Table 4. Concentrations of Trace Elements in groundwater and tap water sources in Kaduna metropolis, Nigeria

Sampling points	GWRA	GWCA	GWAA	TWRA	WHO	NDWQS
Number of samples	n = 10, χ	n = 3, χ	n = 5, χ	n = 10, χ		
pH	6.3	6.5	6.5	6.8	6. - 8.5	6.5 - 8.5
Temp [ºc]	27.5	26.1	25.7	26.3	NA	NA
EC [µS/cm]	320	340	310	150	250	1000
TDS [mg/L]	180	356.7	170	80	1000	500
V [µg/L]	0.01	0.2	0.2	0.2	NA	NA
Cr [µg/L]	0.01	0.02	0.05	0.2	0.05	0.05
Mn [µg/L]	1.3	5.5	0.8	0.03	0.4	0.2
Co [µg/L]	ND	1.3	1.2	0.2	NA	NA
Ni [µg/L]	0.3	0.02	0.1	0.4	0.07	0.02
Cu [µg/L]	0.2	0.7	0.3	14.5	2	1
Zn [µg/L]	2.5	0.4	0.4	0.1	NA	3
As [µg/L]	0.04	4.6	1.1	ND	0.01	0.01
Se[µg/L]	0.03	0.06	0.2	ND	0.01	NA
Pb [µg/L]	0.02	ND	ND	ND	0.01	0.01

Key: - GWRA – groundwater from residential areas, GWCA- groundwater from commercial areas GWAA – groundwater from agricultural areas, TWRA – tap water from residential areas, EC – Electrical conductivity, TDS – Total dissolved solids, NA – not available, ND – not detected, WHO – World Health Organization guidelines on drinking water quality, NDWQS – Nigerian drinking water quality standards all trace elements in µg/ L, n= no of samples.

At the surface water sampling points the pH levels were of pH ranged from 7.0 in commercial areas to 7.8 in industrial areas (Table 7). The levels of electrical conductivity (EC) and total dissolved solids (TDS) were below the World Health Organisation (WHO) and Nigerian Government Guideline limits for all the surface water sampling points (Table7). The levels were, however, found to be lowest in residential areas and the highest at sites located in the refinery area respectively.

Vanadium was detected at all sample points. However, the data showed higher concentration of the element in surface water than in groundwater sources, indicating its source and use in metallurgy(Narayanan, 2011). The highest concentration was found to be less than that reported in China (Xiju *et al*., 2000).The chromium concentrations were found in agricultural groundwater and tap water from residential areas and surface water sample sites. High tap water concentrations may be due to the plating of pipes (Narayanan, 2011).Interestingly, surface water concentrations of Cr in industrial sites were found to be insignificant. This may have been due to dilution by the flowing nature of the surface water and adsorption.

Table 5.Trace Elements Concentrations of Surface Water from Residential Areas (SWRA) and Commercial areas (SWCA) in Kaduna Metropolis, Nigeria.

SWRA					SWCA			
n = 10	Median	Min	Max		n = 4	Median	Min	Max
pH	7.5	6.3	8.2		pH	7.0	5.6	6.9
Temp [ºc]	28.0	23.20	30.1		Temp [ºc]	30.7	25.9	27.3
EC [µS/cm]	330.0	300.00	360.0		EC [µS/cm]	535.0	140.0	711.0
TDS [mg/L]	180.0	160.00	200.0		TDS [mg/L]	300.0	70.0	390.0
V	0.3	0.2	0.4		V	0.6	0.2	0.3
Cr	0.03	0.01	0.1		Cr	0.09	0.0	0.05
Mn	0.3	0.2	1.2		Mn	0.2	0.2	0.6
Fe	0.6	ND	2.1		Co	0.4	0.04	0.6
Co	0.1	0.06	0.1		Ni	0.9	0.2	1.2
Ni	0.5	0.3	0.7		Cu	0.4	0.2	0.8
Cu	0.4	0.2	1.0		Zn	2.8	1.7	11.2
Zn	2.03	0.2	9.9		As	0.3	0.2	0.4
As	0.2	0.05	0.3		Mo	0.2	0.1	0.3
Se	ND	ND	0.1					
Mo	0.1	0.1	0.3					

Key: - SWRA – Surface Water from Residential Areas, SWCA – Surface Water from Commercial Areas, EC – Electrical conductivity, TDS – Total dissolved solids, all trace elements in µg/ L, ND – not detected, n= no of samples

Table 6. Trace elements concentrations of surface water from industrial areas (SWIN) and refinery areas (SWRF) in Kaduna Metropolis, Nigeria.

SWIN					SWRF			
n = 59	Median	Min	Max		n = 12	Median	Min	Max
pH	7.8	5.9	8.6		pH	7.7	5.1	8.2
Temp [ºc]	28.2	20.60	29.6		Temp [ºc]	24.1	20.5	26.6
EC [µS/cm]	245.0	210.00	1184.0		EC [µS/cm]	785.0	620.0	880.0
TDS [mg/L]	140.0	110.00	1030.0		TDS [mg/L]	435.0	340.0	510.0
V	0.2	ND	3.7		V	1.2	ND	2.2
Cr	0.02	ND	0.3		Cr	0.04	ND	0.09
Mn	0.4	0.11	288.0		Mn	0.9	0.4	16.2
Fe	0.1	ND	15.8		Fe	11.1	ND	26.9
Co	0.08	0.03	1.2		Co	0.04	0.02	0.1
Ni	0.3	0.09	2166.0		Ni	0.7	0.5	1.3
Cu	0.3	ND	3.3		Cu	0.2	0.01	0.6
Zn	2.0	0.24	8.4		Zn	18.2	4.0	34.7
As	0.2	0.06	1.1		As	0.3	0.03	0.6
Se	0.01	ND	0.3		Mo	0.7	0.5	1.6
Mo	0.09	ND	3.6		Pb	0.06	ND	0.1

Key: - SWIN - Surface Water from Industrial Areas, SWRF – Surface Water from Refinery Area, EC – Electrical conductivity, TDS – Total dissolved solids, all trace elements in µg/ L, ND – not detected, n= no of samples

Table 7. Concentrations of Trace Elements from Surface Water Sources in Kaduna Metropolis, Nigeria

Sampling points Number of samples	SWRA n = 10, χ	SWCA n = 4, χ	SWIN n = 60, χ	SWRF n = 12, χ	WHO	NDWQS
pH	7.5	7	7.8	7.7	6. - 8.5	6.5 - 8.5
Temp [ºc]	28	30.7	28.2	24.1	NA	NA
EC [µS/cm]	330	535	245	785	250	1000
TDS [µg/L]	180	300	140	435	1000	500
V [µg/L]	0.3	0.6	0.2	1.2	NA	NA
Cr [µg/L]	0.03	0.09	0.02	0.04	0.05	0.05
Mn [µg/L]	0.3	0.2	0.4	0.9	0.4	0.2
Fe [µg/L]	0.6	0.4	0.1	11.1	NA	0.3
Co [µg/L]	0.1	0.9	0.08	0.04	NA	NA
Ni [µg/L]	0.5	0.4	0.3	0.7	0.07	0.02
Cu µg/L]	0.4	2.8	0.3	0.2	2	1
Zn [µg/L]	2.03	0.3	2	18.2	NA	3
As [µg/L]	0.2	0.2	0.2	0.3	0.01	NA
Se [µg/L]	ND		0.01	0.7	0.01	NA

		ND				
Mo [µg/L]	0.1	ND	0.09	0.06	0.07	NA
Pb [µg/L]	ND	ND	ND	3.2	0.04	0.04

Key: - SWRA –surface water from residential areas, SWCA- surface water from commercial areas, SWIN- surface water from industrial areas, SWRF – surface water from Refinery area, EC – Electrical conductivity, TDS – Total dissolved solids, WHO – World Health Organization guidelines on drinking water quality, NDWQS – Nigerian drinking water quality standards, all trace elements in µg/ L, NA – not available, ND – not detected, n= no of samples

The highest groundwater level of Mn (5.5 µg/L)was found in commercial areas (Table 4). This may be due to the underlying geology especially areas with clayey soils (Offodile, 1992). Manganese may cause staining of laundry and sanitary wares (Ratnayaka *et al*., 2009).However, Mnin surface water samples were found in all sampling points with the exception of domestic tap water. The lowest concentration was found for surface water from commercial areas (SWCA), 0.2 µg/L while the highest mean value of0.9 µg/L was found at the Refinery area (Table 7). High concentrations of Mn can be found in domestic wastewaters, industrial effluents and receiving streams (Sawyer *et al*., 2003). This agrees with the findings of this study where the highest concentration was found at areas with textile industries, bottling companies and an assembly plant. Iron was detected at all sampling points but only in appreciable quantities in groundwater from agricultural areas (GWAA) and commercial areas (GWCA)with mean concentrations of 1.2 and 1.3 µg/L respectively (Table 4).In other places the quantities were below the detection limits. The presence of Fe in groundwater is thought to have come from the leaching of lateritic sediments (Omo- Irabor *et al*., 2008). Iron was to be at low concentrations in the tap water from residential areas despite its use as a coagulant in water treatment and tends to result in significant amounts in the distribution system (Ratnayaka *et al*., 2009). Nickel was detected in surface water from industrial areas with a mean values 0.3 and 0.9 µg/L respectively, Table 7.). The lowest Ni value was recorded for tap water from domestic areas (0.2 µg/L, Table 4). The main source of Ni in the environment is electroplating and the rinse water from these operations (Sawyer *et al.,* 2003). High levels of Ni were found in an area close to an assembly plant suggesting effluent release from the factory. This agrees with a study in western Niger Delta, Nigeria (Omo-Irabor *et al*., 2008).

Zinc concentrations were also obtained from all sample points with the highest mean concentration of 14.5 µg/L found in tap water from residential areas (Table 4) due probably to the deterioration of galvanised iron used in the tank that stores water while its presence in surface water samples from the refinery area may be due to industrial waste pollution (APHA, 2005). This may be due to the use of Zn in drilling fluids associated with oil production (Sayyadnejad *et al*., 2008).

Arsenic was detected in all surface water samples and in all but one groundwater samples (Table 4). The high concentrations in the surface water from commercial and refinery areas compared to other sampling sites may be due to surface runoff (Table 7, Ratnayaka *et al.,* 2009). Arsenic concentrations in groundwater were lower than values reported in rural areas of Bangladesh (Hoque *et al*., 2006) and in the mining town of Tarkwa, Ghana (Asante *et al*., 2007) and Bhattacharya *et al*., (2012). The levels were also lower than those reported in Argentina by Farnfield *et al*., 2012 and from Cyprus by Christodoulidou *et al*., 2012.

CONCLUSION

The paper investigated the concentration of trace elements from various water sources in Kaduna metropolis, Nigeria. The study revealed that the levels of physical parameters and trace elements were generally below the Guideline limits of the World Health Organization and the Nigerian drinking water quality standards. However, some trace elements such as Ni, Cu and Zn were found at elevated concentrations at some sample points due to rock weathering in groundwater and from industrial and refinery effluents in surface water in the study area. It is necessary to undertake regular water monitoring to ensure the concentrations of the trace elements are within acceptable limits of the regulatory bodies. It is also necessary to replace aging pipes in order to avoid the dissolution of trace elements into tap water.

REFERENCES

Adebamowo, E.O., Agbele, O.A., Sridhar, M.K.C., Adebamowo, C.A., (2006). An evaluation of Pb levels in residential paints sold in Nigerian markets, *Indoor Built Environ*, ***15***, 551 – 554.

Akujieze, C.N., Coker, S.J.L., Oteze, G.E., (2003). Groundwater in Nigeria – a millennium experience – distribute in, practice and solutions, *Hydrogeology Journal, 11, 259 – 274.*

American Public Health Association (APHA, 2005). Standard Methods for the Examination of Water and Wastewater, Washington, 21st Edition.

Asante, K.A., Agusa, T., Subramanian, A., Ansa- Asare, D., Biney, C.A., Tanabe, S., (2007). Contamination status of arsenic and other trace elements in drinking water and residents from Tarkwa, a historic mining township in Ghana, *Chemosphere, **66,*** 1513 – 1522.

Bhattacharya, P., Sracek, O., Eldvall, B., Asklund, R., Barmen, G., Jacks, G., Koku, J., Gustafsson, J-E., Singh, N., Balfors, B.B., (2012). Hydrogeochemical study on the contamination of water resources in a part of Tarkwa mining area, Western Ghana, *Journal of African Earth Sciences, **66 – 67,*** 72 – 84.

Christodoulidou, M., Charalambous, C., Aletrari, M., Nicolaidou, K., Petronda, A., Ward, N.I. (2012). Arsenic concentrations in groundwater of Cyprus, *J. Hydrology, **468 – 469***, 94 – 100.

du Preez,J.W. and Barber,D.F.M. (1965),The Distribution and Chemical Quality of Groundwater in Northern Nigeria,GSN.Min of Mines and Power,FGN,Lagos.

Ekino, S., Susa, M., Ninomiya, T., Imamura, K., Kitamura, T., (2007). Minamata disease revisited: An update on the acute and chronic manifestations of methylmercury poisoning, *Journal of Neurological Sciences, **262*****,** (1 – 2), 131 – 144.

Eriyamremu, G., Asagba, S., Akpoborie, I., Ojeaburu, S., (2005) Evaluation of lead and cadmium levels in some commonly consumed vegetables in the Niger Delta oil area of Nigeria, *Bull. Environ. Contam. Toxicol, **75***, 278- 283.

Farnfield, H.R., Marcilla, A.L., Ward, N.I (2012). Arsenic speciation and trace element analysis of volcanic rio Agrio and the geothermal waters of Copahue, Argentina, *The Science of the Total Environment, **433**,* 371 – 378.

Fawell, J., Nieuwenhuijsen, M.J., (2003). Contaminants in drinking water, *British Medical Bulletin, **68,*** 199 – 208.

Hoque, B.A., Hallman, K., Levy, J., Bouis, H., Ali, N., Khan, F., Khanam, S., Kabir, M., Hossain, S., Alam, M.S., (2006). Rural drinking water at supply and household levels: Quality and Management, *International Journal of Hygiene and Environmental Health, **209***, 451-460.

Jarup, L. (2003). Hazards of heavy metal contamination, *British Medical Bulletin, **68*****,** 167 – 182.

Jinwal, A., Dixit, S., and Malik, S. (2009). Some Trace Elements Investigation in Groundwater of Bhopal &Sehore District in Madhya Pradesh*, India. J. Appl. Sci. Environ. Management*, 133 (4), 4 – 50.

Kimbrough, D.E., Cohen, Y., Winer, A.M., Creelman, L., Mabuni, C., (1999). A critical assessment of Cr in the environment, *Critical Reviews in Environmental Science and Technology, **29**,* (1), 1-46.

Maduabuchi, J., Nzegwu, C., adigba, E., Aloke, R., Ezomike, C., Okocha, C., Obi, E., Orisakwe, O., (2006). Lead and cadmium exposures from canned and non-canned beverages in Nigeria: a public health concern, *Science of the Total Environment, **366***, 621 – 626.

Mallo, I.I.Y., (2000). 'Hydrogeomorphical and pedological implications for dumping linear density polyethylene on land surface of Kaduna metropolis, Northern Nigeria', *Z Geomorph NF**, 443,*** 305-316, Berlin- Stuttgart

Mustapha, M.K., (2008). Assessment of water quality of Oyun reservoir, Offa, Nigeria, using selected physic-chemical parameters, *Turkish Journal of Fisheries and Aquatic Sciences***8**,309-319.

Narayanan, P. (2011). Environmental Pollution: principles, analysis and control, CBS Publishers and Distributors PVT, LTD, New Delhi, India.

National Population Commission (2006). List of Nigerian States by population, FCT, Abuja, Nigeria.

Nazir, R., Khan, M., Masab, M., Rehman, H.U., Rauf, Shahab, S., Ameer, N., Sajed, M., Ullah, M., Rafeeq, M., Sheheen, Z. (2015).

Accumulation of Heavy Metals (Ni, Cu, Cd, Pb, Zn, Fe) in the soil and water collected from Tanda Dam Kohat, Pakistan, *Journal of Pharmaceutical Sciences and Research,* 7 (3), 89 - -97.

Nduka, J.K.C., Orisakwe, O.E., (2007). Heavy metal levels and physic-chemical quality of potable water supply in Warri, Nigeria, *Annali di Chimica, **97**,* (9), 867- 874.

Nigerian Standard for Drinking Water Quality (2007). Nigerian Industrial Standard, NIS, 554, Standard Organisation of Nigeria.

Nriagu, J (2011). Oil Industry and the health of communities in the Niger Delta of Nigeria, *Encyclopaedia of Environmental Health, Elsevier B.V*, 240-350.

O'Reilly, J., Watts, M. J., Marcilla, A.L., Ward, N. I. (2010). Arsenic contamination of natural waters in San Juan and La Pampa, Argentina. *Environ. Geochem. Health, **32,*** (6), 491 – 515.

Offodile, M.E (1992)An Approach to Groundwater Study and Development in Nigeria,Mecon Services Ltd,Jos,Nigeria.

Olaoye, O.A., Onilade, A.A., (2009). Assessment of microbiological quality of sachet- packaged water in western Nigeria and its public health significance, *Public Health*, 729 - 734.

Olowu, R.A., Ayejuyo, O.O., Adewuyi, G.O., Adejoro, I.A., Denloye, A.A.B., Babatunde, A.O., Ogundajo, A.L., (2010). Determination of heavy metals in fish tissues, water and sediment from Epe and Badagry lagoons, Lagos, Nigeria, *E Journal of Chemistry, **7***, (1), 215 - 221.

Omo-Irabor, O.O., Olabaniyi, S.B., Oduyemi, K., Akunna, J., (2008). Surface and groundwater quality assessment using multivariate analytical methods: a case study of western Niger Delta, *Physics and Chemistry of the Earth, **33***, 666 – 673.

Outa, J.O., Kowenje, C.O., Plessi, C., Jirsa, F. (2019). Distribution of arsenic, silver, cadmium, lead and other trace elements in water, sediment and macrophytes in the Kenyan part of Lake Victoria: spatial, temporal and bioindicative aspects, *Environmental Science and Pollution Research*, http//doi.org/10.1007/s11356-019-063525-9.

Perera, P.A.C., Sundarabarathy, T.V., Sivananthawerl, T., Kodithuwakku, S.P., Edirisinghe, U. (2016). Arsenic and Cadmium Contamination in Water, Sediments and Fish is a Consequence of Paddy Cultivation: Evidence of River Pollution in Sri Lanka, *Achievements in Life Sciences (2016)*, http// dx.doi.org/10.1016/j.als.2016.11.002.

Purcell, P. (2003). Design of Water Resources Systems, Thomas Telford, London, United Kingdom.

Ratnayaka, D.D., Brandt, M.J., Johnson, K.M., (2009). Twort's Water Supply, Butterworth- Heinemann Elsevier, London, 6th Edition, 195-244.

Sakamoto, M., Nakano, A., Akagi, H., (2001). Declining Minamata male birth ratio associated with increased male fatal death due to heavy methylmercury pollution, *Environmental Research, **87***, (2), October 2001, 72 – 98.

Sawyer, C.N., McCarty, P.L., Parkin, G.F., (2003). Chemistry for Environmental Engineering and Science, McGraw- Hill, Boston, 5th Edition, 536- 616.

Sayyadnejad, M.A., Ghaffarian, H.R., Seidi, M., (2008). Removal of hydrogen sulphide by zinc oxide nanoparticles in drilling fluid, *Int. J. Environ Sci. Tech, **5,*** (4), 565 – 569.

Wang, J., Liu, G., Liu, H., Lam, P.K.S. (2017). Multivariate statistical evaluation of dissolved trace elements and a water quality assessment in the middle reaches of Huaihe River, Anhui, China, Science of the Total Environment, http//dx, doi.org/10.1016/j.scitotenv.2017.01.088.

Ward, N.I., (2000). Trace elements, In: Environmental Analytical Chemistry, 2nd F.W. Fifield and P.J. Haines, Blackwell Science Ltd, Oxford, UK, pp. 360 – 392.

WHO (2011a) Guidelines for Drinking Water Quality, World Health Organisation Geneva, 2011, 4ed.

Xiju, L., Qingqian, L., Lianping, Z., Jie, C., Gulping, C., Baofen, M., Zhaonan, X., (2000) Analysis of trace elements in drinking water from high and low incidence districts of gastric carcinoma by CNKI, www.cnki.com.cn

Yusuf, K., (2007). Evaluation of groundwater quality characteristics in Lagos city, *Journal of Applied Sciences, **7,*** (13), 1780 - 1784.

Appendix 1:Selection of Groundwater Sampling Points

Code	Location	Description (depth of hand dug wells in metres)	Activity
ORF	Refinery area	7	Petroleum
KPS	Kawo motor garage	6	Commercial
TPS	Unguwar Sanusi	15	Residential
OPS	UnguwarSarki	50	Commercial
NPK	KurminMashi	1	Industrial
ASB	Asikolaye	5	Industrial
BNG	Barnawa	1	Agricultural
FGM	Mando	8	Residential
REG 01	Tudun Wada, Zango	10	Residential
REG 02	HayinBanki	15	Residential
REG 03	Badarawa, NEMA	13	Residential
REG 04	Badarawa	15	Residential
REG 05	Asikolaye 01	10	Residential
REG 06	Asikolaye 02	12	Residential
REG 07	Panteka	2	Residential
REG 08	Mando,Kawo	6	Residential
REG 09	UnguwarSarki	40	Residential
REG 10	Barnawa	5	Residential
AGG 01	KurminMashi 01	5	Agricultural
AGG 02	KurminMashi 02	5	Agricultural
AGG 03	RafinGuza	10	Agricultural
AGG 04	Hayin Dan Mani	2	Agricultural
AGG 05	Mando bridge	3	Agricultural
RMG 11	Barnawa	2	Residential
RMG 12	New Barracks	7	Residential
RMG 13	HayinBanki	8	Residential

Appendix 2: Selection of Surface water Sampling Points

Code	Location	Description	Activity
RAS01-RAS12	Refinery area	Stream draining refinery effluents	Petroleum
CDR	Refinery area	Confluence of refinery drains and Romi river	Petroleum
INS01 - INS 25	River Kaduna Stadium	Perennial river	Industrial
INS26 - INS 46	Nasarawa Bridge	Perennial river	Industrial
INS 47 - INS 51	Kudandan Bridge	Perennial river	Industrial
INS 52 - INS 55	Panteka	Stream	Auto spares sales and repairs
INS 56	Bakin Ruwa	Perennial river	Auto spares sales and repairs
INS 57	RafinGuza	Perennial river	Auto spares sales and repairs
INS 58-INS60	Eye Centre	Stream	Auto spares sales and repairs
INS01-INS04	Kudandan	Perennial river	Industrial
RET 01	Barnawa 01	Tap water	Residential
RET 02	Barnawa,02	Tap water	Residential
RET 03	UnguwanRimi	Tap water	Residential
RET 04	New Barracks, Kawo	Tap water	Residential
RET 05	WAEC Office, Kawo	Tap water	Residential
RET 06	Badarawa, NEMA	Tap water	Residential
RET 07	Ali Akilu Road	Tap water	Residential
RET 08	Panteka	Tap water	Residential
RET 09	T/ Wada, Zango 01	Tap water	Residential
RET 10	T/ Wada, Zango 02	Tap water	Residential